

FIRST-PRINCIPLES FOR SERVICES AND PRODUCT-SERVICES-SYSTEMS: AN R&D AGENDA

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ABSTRACT

The inexorable and prodigious shift to services in macro-economies is driving a “servicization” in product development. Physical products and services are increasingly bundled as an integral offering to meet customer needs. These bundles are called Product-Service-Systems (PSS). Unexpectedly, the literature is silent on first-principles for services and PSS development. We argue that a parsimonious set of first-principles is fundamentally necessary for the maturation of services as a rigorous discipline for research, product development, and the practice. Using Qualitative Content Analysis Methods of the services literature, we derive a fresh and more complete definition for services. Then using this definition, we derive our set first-principles for services and PSS development. We show that these first-principles embody key learning and knowledge from research scholars. Salient features of our principles are: a multidisciplinary system perspective, conformance to the doctrine of the “sciences of the artificial”, and a concentrated attention to future research, development, and operations. We close with a proposed meta-framework for research and development of services and PSS.

Keywords: *Product-Service-Systems, PSS, PSS development, services, service science, services R&D*

1 INTRODUCTION

This article is motivated by the services tsunami worldwide, which is a major contributor to economic wealth. The 2007 International Labor Organization reports that for the first time in history, employment in services (40%) exceeds agriculture (39.4%) and manufacturing (20.7%). Economies are undergoing a “servicization” transformation, physical products and services are bundled as an integral offering to meet customer needs. These bundles are called Product-Service-Systems (PSS) [1]. For a historic socio-technical shift of this magnitude, there is an unexpected and conspicuous absence of articulated first-principles for the research and development of services and PSS. This article will address this gap by proposing a set of first-principles for the research and development of services and PSS. Our intent is for scholars to support, refute, or add to the ideas presented. Our goal is to stimulate the accretion of progressively more rigorous, useful, and effective knowledge about services and PSS. This is also a process of natural selection: weak ideas about PSS that cannot stand scrutiny will be discarded. The research questions that interest us are:

- What is a frugal set of first-principles for services and therefore for PSS?
- How do we go about uncovering them?
- Based on these first-principles, can we frame a research strategy?
- How might these first-principles guide PSS design and development practice?

Why do we need first-principles? Knowledge creation and accretion requires first-principles as a foundation for systematic research and disciplined practice. For example, engineering is grounded on the first-principles of physics; management science on the first-principles of economics, behavioral psychology, and theory of the firm; and medicine on biology, physiology, and the universal principles of ethics and humane treatment. In contrast, the services and PSS literature are conspicuously silent on first-principles. Services are acts of human will and effort. Such acts are not like electrons repelling each other, a behavior that does not require human effort. Human acts of intention and effort need principles and norms to produce meaningful and purposeful outcomes. First-principles for services and thus for PSS, deal with human will and man-made artifacts. As such, these principles are in the *sciences of the artificial*. In this article, we take a first step and propose to ground services on a corpus of first-principles to enable the development and accretion of knowledge endowed with progressively more explanatory and predictive power to fuel the rigor of PSS design and development.

What is a service? We share the view expressed by scholars that services are multidisciplinary. It follows that the first-principles for services must be rooted in different disciplines. To uncover these disciplines, we use methods from qualitative content analysis (QCA) to study the work of scholars. From this analysis, we distill a unified working definition for services that embodies the key intrinsic properties of services reported in the literature. Then using qualitative content analysis procedures, we derive a parsimonious set of first-principles. Key to this extraction is our formulation of five epistemic rules that we impose on our first-principles. They are the rules of: parity, research, falsibility, accretion, and the sciences-of-the-artificial. Our first-principles for services and PSS are: lean production; customer satisfaction; taktchronicity and engineering design; fair Nash-equilibrium; and satisficing under uncertainty. A PSS is a system; therefore, our aforementioned principles must work as a coherent and integrated ensemble. This leads us to our sixth principle, a unifying system principle, i.e. all the principles working in unison must produce the designed emergent system-level behavior for which the PSS was intended. This is discussed as the system principle of the “ilities”.

