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1. Introduction

The literature on innovation has traditionally focused on outcomes rather than the processes through which innovative ideas come together (Chandler et al., 2019), and the forest sector is no exception. Hansen et al. (2007) categorize innovation outcomes in the forest-products industry in three themes: product, process, and business system. More recently, Kajanus et al. (2014) found in their review that forest-sector practices and research have focused largely on product and process innovations in business-to-business contexts. Less attention has been given to innovation in business systems (Kajanus et al., 2014) and business models (Watanabe et al., 2018; Donagh et al., 2019). It is acknowledged that the sector lacks literature on service innovations, and further on innovation strategies and processes (Hansen and Juslin, 2011). As Ficko et al. (2017) suggest, more dynamic and future-oriented research is needed in the forest-service sector.

The introduction of Service Dominant Logic (SDL) in the literature on services and marketing has changed the philosophy and definition of services (Vargo and Lusch, 2004; 2017). According to SDL, service is at the heart of all exchanges, and service innovations can be facilitated through collaboration, platforms, and resource integration (Lusch and Nambisan, 2015). It is further assumed that all forest products, processes, and business systems are simply prerequisites for providing a certain service. Investment-intensive process industries focusing on forest products (Lager, 2016), and forest resources more broadly (Häyrinen et al., 2015), are challenged by rapid changes in consumer demands for new services that tend to originate from digitalization (e.g. Holmlund et al., 2017). However, many product firms find it challenging to develop organizational capabilities for service provision (Nambisan, 2002), and developing digital services in particular may require specialized skills (Cusumano et al., 2015). Within the forest sector the literature has adopted SDL in the context of management services (Mattila et al., 2013; Mattila and Roos, 2014), ecosystem services (Matthies et al., 2016), services for private forest owners (Berghäll, 2018), business-to-business services (Makkonen and Sundqvist-Andberg, 2017), and intangible forest resources (Laakkonen et al., 2019). The approach has also been used in sector-level analyses (e.g. Pelli et al., 2015; Näyhä et al., 2015). As reflected in the general criticism of SDL (e.g. Lindhult et al., 2018), however, the most practical and useful ways of understanding service innovation remains an unresolved issue in these studies. According to Kubeczko et al. (2006), service research in the forest sector would benefit from more cross-sectoral and interdisciplinary knowledge. Vargo and Lusch (2017), in turn, encourage more evidence-based research to better bridge the gap between theory and practice.

The development of Design Science Research Methodology (DSRM) (Peffers et al., 2007) in Information System (IS) research has followed SDL and the requirements for interdisciplinarity, deeper theoretical scrutiny and practical implications. Since its introduction it has become widely used as an approach in the development of service systems and innovations that combine practice, systematic academic evaluation and consecutive iterations to foster application development (e.g. Dingsøyr et al., 2012). Due to digitalization, IS concepts and methods are increasingly applicable to other fields such as medicine (Alharbey and Chatterjee, 2019), pedagogics (Carstensen and Bernhard, 2019) and architecture (Rocha et at., 2015), but they are not commonly applied in the forest sector. A few studies in the sector concern innovation and development in service systems, in contexts such as timber engineering (Bainbridge, 2003), precision forestry (Mikkonen, 2006), ecological databases (McIntosh 2007 et al., 2007), diffusion in Information Technology (IT) innovation (Melville and Ramirez, 2008), and wood architecture and construction (e.g. Menges, 2012; Bianconi et al., 2019), but they do not analyze the application of IS concepts and methods in any depth. In a recent study, von Willert and Krott (2019) define a new IT platform that serves forest owners, the design and evaluation of which are based on forest policy and IT science, but they make no mention of systematic development and evaluation processes such as DSRM.

In sum, the major motivation for this study is the need for more academic research in the forest sector, specifically in the field of innovation strategies and processes (Hansen and Juslin, 2011) and for dynamic and future-oriented investigation (Ficko et al., 2017). Although SDL has been adopted in the research, there have been few practical and useful outcomes (e.g. Lindhult et al., 2018). Given these shortcomings, the purpose of this paper is to introduce DSRM to forest-sector research. The methodology has been successfully adopted in IS and many other sectors to tackle the very same problems that currently face the forest sector and its research on innovation and services.

The paper proceeds as follows. In Section 2 we review the application of DSRM in the literature on service innovation as well as current research on services in the forest sector. We go on in Section 3 to demonstrate the use of DSRM in the development of Virtual Reality (VR) forest-management services. Section 4 describes the results of the DSRM process. These results are discussed in Section 5, which also offers insights into service design and forest-owner preferences. Finally, in Section 6, we draw our conclusions on the use of DSRM in forest-sector innovation and service research, including remarks on its benefits and limitations.

