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USING SYSTEMS THINKING FOR THE MANAGEMENT OF COMPLEXITY IN SERVICE SYSTEMS

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Abstract. *The purpose of this paper is to highlight how systems thinking contributes to decision making in uncertain contexts that are characteristic of service systems. Based on the assumption that service systems face complex conditions, the paper posits that systems thinking may support the understanding of key issues in the management of service systems.*

Keywords: Service science, Service systems, Complexity, Service management, Systems thinking tools.

1. Introduction

Service and service systems concepts are fundamental constructs for the development of the emergent IT technologies like Service science, management, and engineering (SSME), IT service management (ITSM), and Service Oriented Software Engineering (SOS) knowledge streams.

SSME is a term introduced by IBM to describe service science, an interdisciplinary approach to the study, design, and implementation of services systems – complex systems in which specific arrangements of people and technologies take actions that provide value for others. More precisely, SSME has been defined as the application of science, management, and engineering disciplines to tasks that one organization beneficially performs for and with another.

ITSM refers to the entirety of activities – directed by policies, organized and structured in processes and supporting procedures – that are performed by an organization to plan, design, deliver, operate and control information technology services offered to customers. It is thus concerned with the implementation of IT services that meet customers' needs, and it is performed by the IT service provider through an appropriate mix of people, process and information technology.

SOSE is a software engineering methodology focused on the development of software systems by composition of reusable services (service-orientation) often provided by other service providers. Since it involves composition, it shares many characteristics of component-based software engineering, the composition of software systems from reusable components, but it adds the ability to dynamically locate necessary services at run-time.

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These services may be provided by others as web services, but the essential element is the dynamic nature of the connection between the service users and the service providers. In particular it provides standard frameworks for the creation of Service Management Systems (SMS) as well as provides the concepts and best practices behind service management itself. SMS are large modular systems which incorporate all or most aspects of a service-oriented organization. To have a service-management mindset, an organization must understand the level of process maturity that is required to become a service-oriented organization.

Given this problematic situation, we pose that a systems approach is useful to address it. In this article, we aim to create awareness on the need for lifting up the level of analysis in service research by focusing on service systems, and to contribute to the research expansion of the traditionally narrow view of service. In compliance with this need for a more holistic and dynamic view of service systems, we explore the contribution of systems thinking as a methodology of both investigation and management of service systems, networks as infrastructure support, and ecosystems as typical beneficiary organizations. In addition, we discuss the rising complexity in service systems, because its focus on the dynamics of interaction, emergent properties, and adaptation.

2. Conceptual definition of service systems

In the last few decades, the management of processes (industry, business, healthcare etc.) and the associated leadership of institutions and organizations has undergone significant changes due to rapid developments due to the technological progress. New competitive strategies and technologies have stimulated global discussion about management models and tools. The role of relationships has become increasingly relevant in businesses, and researchers as well as industries are shifting their focus to a service-oriented approach, moving from a paradigm of product to one of service. A service is essentially relational in nature, as it provides assistance and expertise and involves a co-productive relationship within which both providers and clients (actors) are participants in the service exchange [1]. The notion of service is increasingly becoming related to one of system, resulting in the notion of *service system*, which is composed of heterogeneous entities interacting with a shared goal.

Another recent advancement in service research is service science, which adopts a systems view of service aimed at developing a wider multidisciplinary knowledge of service management, engineering and design [2]. In its context, service is seen as a dynamic system of interacting and interdependent parts (people, technologies, and business activities) to create and deliver value, thus achieving and maintaining a sustainable competitive advantage. In emphasizing service systems, service science is thus focused on networks of relationships as the fundamental elements in the concept of service [3]. Therefore, in service systems, relationships among interacting systems are based upon "win-win" logic and are developed to achieve mutual satisfaction and optimal outcomes for all involved parties [4]. As such, a critical analysis of the concept of service system stimulates a discussion about complex service systems.