The 2003 National Academy of Engineering reports that the academic research enterprises have not effectively organized to meet the needs of the services sectors. Scholars observe that this dearth of research has retarded important and productive innovation in national economies, industries, and firms. Others note that, on services, academics have no shared sense. And that moreover, the field needs to develop a scientific approach and have a clear set of principles for services. This article is a response to these clarion calls.

The remainder of this article is organized as follows. We begin with a survey of the literature. From this survey, we mark four epochs we discern in the progressive maturation and understanding of services. Then, using QCA we content analyze the work of scholars that have articulated fundamental attributes of services. We embody them into a definition. From the content of these definitions and our integrated understanding of them, we extract our definition for services. Using this definition, we continue with our extraction procedure to uncover first-principles. Consistent with our goal to promote the rigor of research and the development practice of PSS, we discuss a meta-framework for research and the practice. We close with a discussion and implications of this work.

2 LITERATURE SURVEY

Scholars present comprehensive surveys of the services literature [2-6]. Collectively they reveal four eras, which characterize and reveal the progressively increased understanding of services.

The first era defines services by exclusion. In the US Department of Commerce SIC (Standard Industry Classification) codes of the 1930s, services were a residual, classified as neither agriculture nor manufacturing, but simply as “other” [7], [5].

The second era is characterized by the search for intrinsic and differentiating characteristics in services. This is the “IHIP” era, in which scholars reached a generally accepted consensus on the defining attributes of services, collectively known as IHIP: Intangibility, Heterogeneity, Inseparability, and Perishability, e.g. [8], [9]. Intangibility is the distinction that unlike a “physical good, services cannot be seen, tasted, heard, felt, or smelled before purchase” [10]. Heterogeneity refers to the fact that unlike manufactured goods, services are delivered by people of different skills and motivations; thus making each service experience unique. Inseparability articulates the notion that production and consumption of services are simultaneous and inseparable. Perishability is the property that a service “perishes” unless experienced. Thus, services cannot be inventoried. These ideas, however, could not stand close scrutiny. Vargo and Lusch [11] convincingly argue against these “remnants of a goods-based, manufacturing model.” Lovelock and Gummerson [12] refute the IHIP distinctions, present persuasive counter-examples, and conclude that the IHIP characteristics are “not supported by the evidence.” For example, there is nothing intangible about the bacon and eggs in a breakfast at a diner. However, to reject IHIP in its entirety is inappropriate. We think of a service as a structured bundle of physical and non-physical elements, i.e. a PSS. IHIP attributes are a necessary but an insufficient part of a PSS. The bundle is a mix provided by the provider and client. Consider a shoe shine: providers shine shoes with their shoe polish and efforts, clients supply their shoes. Banks supply their data and networks, providers supply the computer and engineers to design the system; and banks and providers design the operational procedures.

We characterize the third era as “a thousand flowers blooming.” Dissatisfaction with IHIP and the increased technology content in services are stimulating scholars to think differently about services [13]. They present diverse and competing ideas to articulate what is distinctive about “services”. For

example, a service is considered as stream of benefits [14], flows of customer information and material processes [8], science, management, and engineering [3], non-science [15], systems engineering [16], engineering systems [17], and so on. These characterizations are driven by new and novel technological embodiments, innovative delivery mechanisms, sophisticated customer requirements, new economic and psychological expectations - are more sophisticated and nuanced than in the previous era. With so many disparate ideas, it is difficult to discern a dominant characterization.

