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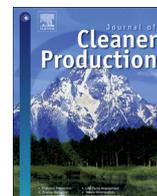
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Designing an organizational system for economically sustainable demand-side management in district heating and cooling

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ABSTRACT

The sustainable implementation of demand-side management (DSM) for district heating and cooling (DHC) is often limited because of DHC's complexity and the requirements to involved stakeholders. The purpose of this study is to define the design principles of an organizational system for implementing economically sustainable DSM innovations in DHC. A design science approach is used to qualitatively analyze a real-life DSM implementation and decontextualize the organizational design toward more widely applicable principles. Combining empirical material gathered from ten interviews, document analysis and six months of participant observations with recent theoretical development on innovation ecosystems, we formulate a conceptual process framework that can facilitate the development and operation of an economically sustainable DSM solution. The process framework features five interlinked design principles. The findings contribute to the literature on multiorganizational systems and the implementation of technological innovations in the building and energy sectors.

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1. Introduction

In the European Union, buildings are responsible for 40% of energy consumption and 36% of CO₂ emissions (European Commission), making them a primary target when attempting to increase energy efficiency (EE). Particularly in colder climates, such as Northern Europe, Russia, and Canada, a significant share of energy consumption in buildings is drawn from district heating and cooling (DHC) (Werner, 2014) and DHC is considered a high potential approach for providing heat and cool in increasingly dense urban areas (Hawkey et al., 2013). However, to fully realize this potential, DHC systems need to become smarter, more flexible, and better integrated into the energy system as a whole (Lund et al., 2014).

Several methods for radically improving the EE of DHC networks have been suggested, including an analysis of heating load diversity in buildings (Weissmann et al., 2017), machine learning in forecasting heat loads (Idowu et al., 2016), and predictive models of

consumers' heat loads (Ancona et al., 2014; Sajjadi et al., 2016). These methods focus on managing the supply side of the network by adapting it to variations in demand. Unlike supply-side innovations, DSM and demand response (DR) programs have been suggested as effective ways to change participants' energy usage in response to the availability or price of energy (Christantoni et al., 2016; Lombard et al., 1999). Although the potential of DSM in DHC has been recognized (Lund et al., 2014), studies of DSM applications in DHC contexts are scarce (Kuosa et al., 2013; Sipilä and Kärkkäinen, 2000; Wernerstedt et al., 2007).

Organizing a DSM innovation naturally ties together the activities and interests of several stakeholders, including inhabitants, property owners, software and hardware producers, and energy corporations. As such, DSM provides new business opportunities (Sepponen and Heimonen, 2016), but it also challenges the diverse list of actors to find new modes of collaboration. These new modes are often at odds with the existing technological and organizational systems (Kanda et al., 2016). To create systemic change and ensure an economically sustainable diffusion of DSM innovations in DHC systems, it is therefore necessary to understand the interaction between the involved actors—including their contributions, compensation, and associated activities—while not focusing purely on technology or the individual business case of any given actor.

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The current research complements previous studies on the technological aspects of DSM in DHC (Kuosa et al., 2013; Sipilä and Kärkkäinen, 2000; Wernerstedt et al., 2007) by specifically focusing on the (inter-)organizational aspects of achieving an economically sustainable DSM solution.

The aim of the present research is to define the design principles for the organizational systems that can be used for implementing sustainable DSM innovations in DHC. We do this by first analyzing a real-life implementation of a DSM system design in Finland and then decontextualizing that design toward more widely applicable principles for setting up DSM in DHC systems. As such, our paper adopts a design science perspective (Romme and Enderburg, 2006; Van Aken, 2004), an approach in organization science that has been advocated as a way to provide theoretically grounded prescriptive work that can help practitioners accomplish organizational change (Holmström et al., 2009). The phenomenon under observation in this paper is the nascent DHC DSM innovation ecosystem (Adner, 2017) and its multiple stakeholder actors. To formulate the design principles, we use a combination of empirical evidence from the case study and recent insights from innovation ecosystem theory (Adner, 2017; Dattée et al., 2018; Jacobides et al., 2018).

2. DSM in DHC and organizational alignment needs

DHC networks can be an energy-efficient means of providing heating and cooling. However, fluctuating demand is a major issue, particularly in areas with a wide variation in weather conditions, both from day to day and season to season. In some of these markets, such as Sweden and Finland, DHC systems have consequently seen a decline (Magnusson, 2012; Paiho and Reda, 2016). To counterbalance this decline, smart DHC systems that mitigate the impact of such volatility of demand by implementing DSM measures have been suggested (Sayegh et al., 2017; Lee et al., 2007).

