EXTENDING SYSTEM DESIGN TOOLS TO INCORPORATE USER- AND CONTEXTUAL ELEMENTS IN DEVELOPING FUTURE PRODUCTS AND SERVICES

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Abstract

This article aims to extend systems thinking to include user-, and contextual elements. Such extension should be angled towards increased human intervention and multiple stakeholder involvement in predetermined contexts. Bounded Rationality, Practice Theory and Situated Design were selected as core theoretical concepts to explain that the relationship between Prospective Ergonomics (PE) and Systems Thinking are built upon both positivist and constructivist worldviews. A systems approach embedded within PE intervention provided a foundation for extending structured systems design methods, such as Function-Task Interaction Matrix Method (FTIM), Dependence Structure Matrix (DSM), etc. As user-, and contextual elements were incorporated and juxtaposed in these extended matrices, a more comprehensive approach in using system design tools has been introduced to anticipate future products and services. Such an extended systems design approach significantly operationalises and systematises innovation, while allowing the flexibility to embrace inconsistencies, and emergent ways of strategising innovation and decision making.

Keywords: Product-Service Systems (PSS), Design methods, Human behaviour in design

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1 INTRODUCTION

Much has been debated on how to direct design research and education to create value-add beyond 'Core Industrial Design'. This value-add is to be established through re-focusing on 'Systems Design', because *the quality of service attitudes between people-to-people have become increasingly questionable. Complexity of context, increased lower-income wages, hectic and individualistic lifestyles, and the acknowledgement that humans are rationality bounded, require services to be significantly operationalised and systematised.* Moreover, as technology continue to converge and become increasingly more important in consumer's daily lives, service expectations continue to rise. This trend instigated a shift from production to utilization, from product to process, and from transaction to relationship (Vargo & Lusch, 2008), demanding a forward-looking way of dealing with products and services in ergonomics.
Complementary to such a product and service orientation, Dul et al. (2012) identified that the potential of ergonomics is underexploited, because organisations and their stakeholders mainly focus on performance and outcome. Even though there is some recognition among design and engineering practitioners and researchers about the potential benefits in applying ergonomics in design, it is not sufficient (Bannon, 2002). The lack of ergonomics being applied in design is also explained by Hollnagel & Woods (2005). Traditional ergonomics never questioned the validity of human-machine distinction, and therefore encountered problems in developing a systems view comprising of stakeholder interactions in context. As such, Norros (2014), perceived a pressing need for conceptual innovation. This means that within a frame of systems thinking, ergonomics needs to be design-driven, while maintaining its focus on two closely related outcomes: "performance" and "well-being" (Dul et al., 2012, p.1).

Using literature review as a research methodology, this article aims to extend systems thinking to include user-, and contextual elements. Such extension should be angled towards increased human intervention and multiple stakeholder involvement in predetermined contexts. However, one should be aware that this intervention is systemic and bounded by rationality. The first part of this article, which has been discussed in chapters 2 and 3, respectively explains how Prospective Ergonomics (PE) developed from traditional ergonomics, and how the concept of PSS has grown out of systems thinking, and is closely related to PE. In the second part, chapter 4 discusses several interrelated theoretical frameworks to argue that a more holistic perspective on systems thinking should be built upon the concepts of (1) bounded rationality, (2) situated knowledge development, learning and designing and (3) practice theory. The third part as described in Chapters 5 and 6 argue for systemic underpinnings to extend the systems design approach with multiple non-technological dimensions. As exemplified by the Function-Task Interaction Matrix (FTIM) (Galvao & Sato, 2005) and Steward´s (1981) Dependence Structure Matrix (DSM), contextual dimensions will be added to extend these tools to become more systemic in nature.

By answering the following research questions, the relationship among practice theory, stakeholder involvement, and bounded rationality will be clarified with respect to systems thinking.