The fourth and current era is a period of “metamorphosis”. The plethora of flowering ideas is triggering a period of consolidation where a dominant service concept is struggling to emerge as a rigorous and accepted base for PSS research, design and development. Strong forces are pushing this process. Pervasive communications networks, value networks’ disintermediation, and competitive imperatives are creating entirely new services. Vargo and Lusch [18] propose a new “dominant logic” for services marketing, and by implication an entirely new way to think about services. Sampson and Froehle [19] propose a Unified Service Theory in which customers provide input and act as suppliers of processes. Larson [17] argues that “service sciences” is a “holistic trinity” of disciplines in which the end result is an “engineering system”. A bold vision is IBM’s Service Science Management & Engineering (SSME) initiative [20], [21]. This initiative argues for science, i.e. services need “a scientific approach and have a clear set of principles and goals [22]” and “common features that sciences require [23]”. The objective of this paper is to make a modest contribution by presenting first-principles to hasten the metamorphosis towards a more rigorous development and science of PSS.

3 RESEARCH METHODS

We use Qualitative Content Analysis (QCA) as our principal research method [24-27] to analyze and understand the literature. QCA is a research method “that emphasizes the role of the investigator in the construction of the meaning of and in the texts ... There is an emphasis on allowing categories to emerge out of data and on recognizing the significance for understanding the meaning of the context in which an item is being analyzed (and the categories derived from it) appeared [28]”. QCA’s approach is used to concentrate on the interpretation of text and its context to uncover pivotal themes [28], [29]. Scholars judge QCA to be most suited to a field in which new and different concepts and hypotheses need to be formed and in which there is abundant literature and documentation [26]. QCA scholars do not preclude the use of quantitative analysis to triangulate on findings.

QCA is another instantiation of the scientific method. In the language of QCA, the key processes are: (i) posing the research question, (ii) data collection, (iii) summary and explication, (iv) extraction and structuring, and (v) interpretation. The first two steps are self explanatory. In the summary and explication phase, the material is condensed through a process of abstraction to illuminate the key concepts and the contexts in which they appear. Extraction and structuring are the hallmarks of QCA. The objective is to uncover “a new basis of information separate from the original text ...” [30]. This new basis serves to reveal a more insightful structure that is consistent with the content of the documents studied, the context in which they are presented, and the scale of analysis. This structure is used to guide and illuminate the analysis and interpretation of the research. One iterates the through selected steps until saturation is reached before proceeding to the next step [31].

4 RESEARCH QUESTIONS AND LITERATURE REVIEW

We have already posed our research questions in the abstract of this article. For data collection, we concentrate on publications from research journals, a subset of which are listed in the references. We have likewise presented a summary of our literature survey. From this body of work, we will extract the definitions of service we judge to be most insightful in revealing the fundamental characteristics of services. In turn, from these definitions we will extract the thematic meaning implied in the definitions of services offered in the literature. The results of our extraction are listed below as “Findings”.

5 ANALYSES AND FINDINGS OF SERVICE DEFINITIONS

Finding 1. Service as output

Hirshleifer [14] offers the following definition: “Services represent a flow of benefits over a period of time, derived from either physical goods (like the shelter service provided by a house) or from human activities (like the entertainment service provided by concert performers)”. The focus of this definition is on the **output** of the supply side of services. This definition does not insist on IHIP to the exclusion

of physical artifacts. We share this view of services and we consider services and PSS as synonyms. There is work that explores the concept of benefits from services and presents a monetary measure to quantify benefits [32]. Benefits must be the output of services; without benefits, there is no service.

Finding 2. Service as production

“A service is any act or performance that one party can offer that is essentially intangible and does not result in the ownership of anything [33]”. In this definition, the focus is on **production**, the supply side, with a constraint (no ownership) on the exchange. Lovelock and Gummesson [12] suggest that the absence of ownership is a potential basis for a new paradigm for services. This is problematic. Is a restaurant a manufacturing business because we are buying a meal? Is a tailor, who is making me a suit, in the manufacturing business? Or are they in the service business? Nevertheless, this definition is insightful because it makes production a salient feature of services. Min [34] makes a stronger point, manufacturing needs to acknowledge the “servicisation” of manufacturing. Service is an intentional act of production performed by a party. There is no service without intentional production.