By conceptualizing the service system as a basic abstraction, it is necessary to discuss also the formation and change of the main infrastructure support, the service networks. In this view, Vargo and Lusch proposed to use the service ecosystem as a nested, networked configuration, having rules work to constrain actor-to-actor or entity-to-entity interactions. A service ecosystem is a relatively self-contained, self-adjusting system of resource-integrating actors or entities, connected by shared institutional logics and mutual value creation through the service exchange [5].
Figure 1 illustrates a three-tier hierarchical structure of the placement and inter-relation between service systems, networked control systems and service ecosystems.

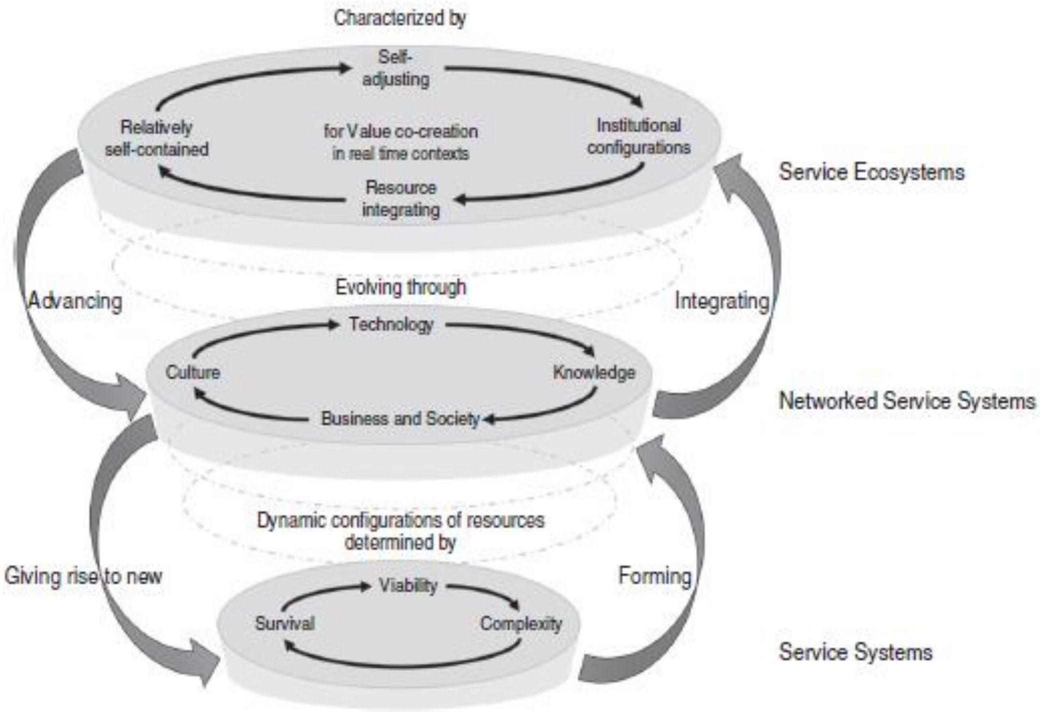

Fig. 1. Interactions of systems, networks and ecosystems in service science context (after [5]).

In the last few years, scientist and researchers considered that systems thinking contribute to service management by proposing a systems interpretation of complexity. A leading position has the work of an eclectic group of scholars, namely Barile (Sapienza University of Rome), Lusch (University of Arizona), Reynoso (Tecnologico de Monterrey), Saviano (University of Salerno), and Spohrer (IBM Research-Almaden, San Jose), which through their researches have emphasized the propension for a more holistic and dynamic view of business and social phenomena, based on the contribution of systems thinking as a methodology of both investigation and management of service systems, networks, and ecosystems [6]. At our turn, we are convinced that in order to properly interpret and manage service systems, we need to deepen our understanding of the concepts of service, service systems and complex service systems, and adopt insights derived from systems thinking which are intrinsically illuminating to issues emerging when dealing with complexity. When dealing with complex service systems, the key issue seems to be one of emergence. Systems thinking offers general interpretative approaches to face the open, dynamic and emergent nature of service systems, which may generate complexity.

