Logistics Robots as an enabler of hospital service system renewal?

Service systems and system thinking

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ABSTRACT

Purpose – This paper examines the introduction of logistics robots from a multi-actor network perspective in a hospital service system. The focus is on complex dynamics, emerging practices and value-in-use.

Methodology – A longitudinal case-study approach was applied to examine the stepwise introduction of the advanced logistics robot system empirically in the Finnish Central Hospital. Aligned with implementation, two-phased interviews of different involving actors/professions in addition to observations were conducted during 2016-2018.

Findings – The empirical findings reveal complex interdependences in the dynamic hospital service system. All actors shared their conception of the systemic change boosted by the logistic robotic system to enable more efficient and customer-centric care work as a core service. However, the multi-actor insights and emerged new practices show the diversity with conflicting interests in terms of changing mutual roles, resource integration and related redesign possibilities.

Research limitations – The chosen research approach provided rich empirical data. However, the findings are tentative with case-study limitations, and thus open avenues for further research.

Research implications – The paper brings new empirical insights by combining practice-based, service systems thinking and S-D Logic approaches with previous research on service, and particularly logistics, robots in the hospital context.

Practical implications – The paper provides a deeper understanding, and alternatives to consider systemic and all relevant actors' perspectives when logistics robots are designed and activated for everyday use.

Originality/value – The study narrows the identified research gap considering the lack of empirical research on the introduction of service robots in health care from the systemic perspective.

Keywords: Service systems, robots, practice, value-in-use, hospitals

Paper type – Research paper

1. INTRODUCTION

Robotics as well as other new technologies provide opportunities for ensuring good quality public services for citizens, despite financial and demographic challenges particularly faced in Western countries. Introduction of robots in the social and welfare sector calls for a *systemic approach* to consider complex system dynamics and fully utilise their potential. In a hospital context, service and particularly logistics robots are still not very common, but arouse a growing interest.

As Čaić et al. (2018) show in their recent empirical study, the success of a new technology depends, not only on the *value, it creates* for the all-involving actors in the service systems, but also on the value that it *destroys* in the actor network. In weighing the benefits and risks, each member of the network experiences *value-in-use* of the new technology in a unique way and consequently may support or hinder value co-creation and related novel opportunities in the entire service system (Vargo & Lusch 2008; 2016). Therefore, to be realised, an innovative future service scenario calls for systemic understanding regarding the value networks in which these individuals interact and complex impacts that a new service will have in terms of value co-creation and co-destruction.

“Healthcare offers an ideal setting to investigate value co-creation and destruction in networks, because it comprises complex webs of interactions among multiple actors, technology, and ambiguous institutional rules and norms” (Čaić et al. 2018, 178-179: Black and Gallan, 2015; McColl-Kennedy et al., 2012). Particularly in the introduction of robotics with complex systemic implications, acknowledging issues that could harm involving actors and service beneficiaries is especially important in healthcare settings, which involve vulnerable service recipients and high-delivery risks.

Interestingly, despite the growing scientific debate and applications in practice, value co-creation in complex networks (e.g., Pinho et al., 2014), and particularly boosted by robotics (e.g., Wirtz et al., 2018; Čaić et al., 2018), is still an under-researched area empirically. This study aims to narrow the research gap by examining the introduction of logistics robots from a multi-actor network perspective in a hospital service system. The focus is on complex interdependences, determinants, emerging practices and value-in-use from the multi-actor perspectives. The adopted longitudinal case-study approach and collected rich empirical data enabled exploration of value co-creation dynamics in terms of *changes in value expectations, mutual roles, resource integration and related re-design possibilities* during stepwise introduction of a complex robotic system. By identifying alternative system approaches, the applied networked approach to technology-enabled services promotes insights on *how to design* complex service systems (Chandler and Lusch, 2015). The paper contributes to a holistic approach to service design and change management by making sense and explicit complex interconnections among the actors in (hospital) value networks.

The paper is structured as follows; Section 2 presents the theoretical base for the empirical study. The longitudinal case-study approach and case is described in Section 3 and the main findings are summarised in Section 4. Finally, Section 5 includes conclusions with limitations and suggestions for further research.

2. THEORETICAL BACKGROUND

In order to frame the empirical research theoretically, I next build linkages between the topical debate on service systems thinking, practice-based and S-D Logic approaches with previous research on service, and particularly logistics robots in the hospital context.

2.1. Service Systems and rethink of value co-creation in health care

Service systems can be defined as “configurations of people, technologies, and other resources that interact with other service systems to create mutual value” (Maglio et al., 2009, 395). However, in recent studies, previous service system and value network research approaches have been criticised from focusing on the structure and flows of goods, information, or money, rather than value co-creation (e.g., Čaić et al., 2018, 181; Pinho et al., 2014, 473-474). Further, Pinho et al., 2014 (473-474) claim that previous conceptualisations have neglected a crucial aspect of systems regarding their dynamic and potentially self-adjusting nature and the ability to reconfigure themselves. Accordingly, they call for a dynamic approach to examine value networks to capture its *learning, adapting, and evolving properties* (ibid).

