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Service Systems as Customer-Intensive Systems and its Implications for Service Science and Engineering

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Abstract

What does differentiate service systems from traditional subjects of systems engineering such as manufacturing, and software? We address this issue by defining customer-intensive systems, *based on ideas by Sampson [12], and show how customer-intensive systems encompass almost all service systems. After proposing a new form of visualization for customer-intensive processes and discussing its merits and shortcomings, we argue how in customer-intensive systems the presence of human beings and organizations inside the production process radically modifies fundamental tenants of systems engineering. We then describe four fundamental changes in traditional science and engineering system methodologies to adapt them to the realities of customer-intensive systems. We conclude by arguing whether the complexity often observed in service systems is, in fact, a reflection of the complexity of human beings and organizations that are input to them.*

1. Introduction

In recent years, the realization of the need of systematic innovation in services has led to calls for the establishment of science, engineering, and design disciplines specific for services, in the so called Service Science, Management, and Engineering (SSME) initiative [17]. However, efforts to determine the subject and scope of these disciplines, as well as their fundamental issues, methods, and research agendas, have been hampered by difficulties on defining more precisely what a service system is.

To address this issue, we define in section 2 the class of *customer-intensive systems*, modifying slightly a definition proposed by Sampson [12, 13]. Accordingly, the key characteristic of customer-intensive systems is the significance of customer input (people, organizations) to the production processes of those systems. We then show in section 3 that almost all service industries deliver services through customer-intensive systems, to the point that it is possible to equate service systems to customer intensive systems.

However, to integrate the human aspects of the input, and the centricity of customers to service processes, it may be necessary to science and engineering to change how they visualize and represent service processes. We discuss this issue in section 4 by proposing a customer-centric representation for customer-intensive processes that highlights key customer experience components: presence, time, property, and information.

One of the important consequences of defining service systems as customer-intensive systems is that the presence of people and organizations inside the production process affects radically, in our view, major assumptions of traditional industrial science and engineering. Although some of these issues have been discussed before by Sampson[12], Gadrey [5], and Karni and Kaner [6], we take the analysis further in section 5 and show how service science and engineering has to adapt to the need of handling human values-loaded inputs and human perceptions of time and quality, and of creating usable formal models of customers.

We echo, for service science and engineering, Chase's call [4] for the use of Behavioral Sciences-inspired methods in services. However, we believe that there are many other disciplines which can be used to model customer-intensive systems, as demonstrated by the works of Mandelbaum and Zeltyn [8, 19] and in analogy to Oliva and Sterman [9] work with employee modeling. What is important to notice in these examples is that making human and organizational issues a part of services systems does not mean making science and engineering models and tools less formal or predictive. A technologically similar scenario occurred when human perceptual aspects were introduced for image and audio compression methods such as JPEG and MP3. Human perception-based compression is the key to achieve the high rates of multimedia transmission we have today.

Finally, in section 6 we briefly discuss why we do not believe that complexity is a defining characteristic of service systems, as suggested by some authors like Maglio et al. [7] .In fact, we propose that the currently perceived complexity of service systems is due to inadequate characterizations of services and that decoupling the complexity of the human input from the service system is likely to decrease the overall complexity of service systems analysis and modeling.

2. Customer-Intensive Systems

The goal of this section is to formally define customer-intensive systems as systems in which the beneficiaries of

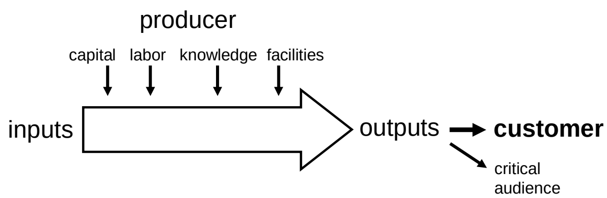

Figure 1. A diagram of a typical production process.

the results of the system's processes are also part of the input to the system. We construct this definition formally by first defining customer-intensive production processes, which are a special type of production processes.

2.1. Production Processes

A *production process* is basically a process in which inputs are transformed into outputs by a producer, using the basic four means of production: capital, labor, knowledge, and facilities. Figure 1 shows the typical diagram of a production process. After production, the outputs are then taken possession by customers.

There is some level of controversy in the literature about what a customer is. For instance, Sampson [12, pg 208] defines customers as "…*the individuals or entities who determine whether or not the service provider shall be compensated for production*". Such definition creates, in our view, technical issues which can be avoided, in our framework, by defining *customers* as the persons or organizations who receive most of the value created by a production process. To simplify the presentation of the ideas in this paper we consider, without significant loss of generality, only the case in which the customer of a production process is a person. Although organizations (businesses, NPOs, government, etc.) tend to be significantly more complex than people, most of the analysis and discussion in this paper is believed to be basically valid in the case of organizations.