- Based upon practice theory and the notion a that humans are bounded by rationality, how can systems thinking and their tools be extended, which have the flexibility to address inconsistencies, emergent decision making behaviours as well as context dependent and systemic developments?
- To match the realities of how different stakeholders and artifacts interact in a systemic environment, what structured methods and processes can be proposed or further developed to include user and contextual elements.

2 FROM TRADITIONAL ERGONOMICS TO PROSPECTIVE ERGONOMICS

The expansion from traditional to contemporary ergonomics has promoted the concept of "prospection" and introduced a new framework for structuring ergonomic activities around corrective, preventive (design) and prospective ergonomics (PE) (Brangier & Robert, 2010; Robert & Brangier, 2012). Research and practice in physical and cognitive ergonomics traditionally focuses on the human-machine system interactions. However, organizational ergonomics, also known as macro-ergonomics, builds on sociotechnical systems theory and is concerned with the design of larger sociotechnical systems. (Hendrick and Kleiner, 2000)

Particularly, this broader approach within ergonomics promotes systems thinking, allowing for the simultaneous achievement of individual employee and organizational goals. For example, individual employees are able to achieve high performance in a safe work environment while the organization is able to grow market share and profitability. Some have referred to organizations that accomplished this feat as healthy work organizations (Murphy and Cooper, 2000).
The above example implies that in the process of designing, micro-, meso-, and macro-level ergonomics should be understood and practiced from a human component perspective, addressing individual, collective and social aspects.
The extension to PE also calls upon ergonomists to facilitate design or be design-driven by encouraging different stakeholders to become more involved in innovation and creation processes. Hereby, the concept of "prospection" is being introduced as a challenge for ergonomists to consider multiple objectives, such as well-being, exposure to learning, and profit maximisation in a balanced and simultaneous manner. From a systems perspective, ergonomists need to manage practical implications and ethical trade-offs (Wilson, Ryan, Schock, Ferreira, Smith & Pitsopoulos, 2009), considering short-, and long term interdependency between performance and well-being.
Prospective ergonomics extend beyond the traditional fields of ergonomics, which are: well-being, productivity and being systems oriented. It anticipates and defines human needs and activities by focussing on human-centeredness, being future, and creativity-oriented, speculative and design-driven. Aiming for pluralistic outcomes innovation is systemically embedded in context. In other words, PE supports the implementation of processes and methods by "realistically creating and innovating the external world" in an anticipative mode, though considering that human activities are bounded by rationality.
To elaborate PE from a systems design perspective, actors are often brought into the systems development process as participants (Noro & Imada 1991). All stakeholders´ insights and competencies regarding methods for designing and assessing technical and organisational environments, analysing and acting on situations, methods for organising and managing participatory approaches, are invaluable for continuously improving Product Service Systems (Woods & Dekker 2000). Designers, ergonomist and participative users should hereby adopt an integrative role in collective design decision-making with other contributors and stakeholders of design (Rasmussen, 2000), based on their knowledge, activities, needs and skills. Furthermore, in the process of analysing, contextualising and managing design problems, PE has the legitimacy to stimulate and moderate design processes by, for instance, translating engineering terminology or concepts to end-user terminologies and vice versa.
To summarise this chapter, ergonomics, seen from a systems research and design perspective is goal-oriented and purposefully influences the design of systems consisting of humans and their environment (Helander 1997, Schlick 2009). Rooted in engineering, its inter-disciplinary systems approach is becoming even more important, when ergonomic expertise is redirected to discover prospective hidden needs of various user populations and stakeholders.