As Čaić et al., (2018, 181) stated, it is necessary to *rethink value* especially in the healthcare environment due to digitalisation, automation, and related changes in human-to-non-human interactions (Breidbach and Maglio, 2016; Danaher and Gallan, 2016). It is essential to examine, “how new technology-enabled service interactions among multiple actors strengthen or weaken the well-being of the individuals involved” (ibid). Despite the vast amount of research on value co-creation within networks, there is a lack of empirical studies, particularly in a complex health care service setting (Čaić et al. 2018; Pinho et al. 2014). Therefore, in their study of the Portuguese Health Data Platform, Pinho et al. (2014) aptly revealed that value co-creation results from actors' resource integration through complex interactions among actors in the value network. The study provides empirical support to previous conceptualisations of value-creation in a multi-actor network (Vargo and Lusch, 2008), in both an iterative and non-linear manner (Gummesson and Mele, 2010) (ibid).

2.2. Value co-creation and -destruction implications of robots

If there is scarcity of robotic-enabled service and value network research, even fewer empirical results of *logistics robot systems* in health care seem to have been published. From the multiple case study regarding adoption of such a robotic system in seven hospitals in the USA, the following benefits can be classified. Firstly, as the strategic value was reported, new service models and applicability (scalability) for the various purposes such as transportation of medicaments, lab samples, meals, laundry and waste. Secondly, reductions in working hours and labour costs of nurses and logistics staff in addition to eliminating loss and thus additional costs of medicament and lab samples deliveries were the main financial improvements. Thirdly, great achievements in operational efficiency such as the availability of 24/7 transportation to facilitate care work and eliminate rush in the corridors were reported. Finally, there were also improvements in well-being such as work satisfaction of staff and joy of young patients (one robot was masked as an engine). Even if the results seem highly promising, the study lacks critical analysis of challenges or setbacks in introductions of robotics in dynamic and complex hospital service systems. Moreover, it is important to notice that the interviewees *represented the technology developer company*.

Both Čaić et al., (2018) and Pinho et al., (2014) highlight the importance of exploring and increasing the understanding of service beneficiaries, the various interactions and interdependencies among actors and their contribution to value co-creation for the realisation of value. S-D logic argues that the use context and *contextual experience* is essential in value co-creation by stating that *value is always uniquely and phenomenologically determined by the beneficiary* (Vargo & Lusch 2008; 2016). *Value-in-use* bases assumption on the active involvement of actors in resource sharing, and therefore contributing to relational outcomes as a result of value co-creation. The dynamic, processual, long-term and constantly evolving nature of value-in-use is emphasised (Vargo et al. 2008; Medberg et al. 2016; Grönroos & Voima, 2013; Gummesson and Mele, 2010).

Furthermore, as Medberg et al. (2016, 718) states, the experience approach also highlights the possibility for value-in-use to generate negatively (see also Grönroos & Voima, 2013). In their scenario-based study, Čaić et al., (2018) adopted Normann and Ramírez's (1993) notion of *value networks as a mental construct* and built an interesting typology regarding how elderly people perceive the roles of socially assistive robots in their care-based value networks. The study focuses on expected value co-creation/destruction potential for elderly people themselves and other network actors.

Respectively, case study findings from Mutlu and Forlizzi (2008) regarding the introduction of logistics robots can be interpreted via value co-creation and -destruction lenses. Their main conclusion was that patient profile and the kind of healthcare service provided cause differences in units' workflow, goals, social/emotional context, and use of their physical environment. As the main value *destruction* issues, they identified that firstly, a misalignment between the goals of the unit and the benefits provided by the robot seemed to lead to people refusing to use the robot (effectiveness vs. quality of care/less work vs. additional work). Secondly, intimate relationships between caretakers and patients caused a lower tolerance for interruptions. Thirdly, when staff's tolerance for interruptions was low, interruptions by the robot were experienced as worsening the workflow. Fourthly, in high traffic and/or cluttered hallways, the robot was perceived as taking precedence over people.

According to Mutlu and Forlizzi (2008), to promote fulfilling the task demands and social needs of the professional actors, the design of the introduction of the logistics robot system must take into consideration the *time-critical characteristics of work* at the medical units while supporting the social characteristics of the staff at the post-partum units. The findings also indicated that nursing staff prioritise the personal care relationships with their patients as their core-task, which makes interruptions from the robot more troublesome and less likely to be prioritised. Therefore, designing the robot-enabled workflows to minimise interruptions might improve the use of the robot at such types of care units, while the study did not focus on the entire value network, also including supportive service actors.

From the service research perspective, as Skålén et al. (2015) stated, a service innovation implies new *value proposition* that holds the promise of value creation for all involved actors. When introducing logistics robots, interconnections between care units, supportive service units and logistics even tighten and thus call for re-definition of internal practices and collaborative value proposition between supportive service and logistics to enable smooth and efficient services for case units accordingly, for instance, instruments' delivery in a time-critical manner for a surgical ward.