2. Literature

2.1. Service innovation and design science

Innovations could be described as systematic processes (Helkkula et al., 2018; Kurtmollaiev et al., 2018), even though the focus in the literature has been on outcomes (Chandler et al., 2019). Advances in technology development, especially IT, are generating new revolutionary services (Ostrom et al., 2015) and scalable concepts to disrupt traditional industries such as transportation, dining and accommodation (e.g. Zhang et al., 2015; Birinci et al., 2018). Since its introduction, SDL has brought multiple frameworks and concepts to service research, such as resource integration, the experiential nature of value (e.g. Vargo and Lusch, 2008), institutions, and service ecosystems (Vargo and Lusch, 2011; Baron et al., 2018). Simultaneously, it has been argued that academic research merely theorizes as opposed to driving marketing thinking, and that its development is led by practitioners and consultants (Vargo and Lusch, 2017). These authors go on to argue that the co-creation orientation of SDL could play a role in theorizing effective strategy implementation, whereas it has previously been suggested that poor experimentation and implementation may be the cause of strategic failure (Nutt, 1999; Hickson et al., 2003).

The integration of academic research and service development has a long tradition in IS. Methods commonly used in IT, such as DSR (Hevner et al., 2004), have been harnessed in service design and innovation. Another approach, known as DSRM, offers a roadmap to encourage designers to approach design problems systematically by first considering functional-level problems such as goals and requirements and progressing towards more specific solutions (Peffers et al., 2007). DSRM is built on a very practical philosophy - “while natural sciences and social sciences try to understand reality, design science attempts to create things that serve human purposes” (Peffers et al., 2007). With its roots in design science and practical research, DSRM purports to serve both designers and managers. The focus is on artifact design and experimentation to maximize user value. Artifact development is always based on existing theories and knowledge, and it should produce the best available solution to a defined problem. The artifacts could be services such as constructs, models, methods, instantiations, social innovations, or new properties of technical, social, and/or informational resources (e.g. Vartiainen and Tuunanen, 2016).

DSRM comprises six activities, although the process is continuous and iterative. The first activity includes identifying the problem and determining whether it is real and worth solving. The second activity involves the setting of quantitative or qualitative “solution objectives”. The focus in the third “design and development” activity is on creating the artifact based on existing knowledge, which is tested in one or more use contexts in the fourth “demonstration” activity, in which comparison of the use contexts may reveal new information on potential solutions. The performance of the artifact is evaluated against the set objectives during the fifth activity. Finally, the sixth ”communication” activity includes documenting the artifact design, its utility and novelty, and sharing this knowledge with practitioners and academicians.

The literature review reveals the use of DSRM in various service-innovation contexts such as the development of service-management concepts and systems (Barafort et al., 2014), business models (Volland and Eurich, 2014; Kleinschmidt et al., 2016), methods in the media and healthcare, for example (Grenha Teixeira et al., 2017), technology (e.g. Pirenen, 2009), and interfaces (Hsu and Tsaih, 2014; Carey and Helfert, 2015). Similarly, Tuunanen et al. (2008) report the use of DSRM to iterate from the system and process levels to implications for technologies and interfaces, also including service innovations. It is also possible to consider several service-innovation instances during different iteration rounds. DSRM further incorporates a multi-stakeholder perspective and a multi-method approach to evaluating service performance, and is frequently applied in moving from a broad conceptual level to the more detailed design of services, technologies, interfaces and content, for example. The outcome is the production of design knowledge that may be on the situational level, in the form of operational principles/architecture, or well-developed, mature knowledge abstracted in design theory (Gregor and Hevner, 2013). This also differentiates DSRM from its practitioner-oriented stage-gate model (Cooper and Kleinschmidt, 1991), which is not a research model and in that way does not apply and develop design knowledge.

2.1. Service research in the forest sector

In line with rigorous DSRM research, we formulate the relevant problem definitions, solution objectives and artifact designs by reviewing the existing literature on forest-sector services. This review produces hits starting from 2009 to these days exemplifying studies that reflect the same problem and solution fields as identified during our DSRM processes. Following DSRM (Peffers et al., 2007), the purpose of reviewing literature is to seek validity to the identified problems and expand the generalizability of the suggested solutions i.e. artifact designs.

Social interaction has been a focal topic in the literature on innovation in forest services. Nybakk et al. (2009) evaluated landowner innovativeness and its impact on economic performance, and found that networking, in other words social interaction with local actors including forestry professionals and other forest owners, was a critical factor in service innovation and development, as was learning motivation among forest owners in terms of improving innovativeness and economic performance. Kueper et al. (2013) found that forest-owner education and peer-learning programs were effective in introducing emerging issues in forestry, whereas online courses and social media have become established channels for disseminating information. Ingold and Zimmermann (2011) report the introduction of decision-making structures and innovation activities in the forestry sector, mentioning learning and adaptation as central activities among forest-industry companies to accelerate new service innovations. With regard to the activities of forest owners, factors such as external contacts and innovation strategies seemed to contribute to new service innovations. The concept of social innovation has also been spreading in rural areas (e.g. Rogelja et al., 2018; Kluvánková et al., 2019; Nijnik et al., 2019), recreational infrastructure (Wilkes-Allemann and Ludvig, 2019), and governance (Sarkki et al., 2019).

The application of a service approach to the forest sector has met with the same challenges as reported in the SDL literature in general. According to Mattila et al. (2013), structural changes may, in fact, promote service innovations in the forestry sector, whereas institutional barriers such as timber procurement as well as service-market and related regulations hinder innovation activities. They put forward a start-up mind set, with lean experimentation and business-model development, as a suggested solution to enhance the strategic capabilities and competitiveness of the service sector, and to promote the adaptation of a new marketing paradigm in the forestry sector along the lines of SDL. However, as Vargo and Lusch (2017) and Lindhult et al. (2018) note, more evidence-based research and deeper connections with practice are still needed.