3 SYSTEMS THINKING, PROSPECTIVE ERGONOMICS AND PRODUCT SERVICE SYSTEMS

According to Wilson (2000) and Carayon (2006), a system can be considered as a set of interacting and interdependent components that form an integrated whole. The central idea of the systems approach is that complex systems, for example organisations, teams and types of technology, are composed of interrelated components, the properties of which are adaptable. The approach also emphasizes two specific aspects of social and organisational behaviour: (1) their systems character, so that movement in one part leads in a predictable fashion to movement in other parts; and, (2) their openness to environmental inputs, so that they are continually in a state of flux (Katz & Kahn, 1966, p. 3).
Initially, System Design Engineering (SDE) *is to develop a full life cycle of the system* "cradle-to-grave" structures and systematic approaches were based upon the trinity of requirements, compliance, and reliability engineering. Later on, SDE adopted an increased interest in designing the 'user experience' (Chapanis, 1996). From a human-centered perspective, it was first applied to the micro-ergonomic range of hardware design/engineering, software development, ergonomics, and seller/purchaser economics, but later extended to macro-ergonomic endeavors, when it was appropriate to effect organizational change (Hendrick, 1997), (Samaras and Horst, 2005).

Within the context of ergonomics, a system can then be described as a scientific discipline concerned with the understanding of the interactions among humans and other elements of a system within a complex environment, comprising of physical objects, activities and how these activities are organized and controlled in a social environment. (Dul et al., 2012). Moreover, the interest in designing experiences can also be seen as an initiative to enlarge the design space, as well as a development of design discourse 'beyond the object', and a response to the shortcomings of existing models of how usage and users are considered in the design process (Thackar, 1988), (Jordan, 2000). However, most of these studies were approached from a product engineering viewpoint. For example, several design methods were introduced to develop quantified structural variations based on functional surfaces and form factors (Tjalve, 2003).

The introduction of Product Service System (PSS) shifted business focus from designing physical products to designing a system of products and services, which became more and more acknowledged as an important innovation strategy (Rocchi, 1997). A comparable shift is also apparent in human factors through the introduction of Prospective Ergonomics (PE). This PE intervention towards innovation was based on the anticipation of "hidden" user needs (Brangier & Robert, 2010) as well as a re- interpretation of the concept of '*product'*, underlining that the client does not really require the products or services, but what these products and services help the user to achieve (Mont, 2000). The emphasis on user experience as a motivator for developing successful services argues for the implementation of systems thinking in Design. At its broadest level, systems thinking encompass a large and body of methods, tools and principles, all oriented towards the interrelatedness of forces, seeing them as a part of a common process (Senge, Roberts, Ross, Smith & Kleiner, 1994)

The PSS model is also attractive from a business perspective, as it introduces new types of stakeholder relationships and/or partnerships, new constructions of mutual economic interests, and optimization of resources (Manzini & Vezzoli, 2003). Within the above context, the designer is required to synthesise solutions emerging from the comparison of different viewpoints, needs and socio-cultural models, iterating from the traditional design domain to the domain of design management, and vice-versa (Morelli, 2003)

4 THEORETICAL FRAMEWORKS

In this section, Bounded Rationality, Practice Theory and Situated Design have been selected as core theoretical concepts to explain that the relationship between Prospective Ergonomics and Systems Thinking are built upon positivist as well as constructivist worldviews. The first section discusses bounded rationality and structured problem solving as not being opposites, but as complementary perspectives in developing systemic strategies for innovation and systems design. The following section provides an argument of how practice theory influences the transition from bounded rationality to situated design and structured problem solving to systemic strategizing.

4.1 From bounded rationality and structured problems solving to systemic strategizing

Complete rationality requires unlimited cognitive capabilities. Therefore, it is difficult to acknowledge the existence of the "fully rational man" who knows the solutions of all mathematical problems and can immediately perform all computations, regardless of how difficult they are (Selten, 1999, p.3). Human beings are very different and their cognitive capabilities are quite limited. For this reason alone, the decision behavior of human beings cannot conform to the ideal of full rationality.