2.3. Systemic change in institutionalised practice boosted by robots

From the few recent studies concerning adoption of robotics in health care, we have learned that the expected benefits/value-in-use is jeopardised if the technology is not integrated into change in service practice in a systemic manner (e.g., Mutlu and Forlizzi, 2008; Barret et al., 2012; Beane and Orlikowski, 2015). As Beane and Orlikowski (2015) highlighted in their study introducing robotic telepresence to coordinate complex, dynamic, and distributed knowledge work in hospitals, technology should be understood as *constitutive* of new practice through *institutionalisation*.

As known, the hospital service system is strongly institutionalised in terms of professions, roles and technology-enabled practices. In service research, S-D logic debate has been shifted to socio-constructive and sociological perspectives on value co-creation. Here, social interaction is highlighted as the basis of service exchange and service innovation shaped by the cultural-historically modified values, competencies, knowledge, and related expectations of all the parties involved (e.g., Edvardsson et al., 2011; Mele et al., 2017). Furthermore, institutional theories provide approaches to explore the role of *institutional logic* behind the dynamic value co-creation and innovation activity in multiple levels of service systems. Accordingly, value co-creation is coordinated through actor-generated institutions and institutional arrangements (Vargo & Lusch, 2016, 8). Based on the previous institutional theories, Vargo and Lusch (2016, 11) defined institutions as "humanly devised rules, norms, and beliefs that enable and constrain action and make social life predictable and meaningful" (cf. Pop et al., 2018). Respectively Koskela-Huotari et al. (2016) described three patterns of institutional change such as *breaking, making and maintaining*. The underlying logic of institutions may function as an enabler or a hindrance in shaping value creation and resource integration among actors (Chandler and Vargo 2011; Edvardsson et al., 2011).

In their empirical study, Barret et al., (2012) demonstrated that such a gradual change in institutional logic resulted in the introduction of dispensing a robot into hospital pharmacy work. The study reveals shifts in (boundary) professional positions and relations, which "emerged from the entangled relational-material dynamics that constituted the robot tuning process over time" (ibid. 1463). Moreover, these emergent changes were not direct and planned implications from technology-enabled service innovation, but have complex impacts on service systems in terms of overall efficiency, as well as an individual sense of control, in addition to meaningful and social value of their work (see Table 1).

Boundary relations	Boundary effects
Cooperation (pharmacists – technicians)	• Collaboration between constituents on either side of the boundary while using digital innovations • Bilateral expansion of work jurisdiction
Neglect (pharmacists – assistants)	• Lack of attentiveness reinforces social structures of domination and marginalisation • Indifference to the plans and interests of one occupational group in the use of the Robot
Strain (technicians – assistants)	• Unilateral loss of control • Increased interdependencies and work fragmentation around robot use

Table 1. Boundary relations and effects resulted in robot use in pharmacy work (Barret et al., 2012, 1461).

Also Pinho et al., (2014, 488) highlighted the importance of interactions and interdependencies among actors in the value network by identifying three types of interdependencies: 1) dynamic role interdependency, when an actor's role may change like Barret et al., (2012) show, 2) temporal interdependency, when interactions occur sequentially at different times, and self-interdependency when value creation depends on actors' own actions. Due to the fact that network-level roles may have the most resonating consequences for the entire care service system, critical and holistic evaluation is crucial when designing to introduce novel technologies in order to enable all-involving actors to move "*from trying to maximize the utility for themselves towards maximizing the utility for the entire network*" (Čaić et al., 2018, 194). "This understanding of *individual-level vs. network-level value potential* offers important insights into the hindrances that must be mitigated to improve the adoption of robots in an overall care-based value network". Typically, not all value co-destruction potential can be eliminated through the design process, but maybe the most critical ones to enable continuous and systemic renewal (ibid.)

Özkil et al., (2009) have studied the introduction of a logistics robot system in a hospital context. Their analysis clearly shows the complexity of a transportation system driven by different sources of material flow, different time constraints on distribution routines, work regulations of the personnel and transportation equipment. Based on the findings, they propose following three alternatives for the implementation of autonomous robots in transportation systems in hospitals. Firstly, *adaptation to the existing system:* The transportation system as such and routines remain the same, while in certain types of transportation, robots are utilised to fulfil existing transportation tasks. Secondly, *partial reconfiguration of the system*: Certain processes and tasks are identified for reconfiguration, and robots for these tasks are designed for optimal performance. Transportation routines are optimised based on the capabilities of robots, for instance to enable 24-hour operation. Thirdly, *restructuring of the system* in order to facilitate system wide optimisation. Due to the need for a substantial amount of environmental modifications that this alternative would require, it is not a feasible option for existing hospitals (ibid, 293). Even though, originally generated from the automation and logistics perspectives, these three system design approaches seem relevant for examining value creation opportunities and systemic renewal boosted by a logistics robot system in the hospital context.