Influencing the peak consumption and the EE of end use is indeed an attractive alternative both economically and environmentally, and an added benefit is the opportunity to use buildings for short-term energy storage (Kensby et al., 2015). In the context of DHC, DSM measures are conducted on the assumption that energy is not an end in itself but rather a means to achieve certain desirable outcomes, such as a comfortable indoor temperature (Wernstedt et al., 2007). DSM may then be regarded as a portfolio of measures that can be used to better match the demand with the supply (Warren, 2014), including “everything that is done on the demand side of an energy system” (Palensky and Dietrich, 2011: 381). According to Eissa’s (2011) accepted definition, DSM covers a wide set of technologies: load management, EE, DR, energy storage, and microgeneration. When implemented correctly, DSM can result in reduced energy consumption and lower CO₂ emissions (Wernstedt et al., 2007).

Despite the growing interest in DSM in DHC networks, previous studies have focused on the technology itself rather than on the organizational systems of implementing DSM innovations. By definition, DSM assumes there are activities being conducted in the interface of several organizations, with any added value arising from the ability of these parties to set up and maintain a mutually beneficial system. Consequently, DSM innovations need aligned business models, information sharing, and interaction between stakeholders (Sepponen and Heimonen, 2016). However, empirical research into the viewpoints of several stakeholders for a particular innovation is rare. The existing studies either focus on one stakeholder at a time (Sepponen and Heimonen, 2016) or highlight the need for interorganizational activities, such as communication (Palensky and Dietrich, 2011), without discussing the broader themes that underlie this collaboration (Walrave et al., 2017). Therefore, more knowledge of the organizational design of DSM

innovations in DHC systems is required, including a better understanding of the actors’ contributions, compensation, and associated alignment structure.

In analyzing the approaches that organizations can take in assembling complex (novel) value offerings, contemporary innovation theory has distinguished three alternatives: 1) integration (i.e., develop and produce the solution in-house), 2) market-based transacting (i.e., outsource various parts, aggregate, and supply the aggregate), and 3) coordinate the emergence of relevant elements across complementary actors (Cennamo et al., 2018). In the current paper, we consider an example and the resulting design principles for a DHC DSM system that arise from the third approach. In particular, we conceptualize DHC DSM solutions here as innovation ecosystems (henceforth “ecosystems”) standing for the “alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize” (Adner, 2017: 40). This choice assumes three characteristics. First, ecosystems arise when there is clear separability of the elements that run along the production and/or consumption chain; this is to as *modularity* (Jacobides et al., 2018). Modularity is enabled by certain rules, such as communication standards, that make it possible for these distinct elements of the production/consumption chain to be delivered by different actors but assembled with relative ease (Baldwin, 2008). Second, the contributions made by the different actors would have to be *complementary* by nature, meaning that they could be combined in such a way as to enhance the qualities of each other (Adner, 2017). Thus, modular architecture is useful in increasing (as opposed to duplicating) the value created by the involved actors. However, complementarity also implies some level of interdependence between the involved parties (Dattée et al., 2018). Consequently, the failure of any key actor to successfully contribute to the ecosystem value proposition (EVP) negatively impacts the chances of success of the whole ecosystem and every actor partaking in it (Brusoni and Prencipe, 2013). Third, in an ecosystem, the final configuration of the product/service is not fully dictated by any one party. Instead, modularity makes it possible for the product/service to be dynamically reassembled so that it can vary from one consumption instance to another, most commonly from the demand of the consumption-side actors. To enable this freedom, the supply-side actors are advised to adopt some level of *nonhierarchical coordination* (Jacobides et al., 2018). Building on these characteristics, a key question in ecosystem research is how to create an interorganizational alignment where the parties are incentivized to work together to achieve a system that is valuable enough to be adopted by the market, and simultaneously can provide enough value capturing opportunities for these parties to be (come) motivated to contribute (Walrave et al., 2017). The design knowledge we distill in the course of the current research will provide a response to these questions in the context of DSM in DHC.

3. Material and methods

To deepen our understanding of organizational design in relation to the implementation of DSM in DHC, we conducted a qualitative single-case study of a DSM solution implementation in Finland. The DSM solution here can be seen as an integrator of several organizations. Therefore, following Jacobides et al.’s (2018: 2255) idea that “at the core of ecosystems lie non-generic complementarities,” the aim of the data collection and analysis was to map the DSM solution’s development history from the perspective of each non-generic complementary organization that participated in or was directly affected by the solution. For example, the energy company providing local DHC and the building maintenance company that held a rather long contract with the housing company were included. Meanwhile, by the same logic, the perspective

of the installation company was not studied because it supplied an interchangeable—or generic—service for the ecosystem.