By adopting a systems perspective however, the service system is no longer considered as complex in itself, as complexity characterizes the conditions that decision makers have to face in managing such systems.

To conclude, let say that systems thinking is needed for problems that are:

- Complex problems that involve helping many actors see the "big picture" and not just their part of it
- Recurring problems or those that have been made worse by past attempts to fix them
- Issues where an action affects (or is affected by) the environment surrounding the issue, either the natural environment or the competitive environment
- Problems whose solutions are not obvious

The term “systems thinking” was alternatively used to have both the same and different meanings. The wide usage of synonymous terminology, and the subsequent differentiation of these terms, corroborates the ambiguous nature of the field of systems thinking. From our point of view systems thinking is a conceptual endeavor and is different for each specific systems approach. Fig. 2. is a diagram of the relationships between the most prevalent terms associated with systems: sciences, theories, methods, concepts, ideas and thinking.

The diagram illustrates how there is some overlap between, for example, systems methods and systems concepts. It shows that general systems theory is contained within “Theories of Systems,” which are specific epistemological theories about how ontological systems work. These can be differentiated from ontological systems theories such as complexity theory or chaos theory, which are specific theories about how specific types of systems behave.

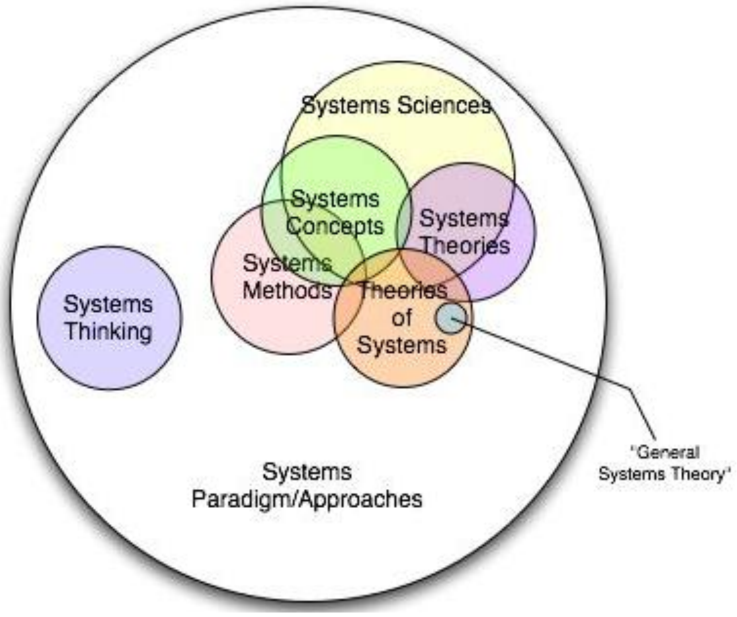

Fig. 2. The Relation of Systems Thinking to Other Systems Terminology.

One can see that systems sciences are a loosely affiliated group of fields and sciences. Systems concepts are merely ideas that might come from various areas but that contribute to our understanding of how a particular system behaves or how systems in general behave. Systems methods are "step-wise" processes used to study systems or that explicitly use systems theories, concepts, or thinking. Any one of these areas can be called a systems approach - the most general and inclusive of the terms. Finally, as has been stated previously, systems thinking represents a very different type of phenomena, because i) is so often an implicit activity; ii) it is the foundation for all of these other activities; iii) it is currently mired in ambiguity.

3. Basic principles of systems thinking as applied to service systems management

Systems thinking is a management discipline that concerns an understanding of a system by examining the linkages and interactions between the components that comprise the entirety of that defined system. The whole system is a systems thinking view of a complete organization in relation to its environment. It provides a means of understanding, analyzing and talking about the design and construction of the organization as an integrated, complex composition of many interconnected systems (human and non-human) that need to work together for the whole to function successfully. Whole systems are composed of systems, the basic unit, which comprise several entities (e.g. policies, processes, practices and people) and may be broken down into further sub-systems.