Finding 3. Service is as *taktchronous* co-development of a solution

“Services are economic activities that create value and provide benefits for customers of specific times and places as a result of bringing about a desired change in - or on behalf of - the recipient of the service [35].” *Desired change* is activated through a process that engages “... clients and providers working together for a state transformation, such as material goods, information, organization ... [36]”. Focus is on problem-solving and the co-creation of future benefits for the client. *Desired change* and *state transformation* make a service a creative act. Creation is synthesis, it is a design endeavor. “Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. [37]”. Thus, services are about how “... to organize a solution to a problem ... which does not principally involve supplying a good. It is to place a bundle of capabilities and competencies (human, technological, organizational) at the disposal of a client to organize a solution...” [38]. These observations can also be made for manufacturing. What makes services unique? One is that provider and client work together. Working together and co-creation means that the provider and the client bring different, but complementary, factors of production to the development of a solution. They work together almost as if the client is a “partial employee of the provider [39]. Two, services are unique in that provider and client must work together in a situational specific cadence, in “taktchronicity”. Taktchronicity is not synchronicity. For example, taktchronicity does not mean that the strings play synchronously with the percussion instruments. Rather, they play at their appropriate times, at times synchronously, most often not, but always at the appropriate cadence such that music is produced at all times as the composer had intended. Synchronicity would produce cacophony rather than music.

Taktchronicity is our adaptation of “taktzeit”, “takt-time”, the lean production concept which refers to the average time between units of production in order to meet customer demand. In an orchestra, takt-time refers to the cadence of the music that must be maintained in its performance. We combine these meanings into the taktchronicity attribute of PSS co-development and co-production. During the PSS development life-cycle, customer input and changes must be implemented. The work speed of the provider and client may vary vastly, but the cadence must maintain a mutually satisfactory equilibrium between the needs of the provider and client. This is especially important when new and important knowledge emerges that change requirements, cost, or schedules. Taktchronicity is the cadence at which streams of co-development/production maintain the equilibrium of provider-client reciprocal satisfaction. For these reasons, taktchronicity is part of our first principles.

Finding 4. Service is an economic exchange

As everywhere else, there is no free lunch. Spohrer and Maglio [36] write that a salient attribute of services is that of “[P]ay for performance in which value is coproduced by client and provider”. This makes the requirement of an economic exchange explicit by using the term “pay”. But, the use of “pay” is restrictive. IBM does not always “pay” for services. At times, the exchange is monetized through “value in kind” (VIK) as in the Nagano Olympic Games of 1998. Rather than “pay”, the legal term “consideration” is broader and it is anchored on legal doctrine. Consideration includes monetary payments, VIK payments, and reciprocal non-monetary arrangements. In contract theory, consideration is something that suffices to make a promise binding in the exchange of responsibilities

and obligations. Intrinsic in the notion of exchange is the existence of an equilibrium in the reciprocal act of exchange. The exchange, of rights and responsibilities for the consideration, is balanced.

Putting all these findings of definition together, we extract the following observations. The input to the service process is a client’s desire for change; this is the service opportunity for the provider. The service process is the act performed by the provider and client “working together” in taktchronicity to design and develop a solution to solve a client’s problem. The result is a solution that is instantiated as a PSS, a product-IHIP composite. The service act is performed for consideration. Thus, we propose the following definition:

- **Service: a solution performed for consideration with a taktchronously co-produced product-IHIP solution to create a stream of benefits.**

6 EXTRACTION OF SERVICE DISCIPLINES

Services are multidisciplinary. Rust, editor of the Journal of Service Science writes: “Service, by its nature, involves a wide range of disciplines, and I would like to see that range ... advance knowledge; it will provide multidisciplinary intellectual leadership to service management worldwide” [40]. But, what are these disciplines? To uncover the service disciplines, we use a semantic extraction procedure on our definition for our QCA [41]. In our context, semantic analysis asks the question: what does a discipline mean to a service?