The fragmented needs of both public (Mattila et al., 2014) and non-industrial, private forest owners (Häyrinen et al., 2015) are challenging organizations providing forestry-related services (Andersson and Keskitalo, 2019). Scalability is another topic that arises from the forestry-related literature (e.g. Mattila et al., 2018). Hokajärvi et al. (2009) introduce and evaluate the effectiveness of different information and communication policy instruments guiding everyday forest-management planning and related advisory services targeting forest owners. Their results show that forestry advisory services lack scalable tools with which to satisfy the increasing and broadening demands of forest owners. In addition, it is difficult to communicate the different objectives of various stakeholders, and contradictions frequently occur. The authors call for social interaction and also the inclusion of research in studying these platforms, thereby facilitating data collection and innovation. Von Willert and Krott's (2019) recent paper on an IT platform developed to serve forest owners, however, does not evaluate the value and impact of the solution.

Weiss et al. (2011) point out the need for public-governance support of market-based mechanisms and of its role as a provider of digitalized advisory services supporting the involvement of private actors in the development and innovation of the forest-sector services. On the other hand, according to the results of an empirical study (Bouriaud et al., 2011) public policies do not necessarily promote innovation activities. The same study refers to forest-sector innovations as rather reactive, providing incremental products or services to growing or emerging markets. However, the lack of financing and investment in technological innovations providing solutions to harvesting, transportation and human-resource problems is curbing the sector's development. Consumer literature in general reports rapid changes in the consumer need for new services, often originating from digitalization (e.g. Holmlund et al., 2017). These findings also imply that the forest sector is under pressure to develop technology innovations and digital services, which could also potentially activate passive forest owners (Mattila et al., 2014; Häyrinen et al., 2015).

There is a vast amount of literature on various typologies and classifications of non-industrial, private forest owners. Basically, this literature represents the customer view on the various services existing in the markets, such as forestry operations, the timber trade, property administration and information provision (see e.g. Mattila et al., 2013). According to a recent review of the literature on forest owners, typologies that are based on values and objectives are of little help in predicting their behavior (Ficko et al., 2017). Kuuluvainen et al. (2014) call for direct links to forest-owner behavior to make such typologies realistic and useful in practice. In other words, this means experimentation on real customers and prospects (Holopainen, 2016; Vargo and Lusch, 2017; Lindhult et al., 2018).

In their literature review, Cowan and Ketron (2019) refer to the need for marketers to predict and understand customer needs and utilities (Wind, 2014; Van der Duin, 2016), analyze uncertainties and lessen risks (Hines and Bishop, 2006), prepare for new roles and societal structures, and examine the widespread impact of decision-making processes (Moutinho et al., 2014). In this regard, the advantages of using VR to understand consumers and predict real-world behavior (Meißner et al., 2019), and also to predict technological change (Wind, 2014), are recognized in the IT literature.

3. Applying Design Science Research Methodology

It is evident from the literature review that the forest sector lacks a systematic research approach such as DSRM through which to build on and validate service innovations. Figure 1 illustrates the adoption of DSRM in the development of two artifacts in the field of virtual forest-management services.

In both cases we started by identifying the problem and setting solution objectives based on previous literature. We presented and developed these problems and solutions in collaboration with a management company concerned with natural resources, the aim being to ensure that each phase was driven by the practical needs of the company and supported by previous research evidence. Three of the researchers were involved in developing the application from the beginning, and throughout the DSRM process for both artifacts when the empirical data was being collected.

The next activity was to design and develop artifacts based on the problem identification and solution objectives in readiness for the demonstration phase, which also reflected the problem identification and solution objectives identified from previous research and literature. In the DSRM context the demonstration phase serves as a proof-of-concept that the artefact feasibly works to solve one or more instances of the problem.

Evaluation follows the demonstration stage, the purpose being to asses the usefulness of the developed artifact. According to the Framework for Evaluation in Design Science Research (FEDS), there are four steps in artifact evaluation: 1) explicating the goals, 2) choosing strategies for the evaluation, 3) determining the properties to evaluate, and 4) designing the individual evaluation episodes (Venable et al., 2014).

As depicted in Figure 1, after each iteration round the findings are discussed with a view to re-defining the solution objectives and subsequent artifact designs. In our case, the first artifact iteration round enhanced our design knowledge which was taken into consideration when we refined the solution objectives and artifact design in the second iteration round. These results are not shown in the framework (Figure 1), but they are introduced in the following sections. The DSRM processes for both artifacts are described in more detail in the next two sections.