This is contrary to Simon's design process, which operates within a closed, abstract system that is controlled and manipulated by a professional problem-solver and free from human judgment and experience (Huppatz, 2015, p35). According to Simon, designing is problem solving within an engineering educational context, whereby "design theory is aimed at broadening the capabilities of computers to aid design, drawing upon the tools of artificial intelligence and operations research." (Simon, 1996, p.114)

However, "en route" to understanding and developing systems, one should not adopt stands, that of bounded rationality versus the structured and problem solving approaches as proclaimed by Simon. Reference to literature from organisational studies and innovation strategies, practitioners and scholars should acknowledge that in the real world, planning, structuring and using prescriptive models, processes and methods may only lead to satisfactory results, because they are bounded by certain

contextual constraints as well as human limitations, capabilities and interests. The above juxtapositioning of deliberate processes and planning activities while acknowledging that humans are bounded by rationality, introduced the systemic approach (Whittington, 2006), which is not only applicable for business strategizing, but also for strategic design and the development of innovative products and services.

4.2 The "practice turn", bridging "Bounded Rationality" and "Situated Design"

The motivation to discuss practice theory to bridge "Bounded Rationality and "Situated Design" as a precursor to the systemic perspective, is derived from how social beings, with their diverse motives and their diverse intentions, make and transform the world in which they live. It is a dialectic between social structure and human agency working back and forth in a dynamic relationship (Dougherty, 2004).

Practices refer to shared routines of behaviour, including traditions, norms and procedures for thinking, acting and using 'things' (Whittington, 2006). Practice theory tends to emphasize the tacit and informal, reflecting its origins in the sociology of everyday life (Schatzki et al., 2001). Such emphasis on the "everyday life" and the growing engagement with activity instigated a wider 'practice turn' in systems design and design methodology. Seminal theorists promoting the "practice turn" include Pierre Bourdieu, Michel de Certeau, Michel Foucault and Anthony Giddens. Aiming to overcome the dualism between individualism and societism (Schatzki, 2005), these practice theorists aim to respect both the efforts of individual actors and the workings of the social. To the individualists, they insist there is such a thing as society; to the societists, they affirm the significance of individual activity (Whittington, 2006, p.614).

Here, three core themes can be distinguished for practice theory. The first theme addresses society. In their different ways, practice theorists are concerned with how social 'fields' (Bourdieu 1990) or 'systems' (Giddens 1984) are able to guide and enable human activity by defining practices based upon shared understandings, cultural rules, languages and procedures. This is emphasized in Foucault's (1977) attention to how society's disciplinary practices subtly shape expectations and behaviour, as well as in Bourdieu's (1990) notion of 'habitus', where ordinary human conduct is typically determined by unconscious incorporation of social traditions and norms. Both of these accounts show that actors are not atomistic individuals, but essential elements of the "social world".

In the second theme, practice theorists continue to pursue individuality by asserting people's actual activity 'in practice'. In his study about daily urban living in apartments, workplaces and shops, De Certeau (1984) paid significant attention to the detailed, idiosyncratic 'murmurings of the everyday' (De Certeau 1984, p.70). He was not only interested on *what* was done, but also of *how* it is done, which requires close anthropological attention of tacit and explicit micro-activities.

Similarly, for Bourdieu (1990), social practices are followed in rough and ready ways, according to the requirements of the situation. Hereby, the challenge is to capture the 'practical sense' by which life is actually lived in the moment. This is something that external observers cannot simply deduce from macroscopic accounts of society's structures and functions.

The third core theme addresses the distinction between practices and what really happens 'in practice', namely "Praxis" (Whittington, 2006). The distinction between praxis and practices follows Reckwitz's (2002. p.249–251) interpretation of the dual sense of practice in social theory, both as something that guides activity and as activity itself, whereby the domain of praxis is wider, embracing the routine and the non- routine, the formal and the informal (Johnson and Huff 1997).

Whittington claims that actors should not just be perceived as simple automata, but as artful interpreters of practices. They are important because their skillfulness makes a difference. Skillfulness, which is determined by their creativity, reflexivity enough, and the ability to free themselves from mindless reproduction of initial conditions (Giddens 1984).

With respect to this article, these three themes of practice theory are interrelated parts of a greater entity and have been elaborated to underline and construct the concept of "systemic". Instead of making choices, it is about "doing things in context" by integrating: (1) micro-detail and larger social forces, (2) deliberate and emergent activities, as well as (3) by balancing different objectives.