Service is a solution performed by a provider. Thus the discipline of *production* is at the core of a service. The goal of a service is to produce a physical product, a non-physical product, or a combination of both, i.e. a PSS, a product-IHIP composite. The essential motivation to perform a service is the provider’s desire to solve a client’s problem. In order to solve problems, clients must communicate their requirements, i.e. what the provider must do. This concern for clients’ needs and wants means that *marketing* is a core discipline of services. A client’s requirements are satisfied with a co-produced solution meaning that each party brings different factors of production. The creation of a solution is engineering, specifically, *product development*. A PSS is a special type of product. Providers perform services for consideration. Consideration is not an automatic reflex; rather, it is reached through an understanding of reciprocal responsibilities and obligations. Thus the key domain of interest is economics and the core disciplines are *managerial finance* and *contract law*. What a client expects from a service is nothing less than a stream of benefits. Benefits are not outcomes that result naturally, like water rolling downhill. Benefits result from human will and effort that require economic, physical, and intellectual resources. Resources and human energy are limited and must be utilized judiciously to produce benefits. The required discipline to efficiently co-produce a predictable flow of benefits, using limited resources, is *project management*. Benefits derive their meaning from the strategic context in which the service is embedded. It follows that the other relevant discipline is *strategic management*. These disciplines are central to any service no matter what the scale of the service recipient, a single customer or an organization. This discussion is summarized in Table 1 where the arrow denotes the semantic significance of a discipline to a PSS. For example, “consideration” means that “managerial finance and contract law” are fundamental to “consideration”.

Table 1. Disciplines derived from the definition of services

Definition: A service is ...	implies	Disciplines
an act performed by a provider...	→	<i>production management</i>
to solve a client’s problem...	→	<i>marketing requirements</i>
with a taktchronously co-produced solution...	→	<i>product design</i>
for consideration...	→	<i>managerial finance, contract law</i>
that result in a stream of benefits.	→	<i>project and strategic management</i>

7 EPISTEMIC RULES FOR OUR PSS PRINCIPLES

What is a principle? “Principles are underlying and long enduring fundamentals [truths] that are always (or almost always) valid [42]”. They serve as normative rules for research and the practice. For example, Newton’s three laws serve as a set of principles for physicists and engineers.. Supply/demand equilibrium by means of pricing mechanisms is another principle from the social science of economics. But what screen should we specify for PSS principles? We propose the following rules:

- **Parity Rule.** The principles must apply to both the provider and the customer. They must be

interpretable by both the provider and customer, albeit not identically.

- **Research Rule.** The principles must have a research base. Scholarly work that investigates these principles and closely related subjects must exist in the literature.
- **Falsibility Rule.** The Popper falsability criterion must apply [43]. Science is distinct from non-science by the fact that only falsifiable hypotheses can be considered scientific. We impose this rule because we seek to bring the rigor of science to PSS.
- **Accretion Rule.** The principles must advance the research and the practice of PSS. Science and scholarly work advance through the accretion of valid knowledge and the rejection of invalid information that lead to unsupportable hypotheses.
- **Sciences-of-the-Artificial Rule.** Our principles must be consistent with the fundamental premises of the “sciences-of-the-artificial” [44]. “Artificial” is the defining attribute of man-made artifacts designed to achieve specified goals. This attribute marks the boundary that separates the natural from the artificial. Artifacts are not limited to man-made physical objects, but include social organizations, economies, markets, and the like. The sciences-of-the-artificial deal with functions, goals, and adaptations of man-made artifacts. And include crucial activities such as concept-development, design, production, operations, and economic valuation.

8 PRODUCT-SERVICES-SYSTEMS PRINCIPLES

From our service disciplines (Table 1), we summarize our service principles (Table 2), which we will discuss in this section.

Table 2. Service Principles derived from PSS disciplines

Disciplines	Principles
production/manufacturing/logistics	→ lean
requirements	→ customer satisfaction
taktchronous product co-development	→ design for clarity, simplicity, safety, robustness
managerial finance, contract law	→ fair Nash equilibrium
project management	→ <u>satisficing under uncertainty</u>
	∏∏∏ unifying system principle: design & manage for “ilities”

From these disciplines, we extract **lean production** as a first-principle for services [45-46].