3. EMPIRICAL RESEARCH DESIGN

A longitudinal case-study approach was applied to empirically examine the stepwise introduction of the advanced logistics robot system in the Finnish Central Hospital, one of the pioneers in this regard in Europe. The hospital plays an essential role in the national health care system by providing specialised medical care for 200,000 inhabitants (out of a total of 5.5 million Finns) in the central region of Finland. The logistics services cover the centre of procurement, central storage and internal transportation. The development of internal logistics by applying advanced technology such as robots has been set as a strategic aim to enable more efficient and customer-centric care work, and the development of specialised medical care as the core task of the central hospital.

The chosen robot system, called TUG, has been developed by American Aethon and supplied via a Finnish distributor. It is an autonomous mobile robot for ordered and timed transportation that is available 24 hours a day. The main features are as follows: 1) navigates without tracks, 2) ease of re-mapping, 3) no depots needed, 4) delivers to user location, 5) moves among people avoiding barriers, 6) informs arrival via buzzer and text message, and 7) ease of change and expansion (cf. Bloss, 2011; Özkil et al., 2009; Mutlu and Forlizzi, 2008).

The idea of the logistics robots was generated nearly 10 years ago, and after the comprehensive purchasing process, the first two TUG robots have been in use since September 2016 (see Figure 1). As alternative implementation strategies presented by Bocij et al. (2015) *phased implementation* and *piloting strategies* were applied in introducing a total investment of *eight* TUG robots within three years. The first robot began to operate with instrument transportations between instrument maintenance and three operational departments, while another robot began to transport materials from a central storage area to selected departments. Gradually, the transportation by the robots has been expanded to new departments to utilise their full capacity. Altogether 17 departments were served in February 2017 at the end of the first interview round. During summer 2017, three new robots were introduced for supplementing central storage and instrument transportation, in addition to special meal deliveries. During the second interview in May 2018 again new expansions were designed in terms of new transportation types, robots, internal customer units and target facilities.

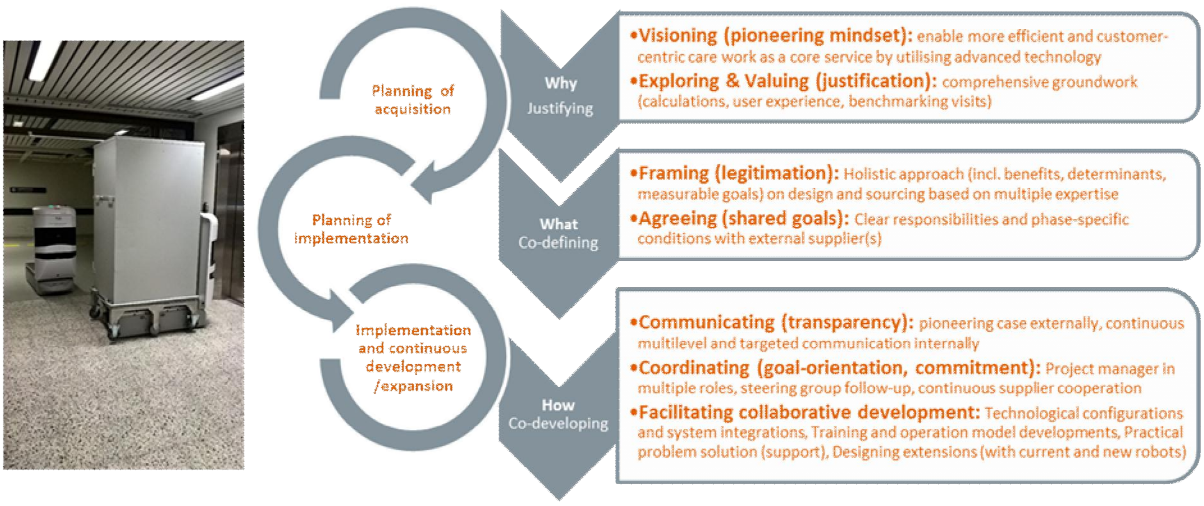

Figure 1. The main implementation phases of logistics robot system in the case study.

As Figure 1 summarises, in addition to comprehensive planning and sourcing, communication, coordinating and facilitating collaborative development have been critical steps in the introduction process. In the hospital service system, care work is served by a complex, supportive service (sub)system, which also includes a wide interconnected logistics network. Consequently, introducing a logistics robot system will change the dynamic, processual value co-creation of all-involved actors.

Aligned with implementation, ***two-phased interviews*** of different involving actors/professions in addition to small-scale observations were conducted during 2016-2018. The interviews were structured around the main themes with open questions, the emphasis of which varied between interviewees according to the role in the purchasing and the implementation phases (Kvale, 1996; Table 2). A qualitative interpretive research approach was chosen to capture the beneficiaries' expected and experienced value-in-use on robots and related systemic impacts. Such an approach is in line with the premise that value is always phenomenologically defined by the beneficiary (Vargo and Lusch, 2016), and with the so-called dialogic paradigm in service research (Tronvoll et al. 2011).