We collected empirical data through semi-structured interviews with the representatives of six different organizations. The semi-structured interviews allowed us to follow the predefined structure of the questions, but they also allowed for flexibility, letting the informants talk freely about what in the solution and its implementation was important to them (see, e.g., Drever, 1995). We further utilized both internal and publicly available documentation about the project, including meeting memos, marketing presentations, contracts, and blueprints (in total 163 pages). In addition, one of the authors carried out a 6-month participant observation inside the housing company that implemented the solution in its buildings. We used the memos of those observations and informal meetings with company representatives as research material.

We list our informants in Table 1 in chronological order of interview and also provide a short description of the role the informant and his/her organization played in the overall solution. In arranging the interviews, we selected informants who represented management, development, and operative personnel with decision-making responsibility about the participation of their organization in the development and use of the solution. This allowed us to gain knowledge of the reasons for their participation, their core activities during participation, and their perceptions of the value and challenges of the solution and its implementation. After the first interviews, we utilized snowball sampling (Biernacki and Waldorf, 1981) to identify new informants. This led us to start interviewing the representatives of the two most salient actors—the developer and the housing company—and select further informants according to the insights and needs we identified in the initial interviews. We continued interviewing participants until our research group collectively felt that a point of saturation had been reached.

In total, we conducted 10 interviews. We interviewed two informants from the housing company after our first analysis of the data because we realized that it was necessary to obtain more

detailed answers to the questions raised by the other interviews. We asked the informants to describe the solution, its stakeholders, and critical events during implementation. We were also interested in the role of each informant's organization in the solution and the effects that the solution had on their business and operations. We encouraged the informants to discuss their opinions of the advantages and disadvantages of the solution. The main questions asked in the interviews are presented in Appendix 1. All the interviews were recorded and transcribed.

We used a thematic analysis (Corbin and Strauss, 2014) to categorize the interview and supporting data. A chronological narrative of the main events concerning the development of the solution, its implementation, and the final organizational design was thereby created. We further mapped the features of the technical system, its development and implementation phases, and the organizational design, including the roles of the actors and their relationships and activities as expressed by our interviewees. We then used the archival materials and participant observations to triangulate information on different events and phases to place them in a clear chronological order. To capture the emergent ecosystem constellation in its final stage, we used the Ecosystem Pie Model (EPM) tool (Talmar et al., 2018), which is a qualitative graphical method to model the organizational constellation of an innovation ecosystem within the so-called structuralist perspective of ecosystems (Adner, 2017), across the key features that explain value creation, delivery, and capture and potential shortcomings within an emerging organizational network.

We further analyzed the interactor links among activities, value addition, and value capture, as illustrated in the EPM, by using as our primary data of the informants' experiences and opinions regarding the solution and its outcomes. After validating the EPM among the authors of this research and the housing company representatives, three of the authors analyzed the data independently from each other to suggest a set of design problems, which according to them were most critical of a successful implementation of the solution. A comparison and iteration of those independently created sets helped the researchers capture five specific

Table 1
List of interviews in chronological order.

Date	Organization	Justification of the organization being involved in the study	Informant's title and characteristics
2 Jun 2016	Developer	Developer and provider of the solution and provider of initial HVAC system balancing support	CEO; main architect of the DSM solution
8 Jun 2016	Housing company: building management	Coordinates routine activities conducted on buildings and building systems, including maintenance service procurement	Senior building manager; responsible for buildings with DSM solutions
15 Jun 2016	Component supplier	Provides hardware for sensors and controlling HVAC equipment on which the solution functions. The DSM solution seen as a strategic sales channel for the components	CEO; responsible for the strategic partnership with the DSM solution developer
17 Jun 2016	Energy company	Participates in the solution to enable load-shifting to minimize energy production costs by providing cost index data for the system to use as a basis for optimization	Product manager; responsible for collaboration with the DSM actors
21 Jun 2016	Maintenance company	Responsible for providing services to facilitate the proper functioning of building systems and enabling the comfort of the inhabitants; responsible for all services provided for buildings with the DSM solution, ranging from lawn mowing to the maintenance of HVAC systems	Maintenance person; daily maintenance responsibilities in the buildings
21 Jun 2016	Maintenance company		Maintenance person; daily maintenance responsibilities in the buildings
21 Jun 2016	Maintenance company		CEO; responsible for contracts and conditions with customers
29 Jun 2016	Housing company: general administration	Purchaser of the solution; utilizes solutions for building stock and HVAC equipment that are on their balance sheet to offer healthy and steady in-room conditions, energy savings, and support maintenance for maximized building life cycle value	Technical maintenance person; responsible for HVAC equipment
16 Nov 2016	Housing company: building management	Coordinates routine activities conducted on buildings and building systems, including maintenance service procurement	Building manager; responsible for contracts and conditions with maintenance
16 Nov 2016	Housing company: building management		Building manager; responsible for contracts and conditions with maintenance
Continuing interaction and observation	Housing company: energy dep./general admin.	Purchaser of the solution; utilizes solutions for building stock and HVAC equipment that are on their balance sheet to offer healthy and steady in-room conditions, energy savings, and support maintenance for maximized building life cycle value	Development manager; responsible for contracts and conditions with the solution developer