Systems may be thought about as having clear external boundaries (closed) or having links with their environment (open). An open systems perspective is the more common and realistic. The boundaries of a whole system may be chosen and defined at a level suitable for the particular purpose under consideration. Similarly, systems can be chosen and defined at different levels and can operate alongside each other as well as hierarchically.

Whole system success requires a performance management system that is pitched above the level of individual systems and their functional leadership. Features may include group or team-level goal-setting, development, incentives, communication, reviews, rewards, accountability. The aim is to focus on what binds individuals together and what binds systems together rather than functional silo performance.

An organization as an entity can suffer systemic failure. This occurs in the whole system or high-level system where there is a failure between and within the system elements that need to work together for overall success.

Factors in systemic failure may include confused goals, weak system-wide understanding, flawed design, individual incentives that encourage loyalty to sub-ordinate (rather than super-ordinate) goals, inadequate feedback, poor cooperation, lack of accountability, etc. Whole system failure may co-exist alongside functional success. The leadership of silos may individually be successful but not be sufficiently integrated into the whole system owing to a shortcoming of systems design, management or understanding.

Systems thinking approach is a methodological approach that considers all the dimensions of the problem influencing the system. It seeks to understand how these dimensions interact with one another and how they can be brought into an appropriate relationship for the improved results.

Systems Thinking aspires for understanding and improving systems by developing conceptual or mental models. The complex models emerging from the initial description of the real system are then modeled for the evaluation. Qualitative and quantitative modeling can be used for conceptualizing and analyzing the interdependency of the system.

The scheme in Fig. 3. illustrates how systems thinking approach can be used in solving a decisional problem. The exploratory strategy of looking at interactions between several factors and risks brings forth gaps from an industry perspective. For conceptualizing the research problem and identifying the suitable methodology, a combination of qualitative (interpretivist) as well as quantitative (positivist) approach is recommended. A systematic and structured approach utilized during the research problem definition clearly follows systems thinking concepts.

After the research problem is conceptualized, the next stage is to analyses the problem. For the analysis of research problem, mixed research methods are used. Simulation and statistical methods are also used for modeling risk propagation. Inductive approach followed for limited data analysis supports in validating the developed research design.

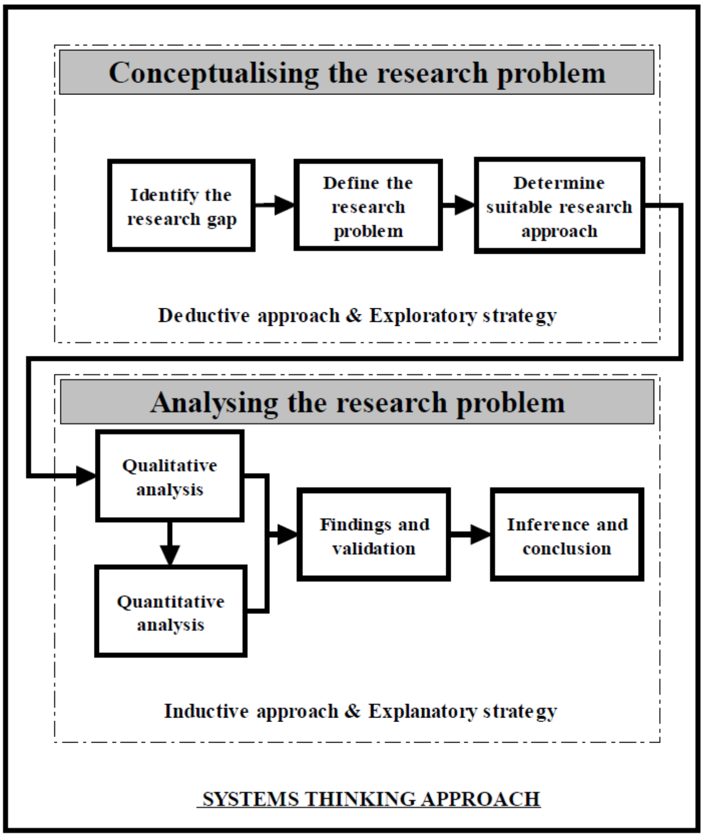

Fig. 3. Research approach for problem solving.