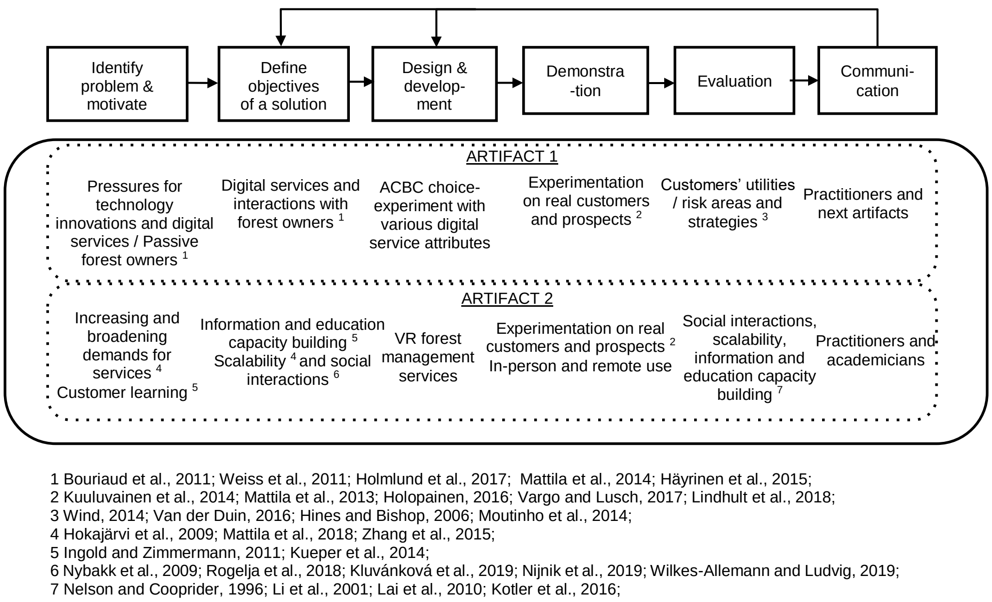

Figure 1: The two DSRM processes and the literature guiding the development

3.1. Artifact 1: the design science research process

The *problem* arose on the practical level as the natural-resource management company wanted to improve its service to its urbanized customer groups, which have been recognized as having more versatile objectives for forest ownership going beyond the timber trade (Mattila et al., 2014; Häyrinen et al., 2015). In addition, companies in general are under pressure caused by technology innovations and the digitalizing of customer services (Bouriaud et al., 2011; Weiss et al., 2011; Holmlund et al., 2017).

Digital services and customer interaction are also suggested as *solution objectives* in the literature on forest-sector services (Bouriaud et al., 2011; Weiss et al., 2011; Mattila et al., 2014). The simultaneous use of available technologies and digital services as well as illustrative visualizations and virtual content is consistent with previous research findings that aesthetics matter for forest owners (Häyrinen et al., 2015).

In terms of *design and development*, the first artifact incorporates new technologies and digital services into the traditional services, i.e. the Forest Management Plans (FMPs), of forest owners. Various FMP attributes are tested and compared: having FMPs or not; having traditional FMPs or FSC-certified FMPs; having 10-year or always up-to-date FMPs. Different types of virtual contents were also tested: action camera footage from a helmet; 360-degree photos; aerial drone videos, 2D-photos and 3D-photos (with a tree-length model); and regular photos from inside the forest. Artifact 1 was built with Sawtooth Software using the Adaptive Choice-Based Conjoint (ACBC) experimental setup (Sawtooth Software, Inc., 2014). ACBC produces various product and service options with different attributes, which are randomly displayed to research subjects. The set-up with its various service attributes and visualizations could be considered an early-stage proof-of-concept and validation of different utilities. It compares favorably with the regular Choice-Based Conjoint (CBC) setup (also called Discrete Choice Experiment), especially if the sample size is rather small and there are many randomized attributes. ACBC reduces unwanted attributes from the choice options and scrutinizes the valuations of the more even attributes. The outcomes include the utility values of each attribute or attribute combination.

The ACBC experimental setup with various FMP attributes were *demonstrated* to 101 forest owners in Finland during the summer months of 2017. The demonstration reflected the recognized need for experimentation with real customers and realistic prospects (Kuuluvainen et al., 2014; Mattila et al., 2013; Holopainen 2016; Vargo and Lusch 2017; Lindhult et al., 2018). A total of 49 of the research subjects were reached face-to-face in a shopping mall and in a forest-owner training session, whereas the other 52 were contacted via an online survey. The sample was representative of Finnish forest owners: the average age was 53 years with a standard deviation of 15 years compared to an average age of 60 according to statistics from 2009 (Rämö et al., 2009). The other demographics were also representative, with an average forest-stand size of 53 hectares and a standard deviation of 67 hectares. On average, the forest owners lived 177 kilometers from their forest stands with a standard deviation of 202 kilometers. To improve the validity, in terms of whether artifact 1 would actually evaluate the set objectives, for example, the service attributes were visualized in the ACBS experimental setup: real virtual contents were available, including action camera footage from a helmet, 360-degree photos, an aerial drone video, aerial drone 2D and 3D photos (with a tree-length model), and regular photos from inside the forest. However, the material was not customized and did not reflect a real use-context, meaning that it was not part of the decision-making, which could be considered a limitation.