Another agent often present in production processes is the *critical audience*. The term, proposed by Sampson [12], identifies people and organizations who have an interest in the quality, volume, or reliability of the production process but are not immediate beneficiaries of the value of the output. Typical examples of critical audiences are managers of employees receiving business services, regulators such as the FDA in the United States, certifying organizations such as bar associations, and other special interest groups.

2.2. Customer-Intensive Processes

The core of our framework relies on some recent work in services theory by Sampson [12], popularized in [13], which proposes a new unifying definition for service processes. According to his work, a necessary and sufficient condition for a production process to be a *service process* is that *"[…] the customer provides significant inputs into the production process."* [13, pg 331]. This primacy of customer input is put in contrast to manufacturing processes, where *"groups of customers may contribute ideas to the design of the product, but individual customers' only participation is to select and consume the output."* [12, pg 16].

Notice that it is implicit in his definition (and discussed at length in [13]) that customers and producers are separate entities. A better way in our opinion to make this distinction is to say that the customer does not control most of the means of production. Accordingly, a production process is a *customer-intensive process* when:

1. **The customer does not control most means of production.**
2. **The customer (self, belongings, information) is a significant part of the input to the production process.**

Part (1) of our definition states that the customer does not control the basic factors of production — capital, labor, knowledge, and facilities — and therefore cannot determine when and how intensively resources are used; where her information is stored and who can access it; how much effort is put on a given task or goal; and what the price of the service is and how it changes. Notice that the definition does not exclude self-service processes, for example when a customer goes to an office support provider (such as *Kinko's*) and uses their printers to make hardcopies of documents. Although the customer in a self-service context is not dependent any more on the provider's labor, she is still dependent on the availability of the provider's tools and facilities. However, we purposefully exclude from our definition processes where there is no second-party provider involved, such as when a person make hardcopies of documents using a printer that she owns at her own office or home (see Pinhanez [11], for a more elaborated discussion on the difference of tools and services).

Part (2) of the definition tries to differentiate traditional views of production from the customer-intensive processes. Notice that the distinction hangs on the interpretation given to the term "significant part" of item (2) of our definition. We acknowledge this to be a possible source of future problems, but we consider premature at this point to establish it clearly. It suffices to say that for the scope of this paper, a commonsensical interpretation of the expression "significant part of the input" does not seem to create significant theoretical problems. At the same time, the use of the term "significant" implicitly acknowledges the fact that there is a continuum between production process without and with significant input from the customers.

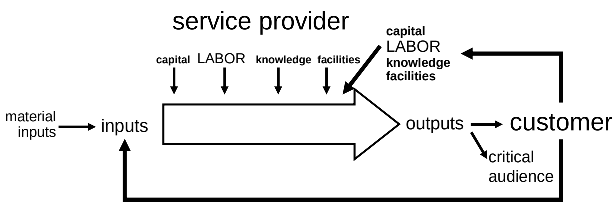

Figure 2. A diagram of a customer-intensive process.

Notice that, as discussed in detail by Sampson [12, 13], the customer can be the input to the production process in different forms: as herself (body or mind) such as when the services of a doctor in a hospital are seek; as her belongings, such as when a car is taken to a repair shop; or her information, as when giving financial information to get a loan from a bank. Notice that in all cases, the production process is unable to even start until the customer provides her input.

Since the customer input is part of the production process, it is quite common that the customer also provides means of production, commonly in the form of labor (often referred as co-production), but sometimes as knowledge, capital, or facilities, such as in cleaning services. Figure 2 shows the typical way to represent customer-intensive processes, with an arrow from the customer to the input and an arrow from the customer to the production process symbolizing the provision of labor, capital, knowledge, or facilities.

2.3. Customer-Intensive Systems

To arrive to our definition of customer-intensive systems, we start by considering a standard definition of *system* provided by Karni and Kaner [6]: *"A system is an organized set of objects which processes inputs into outputs that achieve an organizational purpose and meet the need of customers through the use of human, physical and informatic enablers in a sociological and physical environment…"* [6, pg. 67].

Based on this definition, and by analogy to our definition of customer-intensive processes, we define a *customer-intensive system* as a system where: (1) the customer does not control most of the means of the production of the system; (2) the customer is a significant part of the input to the system.

Examples of customer-intensive systems include air transportation systems, railway systems, postal systems, medical systems, repair and maintenance systems, etc. In fact, almost all services systems are customer-intensive systems as discussed in the next section.