Acknowledging the growing interest in systems thinking within service research, an increasing number of service researchers have begun to investigate service “systems” from an engineering viewpoint ([7], [8]) while various attempts have been made to analyze service systems from a managerial perspective ([9], [10]). In this respect, a systems approach is expected to provide tools “to organize disparate and complex elements as a hierarchical organization under a common purpose” [11].

Thus, service researchers are becoming more interested in systems research while systems researchers are increasingly interested in service research. These converging interests, as mentioned before, have led both research domains to interweave their perspectives as “pillars” of potentially converging research pathways [12].

The adoption of a systems view of a service exchange enables a wider perspective of the service systems research domain, strengthening the capacity to distinguish between a static, objective perspective of service systems and a dynamic, subjective one. This is particularly important as service systems often encompass both the social and the material, resulting in tensions between methodology that could privilege one or the other. Hence, it is in this setting that complexity comes to the fore, highlighting a research gap in the study of complex service systems. In this respect, we should recognize that service systems, "for their inner dynamic and emergent nature both as "service" and as "systems", have to deal with emerging, unexpected and unknown possibilities of interactions that may lead to conditions of complexity" (Qiu, 2009; Barile and Saviano, 2010).

4. Complexity in the context of service systems

This paper proposes an interpretation of complexity in the context of service systems, which highlights the perspective change that occurs when adopting a systems approach, according to the service system is no longer considered as complex in itself, as complexity characterizes the conditions that decision makers have to face in managing such systems. So, as service research increasingly focuses its attention on the study of the design and management of complex service systems, it is important to understand how it has addressed the systemic nature of the system, as well as its complexity. We believe that service research has not fully captured the in-depth implications arising from complexity issues in service management, which highlights a research gap that ought to be addressed. With this objective, we will clarify two important issues: 1) to precise the difference between a "simple service system" and a "complex service system" taking into account that complexity must be proper for each of the two concepts "service" and "systems" and of course of their pairing; 2) to establish, within the support of service science, which approaches or models could support the understanding and management of complexity in service systems. Accordingly, complexity would come from both the distinctiveness of these two components as well as their connection. The duality of entities that creates complexity is therefore their behavior within a system that is both distinct and connected. More entities result in more connections and more heterogeneity in distinctions. Conditions are more complex when entities are themselves systems. Since the entities of a complex system cannot be separated without destroying it, analytical methods that deconstruct the system into its entities cannot be used. However, the quantitative approach, useful in measuring phenomena and interpreting their dynamics to make decisions in stable and predictable conditions, loses its capacity to support decision-making processes in fast-changing contexts characterized by emerging and unexpected interactions. Accordingly, the variety and variability characterizing the evolving context in which the decision-making process is developed, weakens the decision makers' capacity to interpret and comprehend phenomena.

A. Managing complexity of informational infrastructure in networks

Complex networked systems are new types of IT artifacts. We denote them with a generic label of Informational Infrastructures (IIs). IIs form are units of maximum complexity when compared with traditional classes of IT solutions. These classes can be defined in their order of increasing complexity as: 1) IT capabilities; 2) applications; 3) platforms; 4) IIs. The main differences between these classes lie in their overall complexity, how they relate to their design and use environments, and how they behave over time in relation to those environments.

We denote an *IT capability* as the possibility and/or right of the user or a user community to perform a set of actions on a computational object or process. They typically control its evolution locally.