The notion that particular activities cannot be detached from society, because the rules and resources it furnishes are essential to their action, leads us to the concept of "Situated Design". Within the field of design, processes and methods should not be described as though they are universal and can be applied

in the same way across contexts (Simonsen et al, 2014). They take place in particular situations and are carried out from embedded positions (Haraway 1988; Suchman, 2007).
In other words, design is situated to highlight the interactions and interdependencies between designers, designs, design methods, and the use situation with its actors, activities, structures, particulars, and broader context. This means that situated design deals with all the "thinging" that goes into the making of things. Bjögvinsson, Ehn, and Hillgren (2012, p.102) emphasized a fundamental challenge for designers and the design community, which is the transition from designing objects to designing socio-material assemblies.
This perception of design is in line with the concept of mode 2 knowledge developed by Gibbons et al. (1994), who defined practice-oriented scientific knowledge. It stresses that analysis and design should be carried out in continuous dialogue with the field and in collaboration with participants. Complementary to "Situated Design", Haraway (1988) introduced *situated knowledges* by arguing that knowledge is situated and partial. As knowledge production takes place under specific historical, political, and situational circumstances, it is embedded in context (Lave, 1996)
A situated design approach emphasizing the complex relation between the context and the design situation at ground level, involve different actors and stakeholders, as well as societal structures dictated by institutions, regulation, market mechanisms, and so forth. The challenge is to interpret, work within, and simultaneously reconstruct the context to arrive at a situated design that fits as well as stretches the context.

5 THE SYSTEMIC TURN IN SYSTEMS DESIGN

The interrelationship between activity and society can be seen as a central part of the systemic concept. Reference to practice theory, bounded rationality and structured problem solving, the systemic concept should be viewed as a realistic representation of the real world, which must be considered when engineers, designers and business managers engage in systems development. Having characteristics of both classical and processual approaches, systemic strategies are developed in complex networks and are culturally defined. For example, in business management, the objectives and practices of strategy strongly depend on the particular social systems in which strategy-making takes place. Strategy must be 'sociologically sensitive' as according to both outcome and process depend on the character of the local social systems that the firm is acting in, and appropriate to particular social contexts Whittington (2006). Many situations show a discrepancy between indented strategies and practices on one hand and what really has been practised and achieved on the other hand. In other words, some cases in design and management practice have revealed that intended aims were compromised, as suddenly emerging inspirations and ideas were incorporated, leading to realised, but revised aims. Figure 1, adapted from Mintzberg und Waters (1985, p. 257), shows the relationship between intended and realised aims and practices based upon the theories discussed in chapter 4.

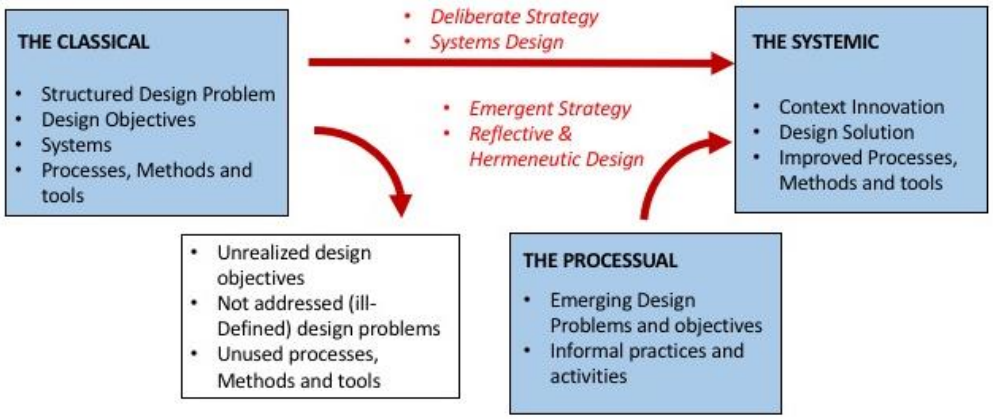

Figure 1: Relationship between the intended and realised (adapted from Mintzberg & Waters, 2005)