3. Are All Services Customer-Intensive?

Unlike Sampson [12], we do not believe that customer intensity is a sufficient condition for a process to be a service process. So which kinds of services systems are not customer-intensive? Let us look into this issue at the industry level, using the North American Industry Classification System 2002 [1]. The NAICS is used by business and government to classify and measure economic activity in Canada, Mexico and the United States. Among the 92 2-digit codes used by NAICS 2002 to classify industries, the range from 42 to 92 is usually associated with services. Going down one level, there are 62 different segments of the service industry characterized by 3-digit codes. Among those 62 segments of the service industry, only 3 cannot be considered customer-intensive: *Publishing Industries* (including shrink-wrap software publishing), *Motion Picture and Sound Recording Industries*, and *Broadcasting and Telecommunications* (in fact, only broadcast). Examining carefully these three non customer-intensive traditional service industries, we see production systems that look more like manufacturing systems than traditional services. In any case, these three industries represent a very tiny part of the traditional services spectrum: the three industries combined account for a little more than 1% of all American businesses.

The relevance of customer-intensity is also acknowledged buy other research works. For instance, Gaudrey's definition of services clearly encompasses the idea of customer input [5], but it lacks the simplicity and easy of applicability of our definition as stated above. Karni and Kaner [6] also rely on customer intensity to define service systems, but their definition seems to imply that any kind of customer participation is sufficient to characterize a service system. In our view, this definition is inadequate since includes certain types of manufacturing processes where there is some participation of the customer in the form of feedback, but not actual customer input.

By examining the NAICS system we have shown that the class of customer-intensive systems covers almost all of what most people understood as services. For the sake of simplicity, we use the term "service" as a substitute for "customer-intensive" for the rest of the paper.

4. Representing Service Processes

Having defined customer-intensive systems, and shown how they cover our intuitive notion of service industries, we move on to understand what the definition implies, and more interesting, enables. To facilitate that, we have found important to highlight, when visually representing service processes, the fundamental differences between customer-intensive and

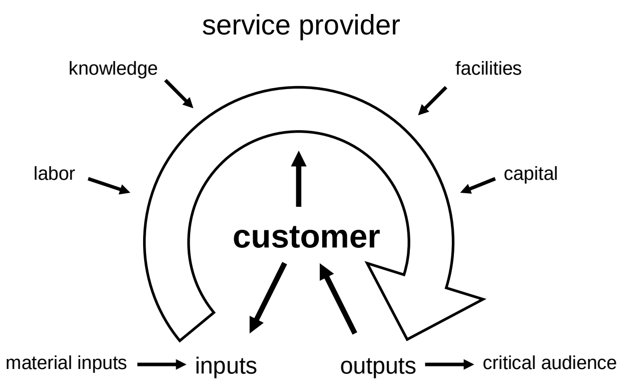

Figure 3. A customer-centric representation of a service process.

manufacturing processes. Interestingly enough, traditional service representations tend either to fail to explicitly acknowledge the significance of the customer input or to use customer representations which are visually insufficient to demonstrate the centricity of customers, such as is the case of blueprints [15]. Often, service processes are depicted identically as manufacturing processes in a sequential form as the diagram in Figure 1, or with arrows pointing from the customer back to the input as shown in Figure 2. This kind of representation is particularly confusing because the arrow from the customer to the inputs can easily be read as "feedback" and not as real input. Moreover, that representation fails also to highlight that the customer defines the start of the process, often is part of its middle, and is the receiver of the results.

4.1. A Customer-Centric Representation

We believe that a true change in the way we look into service systems as different entities from their manufacturing counterparts starts with a strong visual metaphor about the centricity of the customer to the system's processes. Figure 3 shows our proposal for the visual structure of a representation of service processes which has, as its strongest feature, the placement of the customer in the center of the process.

Basically, our proposed *customer-centric representation* of service processes features the sequence of components of a service process represented along the circumference of a ¾-circle arrow, clockwise, as shown in Figure 3. The means of production brought by the service provider are shown in the outside part of the arrow; similarly, means of production when provided by the customer, are represented in the inside part of the arrow. Notice that we do not explicitly depict the means of production provided by the customer in the diagram of Figure 3 first for simplicity, but also because the customer not always provides means of production in a service process. Also depicted in Figure 3 are the material inputs to the process and the connection from the outputs to the critical audience. Since both are beyond the realm of the customer, they are positioned in the outside of the arrow.

Our intention here is not to echo the rhetoric about the importance of customers for the modern enterprise. Instead, we are advocating the use of a customer-centric representation of service processes because: (1) a customer-centric representation highlights the significance of the customer input and participation in a service process; (2) the use of circular instead of linear representations for a process focuses the attention on the central element of the representation and can be used to accentuate fundamental components of the customer's world such as presence, property, information, and time; and, of course, (3) because indeed the customer is the center of a service process.

4.2. Example of Representing a Service

To illustrate the potentials of shifting from the traditional, linear representation of processes to the customer-centric representation, we examine now the representation of a simple service process. A very common IT support process is the procedure to rewrite the hard-disk of a personal laptop computer with basic system code and a set of standard applications. This process is often called *imaging a hard-disk* and its basic sequence of steps involves the customer: bringing the laptop to the IT support station; agreeing with the estimated time needed to perform the process; and providing hard-disk and machine passwords. Often, the technician is imaging multiple machines, so the laptop has to wait until the procedure of physical imaging can be performed. After imaging, the machine is tested and returned to the customer, together with a set of provisional passwords.