Applications consist of suites of IT capabilities. They are developed to meet a set of specified user needs within a select set of communities. An application is a priori determined by choice of design context, user groups and functional goals.

Platforms differ from applications due to their heterogeneous and growing user base. Platforms are composed by formulating a design framework (architecture) that allows organizing a growing set of IT capabilities into a relatively well-bounded and controlled system. The platforms provide thus a (semi)-closed, and highly complex suite of IT capabilities, which, thanks to the original architecting, can be extended. Therefore, many platforms, originally conceived as limited sets of IT capabilities, obtain later emergent features; they start growing in seemingly unlimited fashion and serve unexpected user communities generating exponentially growing technical and social complexity.

Finally, we will define an *Information Infrastructure* (II) as a shared, open, heterogeneous and evolving socio-technical system consisting of a set of IT capabilities and their user, operations and design communities. Structurally an II is recursively composed of other infrastructures, platforms, application and IT capabilities. Often their topology presents self-similarity, because their organizing principle implies that IIs return onto themselves by being composed of similar elements [13]. Socially, IIs are also recursively organized in that they are both outcomes and conditions of design action and involve rule-following and rule-shaping activity. The control of II is distributed and episodic and an outcome of negotiation and shared agreements.

In principle, they exhibit unbounded openness: new components can be added and integrated with them in unexpected ways and contexts. IIs become increasingly heterogeneous as the number of different kinds of technological components are included, but first of all because IIs include (an increasing number of) components of very different nature: user communities, operators, standardization and governance bodies, design communities, etc.

Managing II means to find appropriate ways to organize and relate the components technically and socially (modular design, organize recursively) that address dynamic complexity, to emphasize desirable properties of specifications of II components (e.g. simplicity), and desirable ways to relate II specifications and associated components to one another (modularity, recursive application). In this aim we can define analytical types of IIs that allow – when composed together – the generation of modular IIs. We apply recursively de-composition, that is identify separate subsets of IT capabilities within any II, which also are IIs, but which share either a set of common functions and/or internal or external connections without having strong dependencies with the remaining IIs. For example we can split IIs into vertical application IIs and of horizontal support IIs.

The former will deliver functional capabilities, which are deployable directly by one or more user communities. The latter – support infrastructures – offer generic services often defined in terms of protocols or interfaces necessary in delivering most, if not all application services.

We can further recursively decompose both application and support IIs. Thus, any II can be split into its application and support infrastructures until a set of atomic IT capabilities are reached. In addition, any support infrastructure can be split into transport and service IIs. This split is justified as transport infrastructure is necessary to make any service infrastructure work. The transport IIs offer data or message transportation services like the UDP/TCP/IP protocol stack. On the other hand service infrastructures support, for example, direct addressing, service identification, service property discovery, access and invocation, or security capabilities. They become useful when IIs start to grow in complexity and scale, and designers need more powerful capabilities to configure application capabilities.

B. Managing complexity of dynamical behavior of service systems

A dominant interpretative approach of complex service systems research has addressed the complexity of service systems from an engineering perspective, in particular from the prolific research streams focused on complex engineering service systems [14]. This approach borrows from the complexity science methods to investigate systems that adapt and evolve as they self-organize, inspired from physics and biology, but which can be applied also in the study of financial, economic or social phenomena. Such complex systems are made up of autonomous agents with ability to adapt in response to other agent's behaviors and changes in the environment. Agents respond to stimuli according to a set of rules. There is a need to acknowledge that a systems view may be required when the complexity of service systems is associated with unmanageability due to the numerous perspectives and expectations of different stakeholders involved in the system's dynamics.

However we can view complexity in two ways: first, by qualifying complex systems as a *system of systems*, where complexity arises in part from the fact that a service system entity can fill multiple roles in multiple service systems simultaneously. Complexity is so essentially associated with increasing interconnections and interdependence among agents. This kind of complexity appears evident in current service systems where relations among the observed variables need a multidisciplinary perspective for analysis and comprehension.