With respect to systems thinking and design, systemic perspectives may also intervene planned and intended objectives, because user needs and people´s (economic) behavior are emergent and contextually embedded in a network of social relations, involving their families, state, their educational

and professional backgrounds, religion and ethnicity (Sweberg, Himmelstrand & Brulin, 1987). However, the mismatch between the "intended" and the "realised", because of emergent and unforeseen circumstances, should not refrain design practitioners from using structured design methods to construct and represent future systems.
A typical example of a prescriptive design method, based upon relationships between users' activity and available technology, is the Function-Task Interaction Matrix Method (FTIM) (Galvao & Sato, 2005), which is an extension of the Dependence Structure Matrix (DSM), (Steward, 1981). However, as the focus has shifted from general user needs to addressing multiple stakeholder´s interests in localised context-heavy environments, these methods should be extended a second time to incorporate social, economic, environmental and political dimensions.

6 METHODS FOR DEVELOPING THE SOFT-SIDE OF SYSTEMS DESIGN

According to Sato (2004), context is an essential factor to be considered in acquiring design information for human-centred design practice. This human centeredness is supported by the notion that addressing complexity is the absolute core of design thinking (Dorst, 2011), and by implying that much attention should be directed towards end users. However, from a sustainable system innovation perspective, several models focus on societal and economical changes involving different stakeholders interacting in context. These models are mainly descriptive models aimed at understanding socio-technical or societal developments, mostly from studying developments afterwards ('ex post') instead of influencing them in a certain direction ahead of time ('ex ante') (Joore & Brezet, 2015).
Until now, no attempts were made to propose prescriptive models or methods that provide insight into the development of one new product or service in relation to developments that occur on the socio-technical and societal level. The lack of such prescriptive models or methods urged system designers and researchers to develop softer approach towards systems design, where elements, products and users are perceived as small building blocks of the whole. Such a softer approach is exemplified by extending two system design tools: (1) The Function-Task Interaction Matrix (FTIM) (Galvao & Sato, 2005) and (2) The Dependency Structure Matrix (Steward, 1981) (see Figures 2a & 2b). The purpose of these models is more than to generate a general framework for representing and incorporating design information as well as to show how scenario-based methods were effective in identifying various contexts and their relations to other information elements (Sato, 2004). like a morphological chart method, it relates and force-fits technical-functional, user, and contextual dimensions.

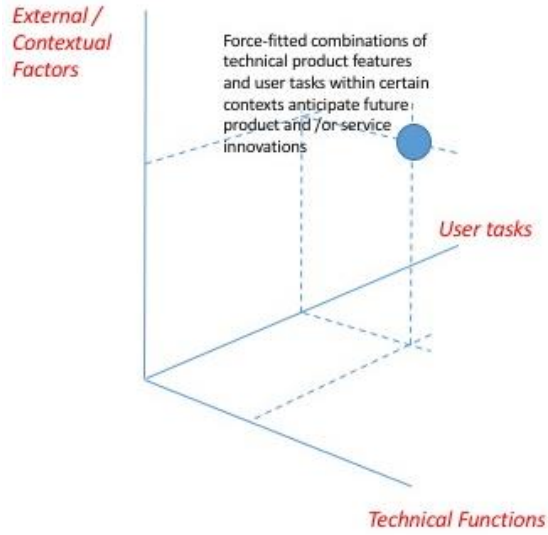

Figure 2a: 3-Dimensional Function-Task-Context Interaction Matrix (FTCIM) (adapted from Galvao & Sato, 2005)