Interviewees and schedule	Themes and purpose of interviews	Supplementary data sources
10/2016-03/2017: Two robots in use: • Head of support services • Material flow manager • Manager of the logistics robot project • Head nurse of the instrument maintenance unit (by phone) • Staff nurse of the surgery outpatient department • Worker at the central storage facility	**Framing the research target and questions:** • Background and responsibilities of an interviewee • Purchasing of the TUG robot system as a process • The main technical and operative features of the system as a competitive investment • Planning and initiation of use of the first two TUG robots as a process • Plans and ideas for the next implementations Implications of the robot systems in the processes and operations vs. set objectives • Additional comments and feedback for the next implementations or the research	Small-scale observation during the interview visit 10/2016 Written background material and documents
1/2018- 05/2018: Five robots in use: Individual interview of management and focus group interviews of staff: • Material flow manager • Manager of the logistics robot project • Staff nurse of surgical ward • Staff nurse of maternity ward • Manager and leader of catering unit • Head nurse and lead nurse of the instrument maintenance unit • Instrument maintenance worker • Assistant worker at surgical ward • Worker in logistics (shelving service) • Worker at the central storage facility	**Specifying the research questions and deeper understanding of the evolving target:** • Background and introduction • Current use experience of logistics robot system, related changes and challenges • Value expectations, experienced value-in-use in work, community and collaboration between actors • Design and preparation of the introduction new robots (who, what, how, when, why) • Ideas and opportunities for continuous development and novel value co-creation	Small-scale observation during the interview visit 5/2018 Written background material and documents

Table 2. Data collection methods and phases.

The *analysing process* was conducted iteratively according to specified themes of the interviews by making classifications, testing and re-defining them. As a result, a new framework was gradually generated from the empirical data in a dialogue with the relevant literature. This abductive, cyclic and iterative research approach is aligned with a "systematic combining" approach defined by Dubois and Gadde (2002; 2014).

As a result, following *three research questions* were specified in order to summarise the main findings and conclusions from the study:

1. What was the multi-voiced expected value and experienced value-in-use of introducing a logistics robot system?
2. How were practices and novel value-creation opportunities designed or initiated between networked actors?
3. What were the primary spatial, temporal and technological constraints and enablers?

4. THE MAIN FINDINGS

The empirical findings reveal complex interdependences in the dynamic hospital service system. Based on interviews, all actors shared a conception of the systemic change boosted by the logistics robot system to enable more efficient and customer-centric care work as a core service. Many kinds of problems were faced in the beginning of the implementation, but mostly they were understood as a natural part of the complex introduction and could be solved internally and with the external suppliers.

However, the multi-actor insights and emerged new practices also show the diversity of conflictual interests in terms of changing mutual roles, resource integration and related re-design possibilities. Moreover, by examining value creation opportunities enabled by logistics robots, three alternative system (design) approaches were identified, such as 1) Adaptation, 2) Partial reconfiguration and 3) Restructuring (cf. Özkil et al., 2009, 293). In the following, the main empirical findings are demonstrated from the perspective of *three supportive services* interconnected with the entire hospital service system including logistics, technological support and the core care service.

4.1. Networked central storage service

In Table 3 the main findings regarding the networked central storage service is categorised and aligned with the main research questions, and ultimately identified three design approaches.

Dimension/ Approach	Expected value	Characteristics & Logistic boundary conditions	Robotic system	Leadership and emerging practice		Experienced value-in-use
Adaptation	Transportation cost savings: 100% robotisation 24/7 transportations Optimising between people and material flows for the benefit of care work (needs, disturbances) Uncertainty, resistance	Customer (unit) - specific service needs Extra care for schedules and delivery content: *"Robots cannot fix like humans"*. Spatial limitations (units, corridors) call for shared rules for clear headway for robots	Interoperability with other systems such as doors, lifts, fire alarm, passage control, informing and maintenance of on-call duty systems. Reliability technology vs. human errors Usability	*Scrutiny daily practice.* Work role-based task and rotating in storage combined with shelving service in customer units Individual adaptations in transportation (retired, shifts to storage) In customer units, no practical changes.	*Centralised leadership* *Learning by doing* Collaborative fine-tuning of schedules & problem solving between customer units and logistics Lead users for problem solving	Transportation cost savings as planned. Flexibility in storage workload Pioneering image, employee pride Eliminating monotonous human work Limited sense of control Additional workload (temporarily)
Partial Reconfiguration	Expanding 24/7 transportations	New facilities with room for 24/7 deliveries.	Reliability Utilisation rate	Need for empowerment in problem-solving capabilities among practitioners.		-
Restructuring	Expanding the service for external actors	Spatial restructuring (storage layout)	Autonomy & modifiability	"Self-organised" system internally to serve externally	Co-design with internal and external actors	-

Table 3. The main findings from the networked central storage service.

As seen in Table 3, central storage service characterised as rather standardised without customer critical issues. Therefore, the service was expected to capture optimal value in terms of fully automated deliveries combined with more efficient rotating tasks in the storage and shelving service in customer units. A technological system's interoperability and spatial limitations form the main boundary conditions for *adapting* the current service with automated deliveries by robots.