Figure 4 compares the traditionally used linear representation of a service process (top) with the proposed customer-centric representation (bottom) for the *imaging a hard-disk* process. Notice that for the sake of a fair comparison, we included in the linear representation explicit customer elements, including the information and property brought to the process by the customer, although the inclusion of such elements is far from usual.

The bottom of Figure 4 shows the same process of *imaging a hard-disk* in the customer-centric representation. The most important difference is that in this representation, the central position of the customer makes visually clearer that the process begins and ends with the customer and that the *imaging a hard-disk* process is about the customer's machine, personal data, and passwords as they are input to the process.

Of course, it is very difficult to determine what a good representation is. To start, how good a

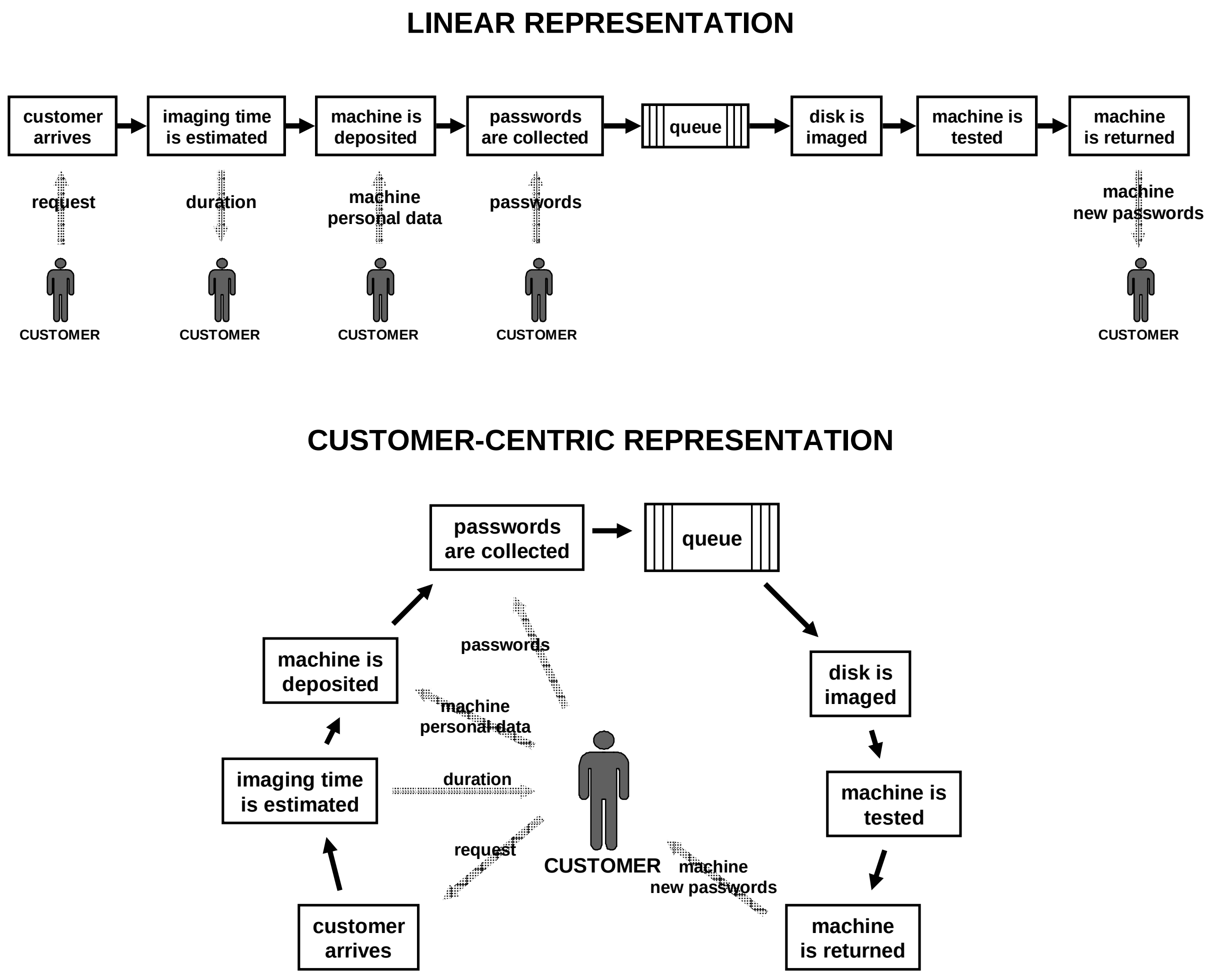

Figure 4. Linear and customer-centric representations of a typical IT support process: imaging the hard-disk of a personal laptop.