8.1 Lean principle

- *Any resource expended for a result that the customer is not willing to pay, is a waste. Avoidable waste must be eliminated. Unavoidable waste must be relentlessly reduced.*

Service industries can benefit from lean methods of production [46-48]. Waste in services is created in many ways. A provider generates waste from delays, building a physical infrastructure for unrealistic demand, work that requires constant repair, designing bloated useless functionality, failing to train workers, and so on. A client also creates waste when it generates ambiguous and vague requirements, or when it brings a bad attitude to the service situation [49]. Some say that lean omits agility [50]. But the lack of agility results in delays, which is a source of waste. Regrettably, the literature is silent on waste elimination for services. For example, a phone menu of seven selections, each of which is several layers deep, is a highly automated waste-generator of customers’ time and patience.

8.2 Customer Satisfaction principle

- *The service experiences must result in satisfied customers. Customer satisfaction is the key driver of desirable future client behavior that can benefit the provider.*

Determining and satisfying customer requirements are subjects investigated most intensively in marketing. From marketing, we extracted the principle of **customer satisfaction**.

It is difficult to imagine of a service engagement without the intention of satisfying a client. It is also hard to think customers preferring a disappointing experience over a satisfactory one (except for dysfunctional customers [49], [50]). For these reasons, satisfaction is a fundamental driver of customer behavior and providers [51-54]. And customer satisfaction improves perceived quality [53] and has a strong influence on repurchase, “pay more decisions”, and a company’s future profits [54-56].

8.3 PSS Design principles

- *The relationships among all the parts of the PSS, the inputs and outputs, the constraints and the boundary conditions must be guaranteed for simplicity, safety, robustness, and taktchronicity.*

Co-production is motivated by “sticky” product development information [58]. Sticky means that information is costly to acquire, transfer, and use away from its locus of origin. Designing a PSS is a joint problem-solving activity in which the provider and client possess vital sticky information. Thus it is more effective to integrate this knowledge in a tight locus through deep and frequent interactions. Management recognition of the effectiveness of customer participation is not new [59], [60]. Abundant literature exists with elaborate descriptions of its meaningful effects [61-64]. Customer participation has a positive effect on innovation [58]. But the attention of co-development has largely been limited to customer involvement at the front-end of product development. Or as customization the back-end. Co-development is a much bigger concept; it is a PSS development life-cycle concept. Co-development is “value co-creation [65] through different development and engagement models that depend on business objectives and the kind of relationship desired [66]”. It requires technological, strategic, and relational alignment to “create synergistic value” [66; 336]. It implies a different business model. But there is a dearth of theory on this subject. “Development of an emergent theory addressing key co-development issues is long overdue [66]”. Recent work [67-69] are important steps in this direction. And the presence of taktchronicity in co-development remains conspicuously absent.

Product development is the core discipline in the co-production of a solution. For product development, we adopt the engineering design principles of Pahl and Beitz [57]. We concentrate on design because it is the most critical phase of the product development process. Design integrates the requirements and the chosen solution concepts from the front-end of the process by them into form. For us, the form is a PSS with intended functionality and performance. Design sets the direction for all the key PSS related decisions down stream the development process. Thus, design is the activity in which a grand synthesis of the uses and usage, technical, marketing, financial, and production decisions are made. Once a design is committed, it is very costly to abandon or change.

The design principles are: simplicity, safety [57], robustness [70-71], and taktchronicity

- **Simplicity.** *Design the PSS and implement for the fewest number of components and processes. This lowers cost and facilitates usage and maintainability.*
- **Safety.** *People and the environment that interact with the PSS must be protected from harm.*
- **Robustness.** *Designated performance metrics of the PSS must persist in spite of uncontrollable perturbations.*
- **Taktchronous co-development.** *Provider and customer must commit resources of different intensity and skills over the entire product development life-cycle to maintain taktchronicity.*

8.4 Fair Nash-Equilibrium principle

- *Establish the provider-client relationship on a fair Nash equilibrium.*

By definition, the provision of a PSS is an act performed for consideration. Consideration is deliberate, it implies costs, reciprocal obligations and responsibilities from provider and client. These economic and relationship variables are either implicit through widely accepted business practices (e.g. a haircut, a cab ride) or through explicit legal agreements (e.g. a consulting engagement). Whether implicit or explicit, the core principles have their genesis in the disciplines of managerial finance and contract law, from which we extract the principle of a Fair Nash-Equilibrium. A behavior is fair when “one party does not attain a gain by imposing a disproportionate loss on another [72]”. Fairness also vacates the issues of moral hazard and adverse selection.