design problems and congruent and incongruent outcomes for those problems. We then considered these five design problems and their actual outcomes in light of the improvements suggested by the stakeholders. In this phase, we also used the ecosystem theory to frame the analysis across the five design problems and interpret the case results. This enabled us to decontextualize the particular design solution toward a set of design principles (Romme and Endenburg, 2006) that have been forward-looking for the particular case (i.e., informing improvements to the next generation of the solution) while also serving as guidelines for developing DHC DSM solutions in other contexts. In total, we constructed five such design principles, capturing the main areas of importance in the design of a nascent organizational (eco)system in DHC DSM. We will discuss the interrelations of these principles and develop a conceptual framework of organizational design for the facilitation of economically sustainable DSM innovation.

4. Description of the case studied

4.1. Overview of the technological system

In the case, the main technological artifact at hand was a package of software and hardware (henceforth “solution”) that was implemented for automatic heating control at an affordable-housing company in Finland. The central idea of the solution was to perform heating control that could be based simultaneously on input from the demand-side agents (the conditions in the building) and supply side (hourly price signals from the energy producer). The solution is designed to be implemented without significant capital expenditure in either new or old buildings. The workflow of the solution is illustrated in Fig. 1. First, it gathers data about in-room conditions from sensors placed across a dwelling. The data are then analyzed using artificial intelligence algorithms to produce a dynamic model of the building and learn about its conditions. Subsequently, the model controls the heat of the water that flows in the secondary network inside the building in such a way that the in-room temperature is as constant as possible and close to the target temperature (21 °C) in the system. With this, the solution provides stable and healthy indoor conditions, delivers energy savings to the landlord, and balances the grid capacity of the energy suppliers while taking into consideration weather conditions, human activity, exposure to sunlight, and the fluctuations in in-room conditions caused by electrical equipment. As such, this system is in stark contrast to the manual scale-based heating adjustment methods traditionally used in district-heated buildings in Finland.

A summary of the technological system of the solution is

presented in Table 2. The columns show the DSM functionality of the solution and evaluate its characteristics against the two main theoretical phenomena in the DSM literature: EE and DR (Palensky and Dietrich, 2011).

The pilot of the solution was initiated in October 2014 and ran until the spring of 2016. The initiator of the solution was a software company, referred to here as the *developer*. The sensors and physical control equipment used in the solution were developed by the *component supplier*, a company that develops and manufactures automation and communication technology. In the pilot, the solution—as a software-hardware package—was installed in the buildings of four housing cooperatives owned by the *housing company*. A subcontracted installation company was chosen to install the component supplier’s hardware in the buildings. The solution was intended to improve EE by balancing temperature differences in the buildings, making it close to the recommended room temperature of 21 °C, thereby decreasing the energy costs of the building owners. As reference, both in the case of the building owner in particular as well as buildings in general, it has been observed that temperatures in residential apartments in Finland vary widely and are often significantly higher. Meanwhile, 21–22 °C has been argued to be the best level considering the health and performance of inhabitants (Seppanen et al., 2006). As an additional functionality intended to increase the effectiveness of the automatic control, the data generated by the solution could also be employed to monitor the status and any possible imbalances of the building, letting maintenance and renovation needs be identified and respective action to be taken more systematically than in the traditional approach based on inhabitant reports. With this added functionality, the *building management organization* and a *maintenance company* became involved in the solution as well.

Once initial installation had been completed, an *energy company* joined the pilot with the motivation to start limiting demand during peak hours when heat production costs were the highest. The respective functionality was provided by the intelligent control embedded in the solution, which made it possible to shift energy consumption to hours when production was the cheapest. The price data input to the solution was also provided by the energy company. As such, a DSM functionality was added to the solution (Palensky and Dietrich, 2011).

The list of integrated parties was extended further when in early 2016, a *heat pump company* started participating in the solution as a provider of geothermal heating. As such, heat pumps were utilized alongside the traditional heating method (district heating), making it possible to switch from one energy source to another depending on the cost.