The artifact *evaluation* followed the FEDS (Venable et al., 2014) model: 1) explicating the goals, 2) choosing strategies, 3) determining the properties to evaluate, and 4) designing the individual evaluation episodes. In terms of evaluation goals, artifact 1 allowed us to measure and compare different FMP attributes against virtual contents. ACBC is a summative evaluation method, meaning that it is effective but broad in scope. Following Venable et al. (2014), the evaluation strategy is therefore called “quick and simple”. The evaluation method and strategy come with limitations: they do not consider human and technical risks and efficiencies, such as whether there are human factors affecting the evaluation, and whether the utility/benefits derived from the use of the artefact are attributable to the artefact, and not to other factors. In terms of properties to evaluate, ACBC allows measurement of utility values for each attribute or attribute combination, which can be used to build optimal products or services and price them in line with current market conditions (Wind, 2014; Van der Duin, 2016). Moreover, this yields information on some risk areas, with implications for both design and business strategies (Hines and Bishop, 2006; Moutinho et al., 2014). The chosen “quick and simple” evaluation strategy allows only for a one-time evaluation, whereas the evaluation episodes for forest owners were intended to be face-to-face in a shopping mall or a training session, as well as via an online survey.

The last DSRM stage for artifact 1 entailed the results being *communicated* to the practitioners and stakeholders involved in this service-system design and development process, whereas in the case of artifact 2 such discussions and results are included in the DSRM process.

3.2. Artifact 2: the design science research process

The major *problems* and concerns raised from the DSRM iteration for artifact 1 related to finding a balance between utility and scalability. In terms of scalability, the problems identified from the literature included the increasing and broadening demand for services (Hokajärvi et al., 2009; Mattila et al., 2018; Zhang et al., 2015). Customer learning was also identified as a critical factor affecting forest-owner involvement and business development (Ingold and Zimmermann, 2011; Kueper et al., 2014). The *solutions* suggested in the literature include social interaction (e.g. Nybakk et al., 2009) and scalability (Zhang et al., 2015), as well as enhancing information and educational capacity (Ingold and Zimmermann, 2011; Kueper et al., 2014) (Figure 1).

In order to incorporate as many solution objectives as possible, we used VR technology in the *design and development* of artifact 2, which concerned forest-management services. We wished to emphasize the major issue of scalability, and therefore designed the application for use in situations in which the service person is in the same room as the customer, as well as remotely via a video connection. In line with Kuuluvainen et al. (2014), we aimed to link the behavior of forest owners more closely with classifying typologies. Artifact 2 was developed by means of a game engine and covered a 10-hectare forest estate. A portable terrestrial laser scanner and terrain data were used to create the model, then 360-degree photographs were taken and added to allow comparison between the laser-scanned 3D-models and reality. This stage did not include the creation of personalized 3D-models of the forest stands of each participant. The forest environment consisted of a detailed collection of various forest-related assets such as models of tree species that were customized to represent local species and their appearance, and rocks, undergrowth and dead branches (Figure 2). The user interface was based on a VR system with hand-held controllers and a head-mounted display, which allowed synchronized movement in both physical and virtual reality within an area of 2.5 X 2.5 meters. It was possible to travel longer distances by means of teleporting or changing the forest compartment. Possible interactions with the environment included removing single trees or making a management decision covering the whole compartment, such as thinning or clear cutting. It was also possible to undo all forest-management operations. These functionalities facilitated the visual comparison of various management plans as if the user was walking in the forest. Tree prices were also included in the system so that comparisons in economic terms could be made. Guidance was remote: the service person was not physically present in the room and communication was via a video call and a VR view shared by the user.

Figure 2. A view of the user in VR

The natural-resource management company organized the artifact 2 *demonstration* in which 64 invited users tested the application. Of these, 37 were guided in-person and 27 remotely (Figure 3). Most users participating in the evaluation phase were forest owners and customers of the firm. They were all observed as they used the service, and they were interviewed both beforehand and afterwards.

Figure 3. A demonstration of artifact 2: a user interacting remotely with a service employee while a researcher observes

In line with FEDS and reflecting the *evaluation* targets (Venable et al., 2014), the goals of artifact 2 included social interaction and scalability as well as building information and educational capacity. The chosen strategy was the “quick and simple” because the experience was evaluated as a whole (neither single phases nor contents were included). The fact that artifact 2 was a real service involving the application of new technologies and experimentation with real customers of the natural-resource management company improved its relevance and validity compared to artifact 1. With regard to the evaluation and the properties to be evaluated we adopted a social-interaction framework (Nelson and Cooprider, 1996) with elements including “shared knowledge”, “trust creation” and “influence”. More specifically, we followed a scale suggested by Li et al. (2001) to measure knowledge sharing in the form of product knowledge: attention, evaluation, association, questioning, and information seeking. Trust creation was assessed in terms of attitudes towards the brand of the management company providing the service (Lai et al., 2010), and influence in terms of the user’s intention to interact with others, use the service again and make purchase decisions (Kotler et al., 2016). The background variables included the frequency of visits to the forest estate, forest management, the use of services, distance to the estate, as well as VR familiarity, and perceived difficulty-of-use of the technology.

The demonstrations were given both in-person and remotely, particularly those concerning the scalability of the service. “Knowledge sharing”, in turn, relates to the building of information and educational capacity, whereas “trust creation” and “influence” measure the preconditions for social interaction as well as scalability (Nelson and Cooprider, 1996). Table 1 gives the initial scale as well as the associations between the scale items and the solution objectives. The dependent variables were assessed on a five-point Likert-type survey scale (1=strongly disagree; 5=strongly agree).