representation is depends on what it is used for. Nonetheless, we have observed in our own work that the customer-centric view, besides naturally emphasizing the fundamental customer's role in a service process, is quite good at depicting the use and processing of some of most fundamental components of the customer experience: *presence, property*, *information,* and *time.* Figure 5 shows an enhanced representation of the *imaging a hard-disk* process of Figure 4 which depicts each of those experiential components in a highlighted way:

- **Customer time:** time in the diagram of Figure 5 is shown not linearly but centered in the customer, clockwise, as if the customer was the center of a clock. It is a strong visual statement that the service process is running on customer's time.
- **Customer presence:** whenever the presence of the customer (in this case, physical) is necessary to steps in the service process, the corresponding slice of time is grayed. For instance, in the service represented in Figure 5, the customer's presence is essential in all the initial steps of the process, as well as in the last step. This is an important engineering consideration since presence-intensive systems tend to require redundant capacity to avoid queues of customers. The diagram also shows that there is a considerable span of time, from the time the machine enters the queue to the time the machine is returned, where no feedback is provided to the customer. Feedback-free long spans of time tend to increase customer's anxiety, often with impacts on customer satisfaction.
- **Customer property:** the temporary possession of customer's property, physical or informational, by the service provider is represented by plotting the property components on the outside of the sequence of steps. For instance, after the step named *machine is deposited* the service provider has the possession of both the machine and the customer's personal data inside it. Possession of

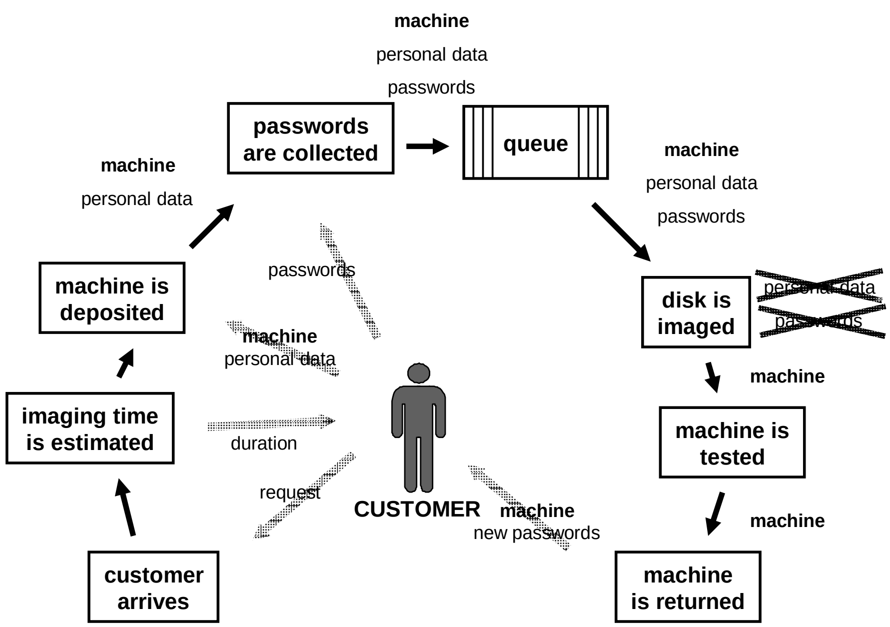

Figure 5. Fundamental customer elements (presence, property, information, time) are easily depicted in the customer-centric representation of the "imaging a hard-disk" service process of Figure 4.

customer property has to be dealt carefully by any service provider, given not only the legal implications, but also the level of trust required from the customer, and the high expectations about how the property is going to be kept. Scratching the cover of a laptop in a traditional manufacturing process causes at most the rejection of the part, while in a service process it is hard to even predict the customer's reaction and how to mitigate the effects of the damage.

- **Customer information:** information and physical property are perceived in very different ways by people, so our representation differentiates them by marking in bold type any physical property that goes through the system. This is not to be viewed as a statement that physical matter is more important than information. Instead, it should be seen as an acknowledgement that flows of the customer's physical objects and information have different characteristic and challenges. Often physical property is unique and cannot be replaced. On the other hand, information can be easily copied, altered, and moved around bringing high stakes to issues such as privacy and security.

Notice that the diagram of Figure 5 should not be seen as a definitive proposal of what and how to represent service processes, but as an example of the richness of options available when we move to a customer-centric form.