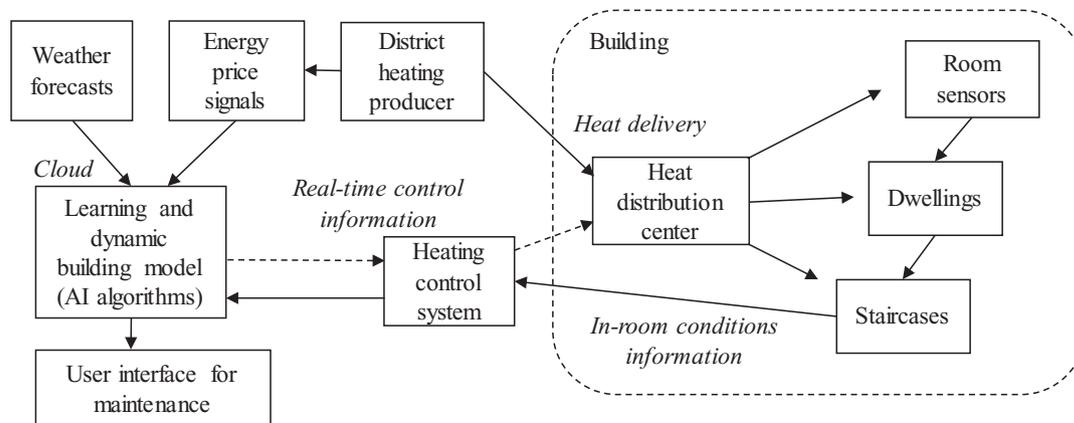


Fig. 1. The principles of the DSM solution.

Table 2
Functionalities of the solution and their connection to the DSM literature.

Theoretical phenomenon	Functionality related to DSM	A description of the functionality related to the phenomenon
Energy efficiency (EE)	Access to building processes and inhabitant behavioral patterns, of which the system creates a model that is the basis of heating optimization, helping avoid overheating	The solution can be seen as a more “intelligent” method of constraining demand without affecting performance; it therefore sits in the category of EE (Palensky and Dietrich, 2011). Palensky and Dietrich (2011) contrast EE with EC, which allows for a degradation in performance to create energy savings.
	Access to building performance and ability to react more effectively to maintenance needs that cause suboptimal energy performance buildings	The solution provides a tool for observing and analyzing maintenance needs, hence upgrading (and maintaining) the energy performance of buildings, fitting Palensky and Dietrich’s (2011) definition of EE.
Demand response (DR): incentive-based demand load control	Access to data from both consumption and production and the ability to control consumption based on hourly production costs	The solution provides DR functionality over which the inhabitant and the building stock owner have no control; it is therefore a form of direct load control, in which the utility or grid operator has free access to the customers’ processes (Palensky and Dietrich, 2011).



Fig. 2. The innovation ecosystem around the solution at the end of the pilot period.

4.2. Overview of the innovation ecosystem after implementation

In this section, we review the case study in terms of the organizational interactions that were needed to implement the solution successfully. Fig. 2 presents a snapshot of the organizational system of the working solution at the end of the pilot period (i.e., after the mentioned parties were already integrated). The organizational system is presented in the form of an EPM (Talmar et al., 2018), where: (1) at the center of the model lies the goal of materializing a value proposition (EVP) that overarches the involved actors; (2) radial lines around the center separate the different actors in the ecosystem; (3) the sequence of the involved actors runs clockwise, following the dominant direction of value transfer in the ecosystem, starting with upstream contributions and finishing downstream with the demand-side actor(s); (4) the different background colors mark distinct parallel value chains involved in the ecosystem; (5) the intra-actor constructs represent value creation enablers (actor-based resources enable the activities that lead to value addition) and the logic of value capture from the viewpoint of each individual actor; (6) the interactor flows are represented by arrows that point in the direction of value transfer, with the dotted arrows representing unaccomplished flow potential; (7) the

¹ Here, green marks that the actor is both able and willing to contribute to accomplishing the EVP, and yellow marks that the actor is partly unable and/or unwilling to contribute to accomplishing the EVP.

colored section around the center represents the risk arising from each individual actor to accomplishing the EVP¹; and (8) the letter markings L(ow)-M(edium)-H(igh) on the radial line separating an actor from the next one represent the dependence of that actor on the overall EVP.

In particular, in Fig. 2, we can see that the solution is accomplished by means of interactions among eight different actors (with the eighth being the inhabitants), each one delivering a complementary product or service that is required to achieve the integrated value offering of healthy and stable indoor living conditions at significantly reduced energy costs. The actors involved in the success of the system are as follows: (1) an energy company; (2) a hardware supplier; (3) a software supplier; (4) a building maintenance company; (5) a heat pump supplier; (6) a building management organization; (7) a housing corporation; and (8) the inhabitants. The eight parties represent five distinct subsystems (indicated in Fig. 2 by purple, green, yellow and teal sections for supply and red for demand), each of them modules in accomplishing the integrated EVP.