Table 1. The initial scale: the solution objectives addressed by the respective condition in brackets

Background variables, nominal scales:
- Treatment in remote and in-person service setups **(Scalability)**
- Visits to forest estate
- Managing forests
- Use of services
- Distance to forest estate
- VR familiarity
- Difficulty-of-use of the technology
Dependent variables, Likert scale 1-5:
Knowledge sharing (Building information and educational capacity)
- This kind of system would help in managing a forest estate
- In my opinion, the modelled forest seemed real
- In my opinion, the timber prices were reliable
- I learned new things about forest management
- I could actually apply the things I learned about forest management
Trust creation / Brand attitude (Preconditions for social interaction)
- In my opinion, the digital services of X offer a good user experience
- In my opinion, the digital services of X are better than other similar services
- I believe that X will offer the best digital services in the future
Influence / Intentions (Social interaction and scalability)
- I will be in contact with a forest specialist after this experience
- I can recommend the use of this kind of service to a friend
- I am interested in participating in testing a similar service again
- I am ready to buy a virtual forest-management plan for my own forest
- Based on this kind of experience, I would be ready to sell timber

Trust related to individual evaluation episodes was measured on pre- and post tests, whereas the survey questions were set following the use of the application. In terms of research design this study was genuinely experimental in that the research subjects were randomly assigned to the treatment groups (Malhotra et al., 2003). In our analysis of the treatment groups we compared in-person and remote guidance in the use of artifact 2 in a controlled experiment with a between-subject design. Non-parametric tests were used to compare the differences between the groups of independent versus the dependent variables. Non-parametric tests are suitable especially when the variables are measured on an ordinal scale and when the sample size is small (Metsämuuronen, 2003). The Mann-Whitney U-test was used for independent variables with two groups, and the Kruskal-Wallis one-way analysis of variance for those with more than two groups. Both tests use the ranking of the data to see whether the independent samples come from populations with the same distribution (Singh, 2007): a significance level of 0.05 was used as cut-off value. The company brand image was assessed before and after the VR treatment by means of three questions. The Cronbach's alpha was adequately high for the questions pre- (.75) and post- (.69) use. A repeated-measures ANOVA was conducted to calculate the aggregate effects on brand image in the two guidance conditions: remote and present.

In accordance with DSRM, the evaluation results are *communicated* to the practitioners and stakeholders involved in the service-system design and development process, as well as to academicians to provoke discussion and improve the validity of the approach.

4. Findings

The results of the two artifact evaluations are presented in the following two sub-sections: the ACBC experiment (artifact 1, sub-section 4.1) and the between-subject experiment in two use contexts - in-person and remote (artifact 2, sub-section 4.2). These findings are summarized and discussed in the Discussion section.

4.1. Artifact 1

We conducted ACBC conjoint analysis to find out how 101 forest owners perceived and valued FMP services and attributes. Table 2 shows the results related to attributes, in which those concerning the virtual contents are combined. It seems that forest owners want very different things from their FMPs: no single attribute stood out as statistically significant or as more important than another. The highest utility (mean) score was for FMP yes: forest owners want some kind of FMP. Traditional FMP also scored relatively highly: 75 percent of the forest owners wanted traditional FMP, whereas 25 percent did not. Attributes such as FSC-certified FMP, 10-year FMP and always up-to-date FMP scored relatively low, whereas "FMP with virtual contents" achieved the highest negative utility mean score, meaning that it had the lowest value for the forest owners. However, the fact that 32 percent of them perceived virtual content as valuable (utility > 0) is worth further analysis.

Table 2. Utility scores for various forest management plan (FMP) attributes

Forest management plan (FPM) attribute	p	Utility (mean)	CI	Utility > 0	Utility < 0
FMP yes	0.29	41.27	15.71	72%	28%
FMP no	0.29	-41.27	15.71	28%	72%
Traditional FMP	0.71	33.17	7.37	75%	25%
FSC-certified FMP	0.21	8.11	11.13	58%	42%
10-year FMP	0.12	3.22	3.69	62%	38%
Always-up-to-date FMP	0.12	-3.22	3.69	38%	62%
FMP with virtual contents	0.20	-44.76	12.92	32%	68%

The results of virtual content utilities as separate attributes are shown in Table 3. The utility scores of all the attributes except 360-degree photos and photos from inside the forest were statistically significant ($p<0.05$): the forest owners were not interested in the action camera footage from a helmet (utility-mean -47.45). The highest mean utility was attributed to the aerial drone video, followed by the aerial drone 3D- and 2D photo, respectively. Despite the lack of any statistical significance, however, 27 percent of the forest owners perceived the 360-degree photos as a valuable FMP attribute. Further analysis revealed that a statistically significant proportion of the 27 percent lived in the metropolitan area, and that other demographics such as age, stand size, and distance from the estate did not have any significance as grouping factors. According to Häyrinen et al. (2015), aesthetics and conservation matter specifically to forest owners living in urban areas, whereas the more traditional view of the forest as a source of income held marginal value for them. This, according to the authors, could be considered a challenge for traditional providers of forestry services. With a view to offering this group better service, the natural-resource management company was ready to develop artifact 2 further and to test more advanced VR technologies with a specific focus on illustrative visualization.