Experienced value-in-use reveals, on one hand, planned achievements in terms of transportation labour cost savings, efficiency and eliminating monotonous work. In addition, there was an increased sense of employee pride given how pioneering image robots have been hyped in domestic public media. On the other hand, there were some negative experiences in terms of value destruction such as limited sense of control and additional workload.

Even though adaptation seemed to be the dominant design approach in the networked central storage service, *partial reconfiguration* was already applied in expanding 24/7 transportations into new facilities equipped with suitable rooms for night deliveries. These spatial conditions enabled them to achieve a high utilisation rate, but also call for increased empowerment of practitioners to supplement busy centralised technical support.

Finally, some value expectations for *restructuring* were also identified regarding plans to also serve increasingly *external* regional customers. However, it was acknowledged that this kind of systemic change calls for not only spatial restructuring and a more reliable and modifiable robot system, but an entirely more self-organised internal service system to serve an expanding value network of external customers.

4.2. Networked instrument maintenance service

Adapting robot deliveries as an integrated part of networked instrument maintenance service seemed to be somewhat challenging, due to content and time-critical service in addition to related special requirements for spatial and technology conditions. There were some reserved expectations towards value creation opportunities such as cost efficiency and humanising work, and value destruction such as decreasing service reliability and disturbances in core care work in confined facilities. However, after the piloting phase, value-in-use of robots in care units were perceived mostly positively as long as they served the intensive, time-critical care work (surgical ward, maternity ward) and care workers could focus on their core task without interruptions. Robots also aroused common joy and jokes among staff, which reflected humanising robots as part of daily practice and social community.

Dimension/ Approach	Expected value	Characteristics & Logistic boundary conditions	Robotic system	Leadership and emerging practice		Experienced value-in-use
Adaptation	Transportation cost savings Efficiency improvements, accuracy, delivery reliability, eliminating human errors. Eliminating monotonous human work Reservations (reliability)	Time and content critical service Care unit specific service needs Spatial limitations: assigned place for robots, clear headway for robots and care equipment	Interoperability with other systems Reliability: technology vs. human errors Usability: some problems Ergonomics: limitations for tall trolleys	*Scrutiny daily practice.* In instrument units: Work role-based task (rotating tasks) In care units: Instrument maintenance (assistant) worker	Supervisors as role models and change agents. Importance of Training: shared positive reinforcement, confidence, even in incremental changes Lack of common problem-solving practice in value network.	Transportation cost savings Humanising robots; common sense of humour & joy
Partial Reconfiguration *Continues…*	Sustaining and improving internal value proposition of efficient and customised service.	Continuous renovations in facilities both hindering and improving service.	Reliability Utilisation rate	Core-task based re-allocation of resources between logistics and instrument maintenance	Continuous collaborative fine-tuning schedules & problem solving Need for empowerment among practitioners	Time pressure/ limited sense of control Additional (temporary) workload

Dimension/ Approach	Expected Value	Characteristics & Logistic boundary conditions	Robotic system	Leadership and emerging practice		Experienced value-in-use
Restructuring	Centralised service with new facilities Enabling transformation Challenges in delivery reliability	Spatial enablers for centralised receiving, dispatching and charging	Autonomy & modifiability: Synchronised with automated instrument maintenance (capacity, etc.)	Transformation towards customer-centric and core-task based service model in internal value network	Networked Co-design: gained mutual trust, capabilities and experience enable agile design and introduction within unit and networked actors.	-

Table 4. The main findings from the networked instrument maintenance service.

Respectively, instrument maintenance was perceived to play a key enabler role in core care service. Due to service characteristics combined with continuous changes, *partial reconfiguring* seemed to be a dominant design paradigm in a networked instrument maintenance service. Consequently, internal work practice was re-defined to adjust internal customer needs and optimal use of an automated delivery system, which required dynamic co-design with logistics and expanding internal customer units.

Internally, concern of service security and limited sense of control were experienced reflecting value destruction prior to planned value co-creation opportunities (cost effectiveness, eliminating monotonous work). As an alternative solution, a core-task basis re-allocation of resources between logistics and instrument maintenance was also proposed to eliminate interruptions of robot-related receiving and dispatching tasks. Furthermore, it seemed to take a while to build shared internal value proposition between instrument maintenance, logistics and technical support (with limited resources particularly at weekends).

A restructuring design approach was clearly adopted when co-designing a shift to centralised instrument maintenance enabled by new facilities where robot transportations has been taken as a constituted part of renewed "total service, or value bundles". From the perspective of this networked service, new facilities, synchronised technology (interoperability, scalability) combined with a centralised service model enables *transformation* towards optimal value co-creation, resource efficiency and meaningful work. At the same time, it *forces* networked actors (customer care units, instrument maintenance, logistics and technical support) to critically *rethink* and restructure a supportive service model in a service-centric and systemic manner. This includes re-defining value proposition to fulfil internal customer needs (time and content criticality vs. long distances), clarifying roles between service providers and streamlining processes for optimal resource utilisation and integration.