4.3. Customer- vs. Information-Centric

Before we move on to discuss engineering issues of services as customer-intensive systems in the next section, it is important to discuss another reason to move away from traditional forms of service representation: the obsession, often found in computer scientists and IT professionals, to reduce all transactions of a system to informational exchanges. Worse, the success of the IT industry sometimes seems as if it has contaminated the minds of people working with all kinds of systems, often creating a paradigm of oversimplification. For instance, often people responsible for systems of networked printers regard the goal of their jobs to be maximizing the throughput of the printers and not as to satisfy efficiently the printing needs of the employees. Under this kind of simplification, printers are routinely removed or relocated based solely in printing usage, sometimes forcing high-paid and critical mission employees into time-consuming walks to pick-up print-outs in ever farther away printers. The rationality of the information-based optimization of resources is irrational from the services perspective.

On the other hand, the linear, step-by-step representation of processes is very popular to depict processes that transform information because it can be easily translated into the linear, step-by-step representation of computer programs. But when we apply the same principles and methods to service processes, IT professionals tend to forget that they are processing bits of information to which strong feelings, concerns, even emotions, are attached, in the very form of the paper bureaucracies that we all hate.

Another problem with the information-centric view, when applied to services, is that it almost implicitly assumes that the computer system time, and efficiency, is the "master clock". An interest example of how considering time in machine terms can frustrate the customer is the practice called *sniping* [18] in online auctions systems such as *eBay*. By creating *bots* that monitor an auction and bid exactly in its last seconds, professional buyers often outsmart human bidders who have no time to react to these last-second bids. At the same time, by not bidding early in the auction, sniping users avoid driving prices up prematurely. Interestingly this practice seems to be driving non-professional buyers away from the auction market, with negative impacts for sellers and for the online auction provider.

At the same time, the IT industry has a reasonable record of success of understanding the needs and difficulties of its customers, thanks to the advent of user-centric design techniques. However, even in this case, it can be argued that the same industry still fails to understand the difference between software tools and services delivered by online computer systems. Pinhanez [11] argues that there are important differences between online services (such as *Google Search*), where the user does not control the means of production, to software tools (such as *Microsoft Word*) where the user controls most of the means of production, with significant impacts on human-computer interface design.

Finally, we want to make clear that we are not advocating that information processing is not an important part of service systems and processes. Instead, we want to make sure that information-centric methodologies do not "distract" service scientists and engineers from giving the necessary priority to customer considerations and issues in service systems.

5. Implications for Service Science and Engineering

Our central argument in this paper is that the best way to characterize the difference between manufacturing and service processes is in terms of customer intensity: the significant participation of the customer and her body, belongings, and information, as the input to the production process. We examine in the following pages four different ways in which services, as customer-intensive systems, transform deeply-rooted engineering and science practices. This is certainly not an exhaustive list of the changes required, but instead four different arguments of why service science and engineering are disciplines significantly different from their manufacturing counterparts.

5.1. Human Values-Loaded Input

Let us consider the design of an electronic circuit. Although the fundamental level of design is concerned with the voltages and flow of current in the circuit, any engineer knows that issues such as heat and electromagnetic interference must be considered for the successful engineering of the circuit. A service, as a customer-intensive system, processes by definition a significant amount of customer inputs. However, service science engineering often reduces customer input to the material or informational aspects of it. A passenger in a subway system is reduced to a body; a customer's problem in a technical support system becomes the information associated with the problem. People are modeled as objects, machines, and data.

This dehumanization of the input is, in our view, a key issue to be solved if we want progress in services science and engineering. Like heat dissipation must be considered in the design of real electronic systems, managing the passenger's anxiety about the subway trip is essential for a good subway service. For example, posting publicly the actual time that the next train is going to arrive allows people to pass overcrowded trains.

Another way to look into this is to understand that, unlike in a manufacturing process, the inputs of the service process are loaded with human values and aspects. The customer himself, his stuff, or his data, is on the "conveyor belt", and the emotional attachments or privacy worries are as much fundamental aspects of those inputs as their weight, condition, or size in Kbytes. A mortgage application is not data, but often a carrier of hope for a better life and for the customer's dreams.

How do we explain, then, that most service systems are engineered without considering the human side of the input, and nevertheless, the service is often acceptable? In our view, the method most often used to compensate for over-simplified representations of customer input is to simply leave to the human employees the dealing with the human aspects of the customer input. Using employees to manage the human value-loaded input is one of the reasons for the labor-intensive nature of most service systems. Similarly, this failure and fear to explicitly address input-connected human needs during service design and engineering is likely to be a main obstacle for the successful automation of service processes.

5.2. Formal Models of Customers

It is unquestionable that successful science and engineering requires formal, often mathematical models of the inputs and components of the subject systems to be researched, developed, and employed in the design and engineering process. Therefore, we argue that service science and engineering requires formal models of customer inputs, which is likely to translate into the need of formal models of the customers themselves.