Table 3. Utility scores for the virtual content attributes

Forest management plan (FPM) attribute	p	Utility (mean)	CI	Utility > 0	Utility < 0
Action camera footage from a helmet	0.00	-47.45	6.18	14%	86%
360-degree photos	0.09	-11.89	5.54	27%	73%
Aerial drone video	0.01	27.18	6.68	84%	16%
Aerial drone 2D photo	0.00	6.53	6.03	37%	63%
Aerial drone 3D photo	0.01	8.89	10.26	37%	63%
Photos from inside the forest	0.49	-16.76	4.91	22%	78%

4.2. Artifact 2

The background variables were used to categorize the forest owners in terms of the kinds of customers that would derive most benefit from the application. Of them, 53 percent reported visiting their forest estate more often than once in a month, 35 percent a few times a year, and 12 percent once a year or less; 28 percent reported actively managing their forest more often than once a month, 45 percent a few times a year and 45 percent once a year or less often; only four percent used forestry services more than once a month, 53 percent a few times a year, and 43 percent once a year or less often; 29 percent lived close (less than 50 kilometers from their forest estate), 41 percent lived between 50 and 250 kilometers away, and 29 percent had a longer distance to travel; finally, 45 percent of the participants were unfamiliar with VR, 41 percent were somewhat familiar and 14 percent were familiar with it.

Seventy percent of the users found the application easy or very easy to use, whereas 30 percent had difficulties; 82 percent thought that a VR forest application would be useful for managing forest properties (M=4.14, SD=0.859); 56 percent agreed or somewhat agreed with the statement that the forest seemed real (M=3.61, SD=0.986); 44 percent agreed that the wood prices used in the application were believable (M=3.45. SD=0.991) whereas almost half of the participants neither agreed nor disagreed with the prices. The results varied as to whether the users thought that they had learned about forest management when using the virtual forest. In general, the participants agreed that the company provided a good user experience (M=4.02, SD=0.826), and the majority agreed that it would have the best digital services in the future (M=4.05, SD=0.765). Comparison of the company's digital services to other similar services was more challenging in that 55 percent of the participants did not take a stand on the question (M=3.56, SD=0.871). Participating in service development interested the users: 89 percent of them were willing to test a similar service again (M=4.50, SD=0.926, and 83 percent were willing to recommend the service to a friend or a relative (M=4.25, SD=1.069). Almost half of the participants were willing to buy a VR forest-management plan of their own forest (M=3.27. SD=1.150) and were ready to sell timber based on the experience (M=3.33, SD=1.227). The participants diverged in their intention to be in contact with their own forestry specialist after the experience: 34 percent agreed strongly or somewhat agreed and 38 percent strongly or somewhat disagreed with the statement, "I will probably be in contact with the forest specialist after this" (M=2.94, SD=1.363).

The results show that the form of interaction, whether it was implemented in-person or remotely, did not have much effect on the dependent variables. The only statistically significant dependent variable in the Mann-Whitney test was "interest in participating in testing a similar service again", which was higher for in-person guidance ($p<0.05$). It was revealed in the Kruskal-Wallis tests that forest owners visiting their estates more frequently also perceived the timber prices as more reliable and thought that they could apply their learning about forest management in practice ($p<0.05$). The last-mentioned result also held among forest owners who were more frequently involved in managing their forest ($p<0.05$). Owners who were more frequent users of forest-management services were also more ready to sell timber if they had such an experience and service in use ($p<0.05$). Owners with longer distances to travel were more ready to buy a virtual forest-management plan related to their own forests ($p<0.05$), and they were more ready to sell timber after such an experience because they felt better able to apply their learning to their forest-management practices ($p<0.05$). Those who were more familiar with the VR technology perceived the learning and applicability more favorably, and they were more ready to sell timber ($p<0.05$), whereas those who perceived the application and system as easy to use also perceived the timber prices as more reliable ($p<0.05$).

The company's brand image strengthened both in personal tutoring from M = 3.86 (SD = 0.73) to 3.99 (SD = 0.70) and in remote tutoring from M = 3.47 (SD = 0.59) to M = 3.72 (SD = 0.52), and there was a statistically significant difference between the tutoring forms ($F(1,62)=4.55$, $p=0.037$, $\eta_p^2=0.068$). In other words, remote tutoring was better for the brand image than in-person tutoring.

5. Discussion

DSRM has been applied in various service-innovation settings related to developing the concept, the system, the method, the technology or the interface (e.g. Tuunanen et al., 2008; Barafort et al., 2014; Hsu and Tsaih, 2014; Volland and Eurich, 2014; Kleinschmidt et al., 2016; Teixeira et al., 2016). These studies show that the DSRM framework is well suited to bridging the gap between academic research and practical service development recognized by Vargo and Lusch (2017).