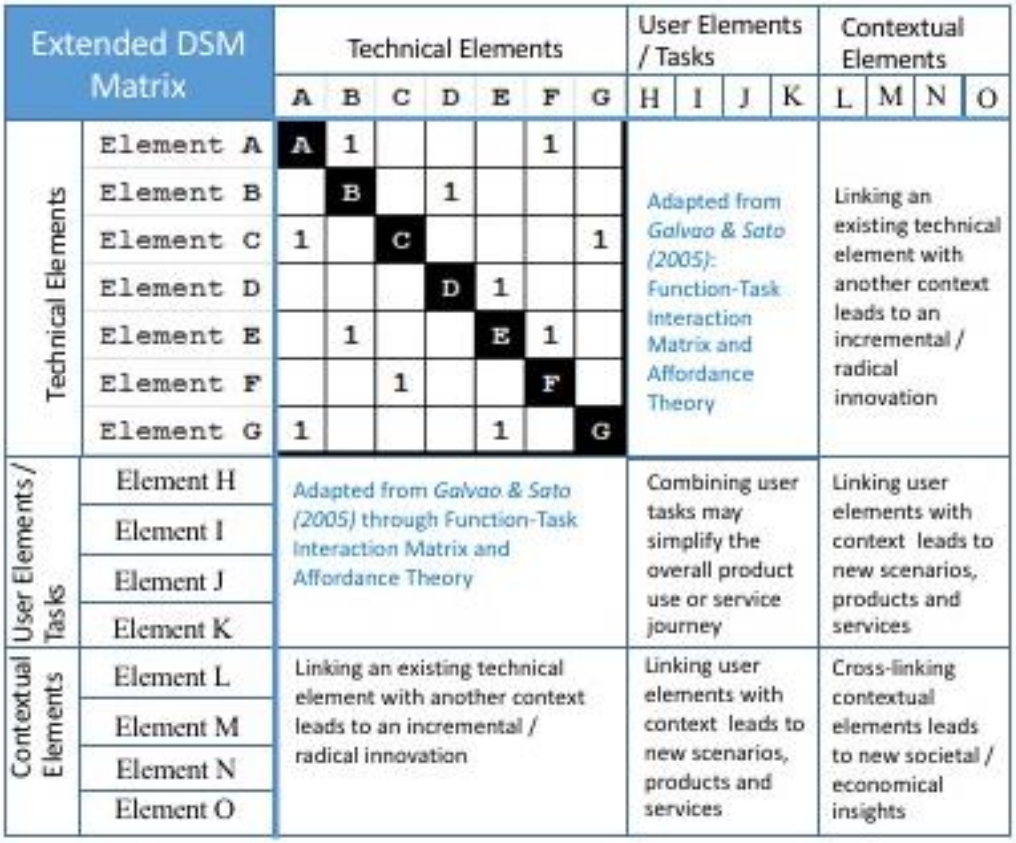

Figure 2b: Extended Dependence Structure Matrix, incorporating user and contextual elements (adapted from Steward, 1981)

7 CONCLUSION

As a precursor to the systemic perspective, this article builds upon practice theory to bridge "Bounded Rationality and "Situated Design". It attempts to develop an understanding of how designers, users and other stakeholders act in real-life contexts, compared and reflected to their intended, planned and prescribed activities. Such understanding is essential for systemically being able to anticipate future products, services and Product Service Systems (PSS´s) in a planned and deliberate manner, while considering context and plurality of objectives of the different stakeholders involved.

Based upon a prospective ergonomic and systemic strategy principles, systems thinking and design approaches have been extended by incorporating user and contextual elements in the Design Structure Matrix. Such an extended DSM helps to structure and manage inconsistencies and emergent developments. It makes systems design approaches more adaptable to specific contexts as well as being able to incorporate the inefficiencies of human behaviour. For example, as shown in figure 2b, juxtaposing different user-tasks may simply product use or service journey, whereas combining user tasks with contextual elements may lead to new scenarios, products and services. Cross-linking contextual elements may provide new societal and economic insights.

On a final note and as shown in Figures 2 a and 2b, to match the realities of how different stakeholders and artefacts interact with one another in a systemic environment, methods and tools, such as the FTCIM and DSM should be extended to encompass a wider spread of dimensions: technical-functional, user, and contextual.

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