The parties were overall satisfied with the outcomes of the solution implementation. The solution delivered the general benefits that were expected: indoor conditions were stabilized, energy consumption of the buildings was reduced (10.5% in 2015 and 10.9% in 2016 when compared to a computational benchmark consumption), peak load was shifted, and the ability to provide timely input to ad hoc repair and maintenance support was demonstrated. The housing company analyzed the savings and payback periods from the solution, and on the grounds that the savings were significant, they decided to continue expansion of the solution outside the original four pilot dwellings. According to the development manager from the housing company, “expansion would not have been the case if the economics would have not been prevailing.” Similar observations were voiced by the energy company.

Overall satisfaction with the outcomes was an important precondition for further adoption. Another important factor was the perceived competence of the development team. For example, in this case, the developer’s team was responsive in tailoring the solution to a change in the pricing model by the energy company. The technical solution was also able to utilize real-time data generated from sensors for the optimization of HVAC systems and from situational data provided by users. This required the developer to solve a range of design issues related to big data algorithms, data interchange, user interface, and supporting components.

Among these successes, however, technological limitations were encountered. The developer was unable to make the solution suitable for buildings equipped with floor heating, and this restricted future expansion of the solution. Incongruencies were also observed among the stakeholders, potentially inhibiting wider adoption and increasing the risks of implementation. The

developer's CEO viewed the solution as a "robotization of HVAC operations," delivering more reliable and timelier in-room condition data than the current manual method of measurement. However, the negative perception of the measurement quality of the solution on the part of the maintenance companies undermined its potential benefits; the maintenance company still conducted site visits and carried out manual measurements because of its low degree of trust in the solution. This skepticism prevented one potential benefit from being achieved: shifting maintenance work from reactionary to predictive. There was also an incongruence related to the control components used in the solution. The developer's aim was to have a control solution that could be used with many types of hardware, whereas the component supplier wanted to see its system as an integral component of the solution. This incongruence limited the component supplier's willingness to invest in the development of the interface in a way that would enable future expansion to other types of hardware components.

Meanwhile, quite understandably, each stakeholder considered the solution in terms of what it meant for each company's business. As such, the housing company did not take into account the implications of implementation for building management and maintenance operations. Similarly, the energy company saw the solution in terms of its load-shifting benefits and was not concerned with the various implementation and maintenance challenges that faced the housing company. In light of this tendency, it was particularly important that there was an integrator party that connected the different value mechanisms in the organizational system to a coherent value proposition.

5. Design principles for implementing DSM innovations in DHC

In this section, we draw from the case study and theory on ecosystems to identify the main points of learning in DSM innovation implementation. The purpose is to decontextualize the particular design solution used in the case study toward design principles that could be applicable across similar contexts of DSM implementation in DHC.

5.1. Perceived utility among most (all) actors

The perceived credibility of the initial solution for each key actor in the ecosystem plays an important role in sustaining its implementation. According to our findings, *verification* of the predicted cost savings was key in determining the willingness of the housing company to further invest in the implementation of the solution. Similarly, the inhabitants benefited from stabilized indoor conditions, the energy company from the shifted peak load, the software company from validation of the solution as a whole and from sales of their software, and the hardware company from the sales potential of hardware arising from the scalability of the solution. For all of these parties, the perceived technical superiority of the solution was a distinct advantage. The development team had high levels of competence in the development of big data and artificial intelligence algorithms that distinguished it from competitors, and this competence allowed the solution to deliver a better level of optimization than competing solutions. [Dattée et al. \(2018\)](#) argue that a high state of enabling technology narrows the range of alternative futures, which again increases momentum both in the ecosystem actors' internal business cases and in collaboration. In this case, when there was perceived utility *specifically for them*, the actors were encouraged not only to invest in the development of the initial offering, but also in the development of new offerings. At the time of writing this paper, the development of the solution is starting to use new opportunities arising from such new

functionalities. For example, the developer is looking for better ways to use its data and provide more direct value for end users. Furthermore, changing energy pricing models, such as those related to increases in the volatility of DHC demand, are creating the need to make corresponding changes to the optimization logic of the solution; and the metering capacity of buildings is leading to the wider introduction of predictive maintenance practices. The following design principle can therefore be argued:

Principle 1. *The perceived utility of the initial DSM solution among most (or, ideally all) complementary supply-side actors enhances further investments in the internal business cases and in searching for further value-enhancing interactions between the ecosystem actors, thus increasing the value potential of the solution.*