A Nash equilibrium (NE) exists, in an n-party game, each party’s optimal strategies not incent anyone to change their strategy [73]. An example of a NE is the intersection in the classical supply and demand curves. Not all NE are fair. It is not hard to imagine situations of unfair deals, e.g. predatory pricing, collusions by cartels, deceit by one or more parties, coercion, and the like. In the “ultimatum game” [74] and our everyday experience, we find many vivid examples that fairness is important. In fact, research shows a strong result about people. They will resist inequitable outcomes and are willing to give up some material pay-off to move in the direction of more equitable outcomes [74].

8.5 Principle of Satisficing Under Uncertainty

- *Develop, implement and manage by satisficing to goals and results. Uncertainty is always present; therefore satisfice under uncertainty.*

Bentham [75] argues that people want more of what is good and less of what is bad. But how much of each, a person is ultimately able to get, is always uncertain. Uncertainty is perpetually present in every human endeavor. With perfect and complete information, uncertainty would not exist. The sciences-of-the-artificial are grounded on the axiom of bounded rationality [42]. Bounded rationality is based on the insight that it is impossible to have perfect information, endless information processing capability, or open-ended schedules to optimize or maximize results. “Pure rationality strains credulity... [76]”. Given these limitations, we do what we can; we use rational procedures under limited time and capabilities, incomplete and imperfect information. We elect to be rational under bounded conditions. This means that we “satisfice” [77] to meet or “exceed some criterion or target” [77; 18].

Uncertainty refers to the imprecision or accuracy about the outcomes of future events [76]. People have a tendency to focus on events that are likely to occur or certain not to occur, but ignore those that are uncertain. Robustness is a way to reduce the negative effects of uncertainty. Incomplete knowledge increases uncertainty. Regardless of scale, a PSS is implemented and executed by people. People and organizations need information for task execution. The difference between the information they have at hand the information they require to complete a task is another source of uncertainty [78]. This uncertainty can be mitigated. Tushman [79] recommends a strategy for organizational design and control based on the organization’s information processing needs and capacity. Another method is to search for disconfirmatory information [80], [81]. Another way is to use “reference” models of similar projects to reduce the information gap [82]. Incomplete contracting between PSS provider and client is another source of uncertainty. Fairness is an effective mitigator, but uncertainty is something to be managed. The mechanisms for this must be entered into the contract. This is part and parcel of co-production and is known as “change management”.

8.6 Principle of the “ilities”

The “ilities” are emergent properties or behaviors of systems that generally end with the letters “ility” [83]; e.g. reliability, and serviceability. An emergent system property is one which cannot be produced by any element or subsystem. All the subsystems and elements must work in unison for the system property to emerge. For example, a system is reliable not because each part is reliable; rather because its architecture has been designed to produce this emergent property. A reliable system can be built from unreliable parts. It is how we design the organization of the parts that result in a set of dynamics that produce the emergent system property. This is important for PSS because the principles we have extracted must work in unison to produce the specified “ilities” in the PSS specifications. The “ilities” produce a centrifugal cohesion to ensure that the application of the principles concentrates on the emerging system properties, which are what customers ultimately care about.

- **Principle of the “ilities”.** *First identify the key “ilities” for the PSS. Then design the PSS so that it will produce these properties.*

9 DISCUSSION

The intention in this article was to present a set of first-principles. A PSS is by definition an economic transaction. A fundamental principles in economics is utility maximization, which meets all our epistemic criteria. It is a very valid PSS first-principle. So, why is it not so specified?