Creating such models faces two different types of challenges: technical and cultural. The technical challenge is related to the difficulty of formally modeling human beings and their behavior. Part of the problem here is, however, what we consider a fundamental misconception of the real goal which is to develop customer models and not full-blown human models. In other words, we argue that for the purposes of service science and engineering, only a subset of the humanness of people needs to be modeled. Specific, smaller subsets of human aspects may be considered in the development of customer models for specific classes of services. A good example of a formal model of people in a service system is the work of Oliva and Sterman [9], which developed and validated a model of employees and managers in a banking service process. Although this work models employees, not customers or customer input, its use of dynamic systems is exemplar.

We see also many reasons why customer modeling is likely to be simpler than human behavior modeling, or intelligence modeling (aka as Artificial Intelligence). First, people often “play” their role of customers, creating simplified versions of themselves on the service stage, often “acting out” anger or frustration when needed. This should translate into simpler, more predictable, and easier to observe and recognize models. Second, customers often do not act in intelligent ways. Thus, customer modeling may require neither common-sense reasoning nor deep reasoning, two major obstacles faced traditionally by Artificial Intelligence. Third, the last 15 years have witnessed a great deal of success in statistical modeling of people, especially in social filtering, affective computing, human action recognition, social networking, and reputation systems. Fourth, there is some evidence from the literature in service quality that many of the different aspects of the customer experience of a service can be captured by a smaller set of human aspects, since all aspects correlate very well with at least of the aspects in the smaller set [10].

The cultural challenge is related to the difficulty of convincing traditional scientists and engineers to include human considerations into their theories and solutions. There are, in our opinion, at least two ways to address the cultural challenge. The first is by digesting human issues into very quantifiable components that can be easily incorporated to larger models. A classic example of this is the inclusion of human perceptual considerations in image and audio compression algorithms discussed in the introduction.

The second way to address the cultural challenge, especially in service engineering, is by adding people to the engineering process which are trained and comfortable with human aspects. That is the approach that has brought aesthetics and simplicity to software, achieved through the integration of interaction designers to the software development process.

5.3. Time vs. Perceived Time

One of the key implications of having customer input to a production process is that time has to be considered under the customer’s perspective and not in absolute terms. Not only the customer of services starts the production process by bringing her input to the system, but also the fact that customers often coproduce makes the perception of time different from absolute time.

For example, suppose a service process is being re-engineered, aiming to reduce production time and therefore customer satisfaction. A common mistake is to focus on reducing absolute time and neglect how the passage of time is being perceived by the customer. In a classical case described by Ackoff [2] complaints about the time to wait for elevators in a skyscraper were solved not by optimizing the elevator’s schedule, but by installing mirrors in the elevator lobbies: people, having something to do while waiting, perceived the elapsed time as shorter.

In the services research, Richard Chase has been the strongest advocate of using Behavioral Science knowledge and methods to manipulate the perception of time and sequence to enhance customer satisfaction [3]. For example, Chase [4] advises the design of customer experiences where bad sides of the experience (such as paying) are dealt upfront; which segment pleasure and combine pain, thus decreasing the perception of the duration of the “pain”; and which have a strong finish.

The importance of incorporation of psychological aspects into operational models has also been demonstrated by Mandelbaum and Zeltyn [8] in their studies of telephone call centers. By studying different models of human patience and their relationship to the likelihood of customers abandoning calls while waiting in queues, they were able to propose better algorithms to model call centers performance.

However, the development of more formal models of perceived time is in its early stages, although there is a significant body of knowledge to leverage from Behavioral Sciences, Ergonomics, Design, and even performance arts.

5.4. Quality Control of Services

There is a considerable amount of research that indicates that, in services, quality perception is both a function of the actual service output quality and the expectations of the customer [10]. As discussed in [14], arriving into this conclusion was the result of extensive research and many scientific debates. We present here a simple mathematical argument for the same conclusion.

Consider first different manufacturing processes (possibly different manufacturers) which produce products $p_1, p_2, ..., p_n$. Suppose the customer appreciation of the quality of the product p_i, at the point of acquisition, is $q(p_i)$, while the customer's desired quality is Q. In these conditions, we can approximate the process of choosing the product by:

$$p = \max_{p_i}(q(p_i) - Q)$$

Let us define a simple measure of customer satisfaction s by considering the addition to 1 of the difference between the estimated quality of the product and the desired quality:

$$s = 1 + (q(p) - Q)$$

In the situation of perfect choice of this manufactured product, i.e., $q(p) - Q = 0$, we have in fact that the quality of the product is equal to the desired quality, $q(p) = Q$. Substituting in the satisfaction equation:

$$s = 1 + (q(p) - Q)$$
$$s = 1 + (Q - Q) = 1 + 0$$
$$s = 1$$

In this simple argument, a perfect product choice in a manufacturing process generates 100% of satisfaction.