5.2. Sequence of value offerings

Building on the previous principle, a DSM solution is more valuable if it increases the value-in-use for the end consumer, especially if providing demand-side actors the freedom to control the exact type and level of utility in any instance of consumption ([Jacobides et al., 2018](#)). At the outset, however, it may be difficult to design a use-oriented DSM solution at that level of complexity regarding the necessary interactions on the supply side. Furthermore, quickly achieving a customer-side scale that is significant enough for DSM functionality to allow for enough supply-side value capture is also an issue. As illustrated in this case, it may therefore be more feasible to develop the DSM functionality as a complement to other value-added services, where these *other services are initially in focus*. In the case study, of the multiple types of utilities embedded in the solution, heating cost savings were initially the most attractive to the largest number of organizations in the ecosystem. On the demand side, cost savings implied an immediate positive financial result, making adoption attractive; on the supply side, the adoption potential attracted actors to contribute to the development of the solution, including eventually the addition of the DSM functionality. A second design principle can therefore be advanced:

Principle 2. *Providing DSM services in combination with other value-added offerings with an initial focus on the highest utility offering can trigger a two-sided magnetism by which, on the one hand, more demand-side actors adopt the solution, but on the other hand, supply-side actors provide stronger efforts to further develop each functionality and add more functionalities to the (overarching) solution. From the resulting increased scale of adoption, the DSM module, in particular, becomes impactful quicker than in dedicated DSM solutions.*

5.3. Leadership from outside the central value chain

Although complementary services may be critical for establishing DSM implementation, our case study underlined the difficulties for the demand-side actors (i.e., housing corporation in particular) to integrate these extra services on their own. The reasons for this include inertia from existing contractual structures, traditional methods of resolution, and, ultimately, a limitation to the scalability of the solution because of a limited asset portfolio. Meanwhile, the energy company may be equally ill-equipped to lead the development of a viable DSM solution because of its strong focus on DHC and within its own network in particular. Both of these points are likely to interfere with the opportunity for DSM to use various other value-added services to "piggyback" to the market (see principles 1 and 2) and in motivating different supply-side

actors with scalability beyond any one DHC network. The strongest candidate that can take leadership in an emerging DSM solution might therefore be an independent technology developer who is located in parallel to the value chain that connects the source of heat and the consumers. Using the scalability of the solution beyond the particular setting as a motivation, in our case, it was the software organization that was the best positioned to lead the integration of the various added value offerings and functionalities into one coherent solution. Furthermore, once this agent leads the development, the barrier to including parallel (substitute) products/services into the solution is brought down. This aspect was represented in the case with the later inclusion of heat pumps into the solution. A second source of heating and cooling, especially one that is highly flexible, enables existing end users to have more control over their conditions and, in general, a wider range of use cases, implying the potential for an increased number of addressable end user segments (Jacobides et al., 2018), as well as major efficiency improvements in general. It is unlikely that this type of inclusion would have been made by the district heating company.

Principle 3. *An independent core technology developer is best positioned to lead the ecosystem toward developing the solution in such a way as to increase the number of complementary value offerings embedded in the solution and to improve its scalability.*

5.4. Shared operating rules

The literature of ecosystems underlines the importance of the rules and standards that regulate the interfaces between the modular elements of an overarching solution (Baldwin, 2008). Meanwhile, in the case study, several interfaces between the actors initially lacked proper communication and collaboration protocols. Insufficient coordination was the most prominent in the activities that followed a complaint regarding in-room conditions in the buildings. This lack of coordination took two forms: an internal misalignment between building management personnel and energy personnel from the housing company and a misalignment between the housing company and external maintenance companies. These stakeholders anticipated that an improved use of procedural instructions would (in terms of what to do in the case of a fault) minimize maintenance visits and ensure improved customer service.

Furthermore, at the pilot stage, no formal value proposition was communicated to the inhabitants. This was justified by the belief that the in-room conditions either would not change noticeably or would change only for the better. It became apparent, however, that the perceptions of the inhabitants were integral to the success or failure of the implementation. On the one hand, informants believed that the project could have failed if the inhabitants' negative experiences had resulted in bad publicity; on the other hand, inhabitants' systematically gathered appreciation of a more comfortable and environmentally conscious way of living could have made the housing company's offering more attractive. Establishing two-way communication with the inhabitants therefore appears a way to mitigate the risks involved and to identify possible opportunities. We found support also that communication of the impacts and value offered by the solution—particularly among the developer, the housing companies, the management organization, and the maintenance companies—could increase organizational learning among the stakeholders and improve conflict resolution and coordination of activities in the ecosystem. Based on this, we outline a fourth principle, as follows:

Principle 4. *Shared and communicated operating rules clarify responsibilities and help overcome the barriers associated with the*

novelty of the DSM solution, resulting in improved perceived utility of the solution.