4.3. Networked catering service to care units

Due to special characteristics of the catering service (e.g., securing continuous warm/hot food chain and responsibility of scheduled meal service for all hospital), a customised meal and grocery service for a limited number of care units has been provided. Despite special equipment-related challenges, *adaptation* to robot-enabled service seemed to happen in a rather co-ordinated manner. Supervisors leapt on a development opportunity perceiving value co-creation opportunities at a networked service level and provided a supportive learning environment internally with clear responsibilities and a common sense of humour. However, in addition to positive impacts such as cost effectiveness, employee pride of external pioneering publicity and shared joy, value destruction was also perceived regarding increased time pressure and additional work at least temporarily. Further, it appeared to take a while to build common understanding of shared value proposition and related processes and problem-solving practice among networked actors.

Dimension/ Approach	Expected Value	Characteristics **&** Logistic boundary conditions	Robotic system	Leadership and emerging practice		Experienced value-in-use
Adaptation	Transportation cost savings	Continuous cold/warm food chain Hospital-wide meal schedule Care unit-specific service needs Ergonomics: picking up hot meals from the top of raised trolleys	Interoperability: raised trolleys for robots do not fit in with catering machines Limited number of trolleys customised for robots, not suitable for trucks. Reliability: technology vs. human error Usability: no problems	*Scrutiny daily practice.* In catering: Work role-based task (rotating tasks) In care units: Work role-based task of mainly logistics workers	Supervisors as role models: ideating, experimenting Shared process and system responsibility for supervisors Importance of Training: shared positive reinforcement, confidence, even if challenge in shift work Lack of common problem solving practice in value network.	Transportation cost savings Pioneering image, employee pride Joy, shared jokes Time pressure Additional (temporary) work load
Partial Reconfiguration	Sustaining and improving internal value proposition of efficient and customised service. Eliminating monotonous human work	Catering unit Renovation: requirements of robots considered to enable change opportunities	Interoperability & autonomy: robots picked up trolleys independently from a cold-storage room.	The entire catering staff involved in Co-design (including robots)	Collaborative fine-tuning schedules & problem-solving	-
Restructuring	-	-	-	-	-	-

Table 5. The main findings from the networked catering service.

Renovation in catering facilities was perceived to provide an ideal opportunity for *partial reconfiguring* networked catering service. Co-designing with staff and networked service actors has already begun to enable human-robot value co-creation in a more effective and customer-centric manner.

5. CONCLUSIONS

To summarise the main findings from three networked supportive services, the *adaptive* design approach seemed to be dominant upon the introduction of a logistics robot system in the established hospital service system. In all three services, there seemed to be a rather shared view on *value expectations* relating to *adapting* robots into current service, alongside more variation in *experienced value-in-use* regarding changes in individual work and mutual roles. Robots appeared to have had varied impacts on involving occupational groups reflecting their roles in the hospital core-task, relation to automated processes as well as change orientation and involvement. Primary impacts were identified in the work of the project manager and technical experts/support, central storage workers (including transportation) and instrument maintenance in terms of daily practice, competences and social appraisal. These results are aligned with the previous study of Barret et al., (2012; cf. Decker et al., 2017). Instead, there were only limited impacts on the actual care work so far. The results differ from the findings of Mutlu and Forlitzzi (2008), primarily due to a different service model and related task allocation between case organisations.

Interestingly, even though early value-in-use in adaption also covers value destructive experiences, still interviewers' value expectations towards *partial reconfiguration* and even *restructuring* (design approaches) appeared mostly positive. This could be interpreted in alternative ways. On one hand, it may reflect a typical individual and co-learning process from uncertainty and tackling early setbacks towards more resilience for robot-enabled value co-creation opportunities. On the other hand, it may result in alternative design approaches as such and particularly regarding their modes of value-creating logic. I will delve into the specifics of this later on this section.

In the case of all three services, several general and service-specific *spatial, temporal and technological (logistic) boundary conditions* were identified. They were perceived as both constraints and enablers. Spatial changes (renovations, new facilities) were perceived to open up new value co-creation opportunities for partial reconfiguring and even restructuring, which is aligned with previous studies (Mutlu & Forlizzi 2008; Özkil et al., 2009, 293). Similarly, interoperability, reliability and usability of technological systems were prioritised in the adaption approach, while utilisation rates appeared to be the focus in partial reconfiguration, while autonomy and modifiability appeared to be the focus in the restructuring approach.

To conclude, the study reveals complex and dynamic value networks in an established hospital service system, where step-wise introduction of logistics robot systems were perceived to result in both value co-creation and -destruction impacts and opportunities from the multi-actor perspective. In Figure 2, the main boundary conditions in introducing a logistics robot system in the hospital service system are summarised as the design framework.