Service Science can be seen as an interdisciplinary activity which attempts to create an appropriate set of new knowledge to bridge and integrate various areas based on trans-disciplinary and cross-disciplinary collaboration. Thus, service systems are complex especially due to the uncertainties associated with the human-centered aspects of such systems, and the emergence of unexpected outcomes seems to be a key issue in complex service systems.

A deeper look at complex service systems also highlights another key research focus, particularly with the observation of how different control mechanisms may be in service systems and their intrinsic complex nature due to openness, multi-agents, value co-creation, dynamism and emergence. In this respect, the main contribution of a systems approach lies in offering several general interpretative approaches towards dealing with the open, dynamic and emergent nature of service systems that generate conditions of complexity.

From our perspective, the answer lays in the modeling of all emergent and unexpected intra- and inter-systems interactions according to a systems thinking approach. This approach must be accompanied by a distinction between complexity and complicatedness. Complexity does not intervene when the phenomenon becomes more articulated due to an increasing number of components, relations, interconnections, and so forth (structural dimensions of the observed phenomenon). Rather, complexity emerges when the observer (decision maker), in analyzing reality, is forced to abandon the structural perspective and needs to evaluate "objects", either tangible or intangible. Hence, the decision maker faces conditions of complexity when relations among entities in the phenomenon dynamics, by virtue of the variability of relevant relationships in context, generate interactions that end up being incomprehensible for the most part of the various interacting agents in the system, consequently generating conditions of indeterminacy.

5. Managing complexity of service systems with systems thinking tools

In order to translate into reality the principles of systems thinking in service systems management, we will have to use one of the many distinct types of systems thinking tools recommended by the research in the field. Usually these tools can be classified in four broad categories: brainstorming tools (using causeand-effect diagrams in order to examine the balance between qualitative and quantitative aspects), dynamic thinking tools (aiming to capture the dynamic relationships among variables by using either Behavior Over Time (BOT) diagrams or Causal Loop Diagrams (CLD)), structural thinking tools (eg. Graphical Function Diagrams to capture the way in which one variable affects another, by plotting the relationship between the two over the full range of relevant values), and computer-based tools (using basic dynamic structures that can serve as building blocks for developing computer models). Although each of the tools is designed to stand alone, they also build upon one another and can be used in combination to achieve deeper insights into dynamic behavior. However, in the following will be presented only few considerations on the use of CLD in service system management. CLDs make explicit one's understanding of a system's structure, provide a visual representation to help communicate that understanding, and capture complex systems in a succinct form.

The components of a causal loop diagram are:

- Variables (any element in a situation which may act or be acted upon; it can vary up or down over time (not an event)

- Links / Arrows (show the relationship and the direction of influence between variables)
- Direction indicators (S's and O's - show the way one variable moves or changes in relation to another: S stands for "same direction", O stands for "opposite direction")
- Status of balance (B's and R's: B stands for „Balancing feedback loop that seeks equilibrium", R stands for „Reinforcing feedback loop that amplifies change".

Every CLD begins with a simple seed structure that includes the output or outcome of interest together with the drivers of that output. The seed structure should reflect the level of interest at which we desire to influence or investigate.

For example, fig. 4. presents a simple CLD of a reinforcing loop in which an action produces a result which influences more of the same action thus resulting in growth or decline at an ever-increasing rate.

Note that positive reinforcing loops produce virtuous cycles, while negative reinforcing loops produce vicious cycles. In the provided example, as the supervisor supportive behavior increases so employee performance increases which reinforces supervisor's supportive behavior which in turn reinforces employee behaviour – a virtuous reinforcing loop. Similarly as supervisor's supportive behavior diminishes, employee performance declines, driving worsening supervisor support which further decreases performance – a vicious reinforcing loop.