The lack of research in the forest sector focusing on dynamic and future-oriented service innovations (Hansen and Juslin, 2011; Ficko et al., 2017), as well as of evidence-based research targeting forest owners and forest-management services (Kuuluvainen et al., 2014), constituted the main motivation for our research. We perceived the established use of DSRM in service innovation and technology development in various use contexts as a promising gateway to its application in the forest sector. Following the DSRM paradigm, we based our problem identification and solution objectives on previous literature focusing on aspects such as technology innovations and digital services (e.g. Bouriaud et al., 2011; Weiss et al., 2011), social interaction (e.g. Nybakk et al., 2009), scalable tools (e.g. Hokajärvi et al., 2009), information / educational capacity building (Kueper et al., 2013; Ingold and Zimmermann, 2011), and experimentation on real customers and prospects (Kuuluvainen et al., 2014; Mattila et al., 2013; Holopainen, 2016; Vargo and Lusch, 2017; Lindhult et al., 2018).

Similarly, we adopted suggested solutions from the existing literature in designing and developing the artifacts, which we demonstrated, tested, and evaluated. Our findings contribute to previous work through the testing of these solutions in real-use cases and with real users. This has enabled us to go into more detail and to gain deeper insights into their application and design in the forest sector. In the following paragraphs we discuss our findings and their contributions to the suggested solutions in the forest sector in more detail.

According to Mattila et al. (2013), adopting SDL and designing products, services, processes and systems accordingly could enhance the strategic capabilities and competitiveness of the forest sector. The authors also highlight the role of experimentation in the complex process of service and system innovation and development in the sector (see also Holopainen, 2016). In addition, the introduction of new technologies has the potential to incentivize service innovations (Bouriaud et al., 2011). In an unprejudiced manner, the artifacts we chose for our study tested new services and technologies and their potential among forest owners, and in forest-management services developed with VR technology. As our results show, although conventional services have their supporters, a significant group of about one third of the forest owners showed an interest in new services and technologies that would support their forest-management planning and decision-making. This finding supports previous implications of the potential contributions that the SDL paradigm, experimentation and new technologies could make in terms of innovation and development in forest-sector services. Finally, the inherently iterative nature of DSRM addresses questions raised by Ficko et al. (2017) about validating the success of various services over time.

More precisely, our artifacts tested social interaction (e.g. Nybakk et al., 2009). Applying the social-interaction framework (Nelson and Cooprider, 1996), we built a scale to measure knowledge sharing, trust creation and influence. In terms of knowledge sharing, forest owners visiting their forests more frequently and managing them more actively perceived that they could apply their VR learning in practice. This also held true among those with longer distances to their forest estates. VR could thus provide active forest owners with a new service for building up information and educational capacity (see previous studies by Kueper et al., 2013, and Ingold and Zimmermann, 2011, for example). The information and educational potential of VR seems to increase along with familiarity with it: active service users and those more familiar with the technology were also more ready to adopt VR when selling their timber. Therefore, in the future when VR technologies are more mainstream and consumed in various contexts, their utility in forest-management services will increase and they will reach a broader range of forest owners.

Whether the VR service is organized in-person or remotely seems to have surprisingly little influence on user experience and subsequent behavior. It is therefore likely that remote user interfaces and scalable VR services for forest owners will make a contribution in the area of scalable forest services (e.g. Hokajärvi et al., 2009). Forest owners having to travel longer distances to their forest estates perceived the VR services as slightly more useful than the other groups in terms of their willingness to purchase a VR forest-management plan for their own forests and their readiness to conduct timber trade using such a system.

VR also has high potential in terms of helping forest-sector service companies to build trust and their brand image in the future. As we showed in our study, service innovation and development in the forest sector involve multidimensional, complex and multidisciplinary tasks, and DSRM could be an effective tool to control such a process.

6. Conclusions

We applied DSRM to iterate from a broad conceptual level to the more detailed design of forest-owner services. However, given that DSRM can be applied in various service-innovation contexts (e.g. developing concepts and service-management systems, business models, methods, technology, interfaces and contents), we decided to concentrate on introducing the results of its evaluation properties as major outcomes and its theoretical contribution to the design of forest services in the context of VR. In addition, having started from a broad conceptual level, we believe it was not in the scope of the study to go into great detail in terms of technologies, interfaces and contents, for example. Future research should therefore consider these different service contexts and generate knowledge aimed at improving theory and practice in the design of forest services for forest owners. DSRM also facilitates a multi-stakeholder perspective, which we did not consider in our study because we were only evaluating forest owners' perceptions and experiences. Involving more stakeholders in the service system would foster the development of a more holistic system design.

The general limitations of DSRM relate to problem identification and solution definitions, in other words whether the research process has enabled the identification of real problems and adequate solutions (Peffers et al., 2007). In addition, the evaluation strategy, properties and episodes come with general limitations related to human and technical risks and efficiencies, specifically whether any human and/or technological factors affect the evaluation and therefore distort the results.

To conclude, we recommend the use of DSRM as a practical and scientifically robust tool for service development in the forest sector. This would respond to many calls in previous literature for more evidence-based service development. In addition to exemplifying the use of DSRM in the context of forest-service innovation and development, our results also offer several implications for forest VR services in terms of resource efficiency, improved interaction and a shared understanding between the forest-sector companies and forest owners.

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