Now consider n different service processes $P_1, P_2, ..., P_n$, to which the customer is considering supply a customer input c, to produce outputs $P_i(c)$. Now, suppose a customer with desired quality Q for the outcome of the service process has to decide among service process P_i. Since, unlike in typical manufacturing, the output $P_i(c)$ is not available to the customer at the point of acquisition, the customer has to estimate both the actual customer input c' and the output of each service process, $P_i'(c')$, and its quality $q(P_i'(c'))$. In these conditions, we can approximate the process of choosing the service by:

$$P = \max_{P_i}(q(P_i'(c')) - Q)$$

Similarly to the manufacturing case, let us define a simple measure of customer satisfaction s with the outcome of the process by considering the addition to 1 of the difference between the estimated quality of the output of the process and the desired quality:

$$s = 1 + (q(P(c)) - Q)$$

Notice that customer satisfaction is computed after the service process occurs and therefore evaluates directly the outcome of the chosen service process P supplied with the actual customer input c, $P(c)$.

Now let us consider again the situation of perfect choice, i.e., $q(P'(c')) - Q = 0$. Since in this case, $q(P'(c')) = Q$, when we substitute in the satisfaction equation we obtain:

$$s = 1 + (q(P(c)) - q(P'(c')))$$

In other words, even with perfect choice of service process, satisfaction is still dependent on the initial expectations of the quality of the output of service.

Although far from a formal proof, this mathematical argument exposes some of the key issues in a service process: service choice is performed before actual production; and the expectations of quality at the decision point bound the satisfaction.

The situation in practice is even more complex. Since often the customer coproduces the output, customer satisfaction is also affected by the satisfaction with the process itself. In a simplified model of the coproduction situation, the overall customer satisfaction $\bar{s}$ can be defined as the product of the satisfaction with the process $sp(P, c)$ with the outcome satisfaction s, denoted by $\bar{s} = sp(P, c).s$, and therefore,

$$\bar{s} = sp(P, c).(1 + (q(P(c)) - q(P'(c'))))$$

Dieting support companies are good examples of how customer satisfaction can be put under control by paying careful attention to the quality of the process itself. A customer who wants to lose weight has often a unrealistic view of himself c', but high expectations for the weight loss Q. More often than not, the actual outcome of the dieting process $P(c)$ falls well short of the initial expectation $P'(c')$, and therefore the satisfaction with the outcome of the process s is very low. Dieting support companies are aware of this fact and control overall customer satisfaction $\bar{s}$ by trying to delight the customer during the process, aiming to obtain a very high process satisfaction $sp(P, c)$ to compensate for the usual deception s with the outcome.

How to measure quality is just one of the issues that difficult quality control in service processes. Another common problem is that in services it is impossible to discard intermediary stages of the processing of customer inputs when they do not meet quality standards. Simply imagine a dry cleaning service that throws away all the shirts which it cannot remove the stains.

Finally, notice that the arguments above are basically agnostic to issues of quality control of human work, a reason often wrongly cited for the difficulty of quality control in services. Customer expectations and process quality are inescapable facets of service quality due to the presence of customer input.

6. Final Discussion

The main idea of this paper is that service science and engineering are inescapably tied to the understanding and modeling of customers. We first defined a new category of production systems, customer-intensive systems, where the customer is a significant part of the input. The best summary of this definition is, in our view, the diagram depicted in Figure 3. We have also argued that almost all service systems are customer-intensive systems, and presented a strong argument for customer-centric representations, as exemplified by the visual expressiveness of Figure 5.

Moreover, as argued above, customer intensity seems to require at least four radical changes in the way science and engineering should be practiced: production models and systems should consider that some of the inputs are loaded with human-values; formal models of customers are needed; human perception of time must be taken in account, especially in optimization issues; and service quality control must include customer expectations and the quality of the process according to the customer view.

Another possible consequence that we are investigating is whether approaching service systems from a customer intensity perspective allows us to decrease the apparent complexity of services. Service modeling has been so intractable that some authors ponder whether complexity is an intrinsic quality of services [7]. However, maybe it is possible to reduce the complexity of service systems by decoupling the complexity of the customer input from the service process, kind of reversing the famous “ant on the beach” fable of Herbert Simon: *“Viewed as a geometric figure, the ant’s path is irregular, complex and hard to describe. But its complexity is really a complexity in the surface of the beach, not the complexity in the ant.”* [16]. Maybe, in the case of services, the ant (i.e., the customer) is the source of complexity, and the beach (the service system) is surprisingly simple.

We are also very interested in expanding this discussion for the case of business services, i.e., when the customer is an organization instead of people. What kinds of models of organization can be used for science and engineering? How organizations perceive time and quality? In the most optimistic view, it seems that such models need at least to have higher dimensions, but most likely they will require a new set of theoretical and practical tools..

Finally, customer intensity is likely to affect and require transformation in service design and management. However, we expect these other components of SSME to require less radical change in methods, since they already incorporate many concepts, methodologies, and practices principled on human issues.

7. References

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