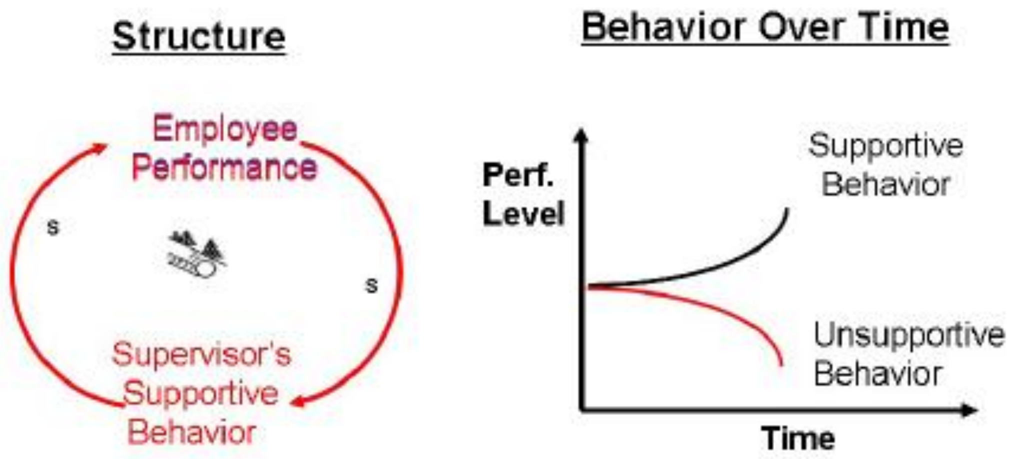

Fig. 4. CLD for a reinforcing loop.

Fig. 5. presents a simple CLD of a balancing loop. Balancing loops generate the forces of resistance, which eventually limit growth, maintain stability, and achieve equilibrium. They reduce the impact of a change and are goal seeking.

In the provided example, one can see that the initial discrepancy between actual inventory and the desired one diminish in time till reaching their equality.

Fig. 5. CLD for a balancing loop.

CLDs allow determining the leverage points in the system's structure, i.e. places where micro changes can result in macro results, or time when an intervention can be applied. A low leverage point means that a small level of intervention or change force results in a small change in the behavior of the system, while a high leverage point means that small level of intervention/change force, causes a large change in the system's behavior.

We can identify also a hierarchy of levers that can be applied to change and strengthen a complex system ranging from low to high.

These can be classified into three groups (low to high levers) – physical, informational, and social.

- *Physical leverage* is focused primarily on a change in the physical amount of the elements/ variables (focus on changing inputs and physical structures).
- *Informational leverage* recognizes that systems can be stabilized/destabilized by rate of change and information flows. Interventions at this level focus on strategies to reduce delays, optimize information flows, manage relationships between feedback loops, address resisting influence of balancing feedback loops, and strengthen reinforcing feedback loops to create virtuous cycles. Strategies to create new loops and connect different system elements are also part of this level of leverage points as they speed up information flows.

- *Social leverage* seeks to change the rules and goals of a system – changing what a system seeks to achieve and how. These changes might include changing rules like who is allowed to perform certain tasks, or incentive structures for working teams.

5. Conclusions

Scientists from service research community seek new tools and methods for making better decisions and finding optimal management strategies in an increasingly interconnected world with numerous, complex, urgent problems.

To supply these tools and methods they must leverage its unprecedented access to massive amounts of open data about service system entities, their interactions, and outcomes, globally across space, time, and organizational scales.

A pertinent challenge will be to organize and compile open data sets that support the ready development of descriptive, explanatory, and predictive tools of system thinking.

The paper introduces advances in service management research, introducing a systems thinking view of complexity and of complex service systems.

In this light, we recommend the use of a meta-model capable of better supporting service systems decision making in conditions of complexity.

To resume, the paper insists on the fact that in a complex service systems not only there are parts to be understood on their own, but that their role as part-wholes in the whole system must be considered simultaneously.

In other words, we suggest that when the term “system” is used, the research must make explicit how system principles are reconciled with the proposed methodological approaches. Our paper contributes to service research by proposing how the reconciliation could be achieved.

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