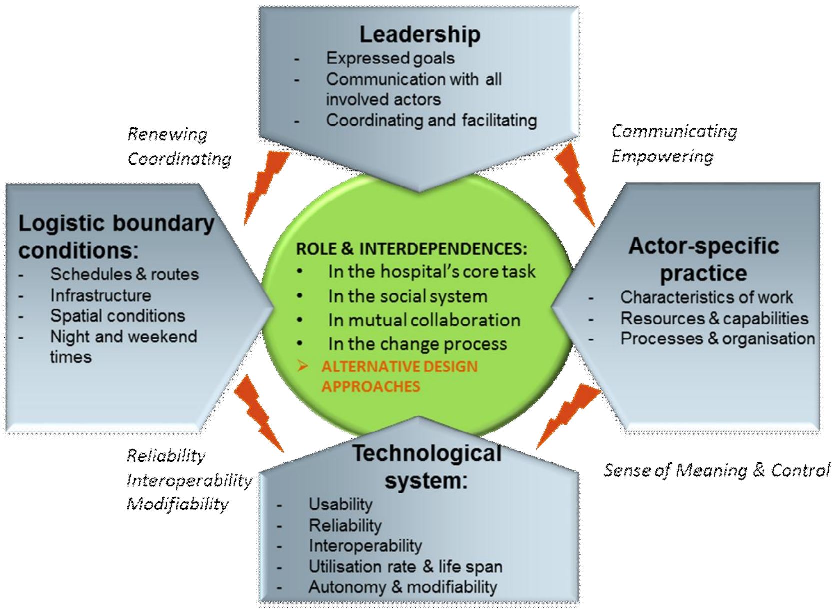

Figure 2. Design framework for the primary boundary conditions in the introduction of logistic robot systems in a hospital service system (cf. Mutlu & Forlizzi, 2008, 6; Talja et al., 2017).

However, Figure 2 does not take account of the dynamic, cyclic and iterative nature of value co-creation and co-destruction embedded in these systemic technology-enabled innovations. As Čaić et al., (2018) and Pinho et al. (2014) stressed, it is essential to understand and raise shared awareness of the institutional logic from the perspective of all-involving actors, and related value co-creation capabilities and opportunities in addition to value co-destruction risks. This critical evaluation provides a basis for alternative design approaches, and the choice of the most relevant approach for the target, while not excluding future opportunities for other alternatives. As a conclusion of further elaboration from Özkil et al., (2009) and the empirical study, the following three alternative system (design) approaches are summarised (cf. Vargo & Lusch 2016; Čaić et al., 2018; Fisk et al., 2018):

Adaptation: *(scrutiny, reliability, interoperability, practical problem solving, limited training)*
- Adjusting robots to current service practice while trying to maintain institutionalised roles
- Top-down approach with limited value co-creation opportunities for all involved actors
- Expected and experienced value-in-use: labour cost savings in transportation, decreased disturbances in corridors due to 24/7 transportation, pioneering image and employee pride
- Experienced value co-destruction: loss of flexibility and negotiability, increased sense of control/time pressure, ergonomics issues
- Spatial, temporal and technological boundary conditions (constraints)

Partial Reconfiguration: *(expansion, scalability, empowerment within current institutional logic)*
- Criticisms /lessons learned from pilots and questioning the current adaptive design approach
- Re-design opportunities provided by renovations/new buildings (spatial boundary conditions)
- Value expectations: scalability of tested technical and practical solutions, and searching and experimenting with novel value creation opportunities in a limited scope
- Do not challenge institutional logic, but utilise the empowerment of practitioners and co-design among value network actors.

Restructuring: *(enabling, integrated automated solutions, rethinking and co-designing)*
- Challenging, rethinking and restructuring current institutional roles/work and logic
- Value expectation: robots as boosters and enablers of systemic service innovation
- Re-defining networked value proposition, clarifying roles between service providers and streamlining processes for optimal resource utilisation and integration (core-task basis)
- Call for self-organised capability enabled by spatial, temporal and technological resources
- Both enabling of and forcing exploration of novel value co-creation opportunities and solutions in a service-centric and systemic manner

The study expands the knowledge base by making visible the dynamic interdependences of the networked actors, related value co-creation and co-destruction within boundary conditions in introducing a logistics robot system in the hospital service system. This paper fosters new empirical insights by combining practice-based, service systems thinking and S-D Logic approaches with previous research on logistic robotics in the hospital context. Technology is understood as constitutive of new practice through institutionalisation (Beane and Orlikowski, 2015). Further, by *framing* three alternative holistic design approaches, the study demonstrates that, for a successful adoption and to enhance systemic innovations, it is of crucial importance that the relevant value network actors are engaged in the co-design process. The study narrows the identified research gap considering the lack of empirical research on the introduction of service robots in health care and by showing that the expected value-in-use is jeopardised if the technology is not integrated into change in service practice in a systemic manner. Particularly for service designers, technology suppliers, hospital managers in support and care services, the paper provides deeper understanding and alternatives to consider systemic perspectives and all relevant actors' perspectives when logistics robots are designed and taken into use.

The chosen research approach provided rich empirical data. Long-term iterative research process and a multi-actor perspective provided possibilities to test interpretations with representatives to improve internal validity of the results (cf. Dubois and Gadde, 2002; 2014). However, the findings are tentative with case-study limitations, and thus open avenues for further research. Due to lack of empirical research and wide societal impacts (in terms of value co-creation and co-destruction), more empirical studies are needed to enhance systemic innovations by supporting complex introductions of robotics in the health care context.

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