First, our goal is to uncover PSS-specific principles, which are directly useful and effective to research and the practice (our epistemic rule 4). Reframing the lean principle in utility maximization terms, it becomes simply: “maximize provider utility”, wherein the effectiveness and efficiency of production, inbound and outbound logistics are appropriately maximized. We fear that such a generic statement requires a layer of interpretation before it is actionable. This imposes an interpretational hurdle to the understanding and application of a principle. We think that the “lean principle” embodies the spirit and normative imperative values of utility maximization principle in the domain of PSS. The same thinking applies to our principle of “customer satisfaction”, which is another instantiation of the utility maximizing axiom, i.e. “maximize customer utility”. Likewise, we consider our “customer satisfaction principle” as an appropriate interpretation of the utility axiom in our domain. Finally our integrating principle of the “ilities” is multi-attribute utility maximization. And consistent with our goal of PSS-specificity, we framed it such a context. Thus, our principles are more PSS-specific. We do not refute the utility interpretation of our principles; rather we consider it as strongly confirmatory.

The second reason we do not specify our principles in utility maximization form is more fundamental. PSS is situated in the sciences-of-the-artificial, where bounded rationality is axiomatic. As such maximization is an ideal, satisficing is the reality.

We now turn our attention to our meta-framework for research and the practice. One of our epistemic rules is that our principles must advance research and the practice. We propose the following meta-framework for researchers and practitioners. We propose that researchers direct their attention to three streams of investigation. The first is normative research. The objective is to support, falsify, refine, or uncover fresh first principles for PSS. As normative principles, we suggest that the set of first-principles proposed in this article as a starting point. This research should use accepted methods from the natural sciences, mathematics, and the social sciences. The second area is descriptive research. The objective is to present work on how PSS projects are engaged, developed, delivered, and managed. This work should illustrate how actual practice supports or challenges normative PSS first-principles. Descriptive research should illuminate or articulate new insights of the normative principles. Finally, the third stream is prescriptive research to help organizations and people provide more novel and effective PSS for clients. Prescriptive research should concentrate on reporting the development of innovative and useful methods and tools.

Methods and tools should demonstrate their effectiveness, validity, as well as, the validity (or lack) of normative principles. There is a hierarchy among principles, methods, and tools based on the variable of time. Following Crawley [40], principles are normative axioms and long enduring. They are widely accepted as valid and very difficult to refute, if at all. Methods are organized approaches grounded on principles, to achieve a concrete end. Methods become obsolete as new understanding is developed over a given principle. It is this temporal difference that sets principles apart from methods. A best practice can appear initially as a first principle, a method, or a tool. If a new scientific finding, research, or newer best practice narrows or obsoletes an accepted best practice, then that practice can be demoted to a method. For example, freezing product design early was accepted as a principle. Now set-based design has shown that freezing design later, can reduce the number of prototypes developed and increase the variety of products produced [84]. There is room for both freezing design early or later. It is natural to ask; “Why are lean and customer satisfaction presented as principles and not as best practices?” Lean has a strong case as an enduring principle. Lean is grounded on the accounting logic that waste is costly. Resources - physical or intangible are not infinite, this makes them costly. The accounting logic of waste is grounded in economics and codified (some say enshrined) in accounting rules and practices, i.e. cost reduces income, that is unlikely to change,. Similarly, without customer satisfaction a fair Nash-equilibrium is impossible; it is therefore a first principle.

Finally, tools are the contemporary ways to facilitate processes in methods and they are frequently applicable [40]. Tools have the shortest life span. As science advances and new innovative artifacts are developed, tools become obsolete, e.g. we no longer rely on a platinum bar in Paris to calibrate distance. Putting all this together, this framework of principles, methods, and tools is a useful organizing principle for research, the reporting the practice, development of methods and tools.

Our goal is to make a modest and useful contribution to the investigation of services. We hope that our principles and framework can stimulate the accretion of progressively more rigorous, useful and effective knowledge about services and PSS. And that this process of natural selection will also discard ideas that cannot stand scrutiny.

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