5.5. Collaborative governance to coordinate local implementation

The literature on ecosystems underlines the role of (partial) nonhierarchical governance as a source of flexibility and adaptability within an ecosystem (Jacobides et al., 2018). In the case study, this flexibility was useful in governing the local versus global scope of the different involved parties. Although both the software and hardware company (and later the heat pump supplier) perceived the project as individually important, their ultimate motivation lay in the scalability of the solution to many different locations. Meanwhile, success at any location depends on the adaptability of the solution to meet local needs with the involvement of parties whose scope is only that one implementation. In this context, the actors involved in the pilot described how on the local level, collaborative governance through a steering group was useful in reorganizing activities required by the implementation of the solution. The steering group facilitated the discussion of issues, opportunities, and joint development, and there was a consensus that this activity had resulted in advantageous outcomes. Furthermore, although transactions between the housing company and maintenance company and between the housing company and energy company were originally governed by market-based contracting and sourcing, resulting in miscommunications (see Principle 4), the uncertainty in relation to the activities necessary for solution-related maintenance used a relationship that was not entirely market based. A hybrid form of governance, market-based contracts and ecosystem-based coordination (Cennamo et al., 2018) could therefore be beneficial in these actor interfaces.

The collaborative governance adopted in the case settings had two crucial features: First, the issues governed by the steering group had an emphasis on implementation issues and shared rules regarding the implementation of the solution in the housing company's premises. Therefore, we argue that collaborative governance was needed to coordinate the local part of the DSM ecosystem to set common goals and share knowledge about changes in activities regarding the crucial control points (Dattée et al., 2018) that could make the solution functional. Second, it was natural that the housing company as a principal customer for other firms in the ecosystem to play the role of facilitator in the steering group. As the leading customer, the housing company seemed to have the best understanding of the nonalignment in actors' activities and of the needed transition from market-based transactions toward ecosystem-based coordination required by the DSM solution implementation. The importance of this is embodied in our fifth principle:

Principle 5. *Establishing collaborative governance in a local DHC ecosystem among non-generic complement providers for the DSM solution, for example, via a steering group facilitated by the solution customer, aligns the operating rules among the firms to better manage the crucial control points of the solution.*

6. Discussion

In the current paper, we have investigated how to design an organizational system to implement economically sustainable DSM innovation in DHC. Our empirical analysis provides specific action points for how focal actors can implement DSM in DHC and how this can facilitate system change. Our decontextualization of the case into a set of design principles shows that the key elements of organizational design—collaborative governance, leadership

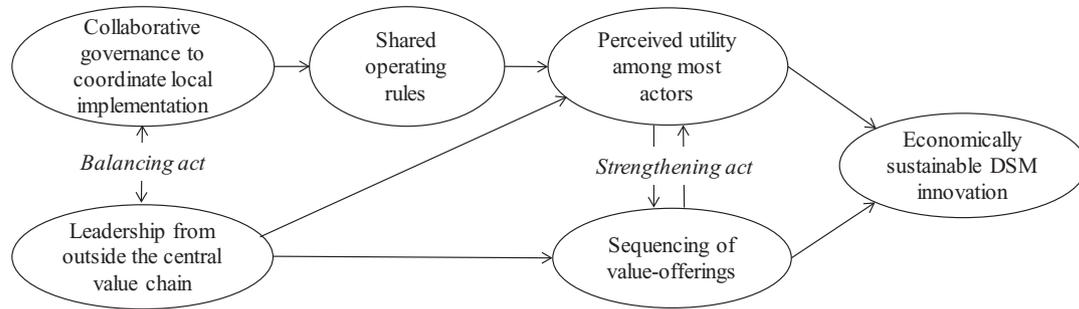


Fig. 3. A conceptual process framework for organizational design to facilitate economically sustainable DSM innovation.

assignment, and shared operating rules—had a significant impact on the development of the value offerings of the solution, as well as on how complementary actors with diverging interests perceived it. In turn, this affected stakeholders' long-term commitment to the development and operation of the solution. Based on our findings, we propose a conceptual process framework for organizational design to facilitate economically sustainable DSM innovation (Fig. 3).

6.1. Theoretical contributions

Our design principles and conceptual framework contribute to the literature on DSM innovations in DHC and to the literature on ecosystem-based coordination.

First, our framework emphasizes the role of the competitiveness of an initial solution in ensuring the sustainability of a DSM solution. Economically sustainable innovation requires both that the initial solution be perceived as value creating for most critical actors in the ecosystem and that the solution be continuously developed by sequentially adding new complementary value offerings. DSM provides several new business opportunities, and here, single business concepts are often combined into broader service offerings (Sepponen and Heimonen, 2016). Our research improves the understanding of this by showing that the utility of the initial solution and the future possibilities for complementary value offerings feed and strengthen each other, thus forcing actors to develop their own business concepts as part of the broader offering of the whole network. The perceived initial utility and sequencing of new value offerings may decrease any resistance to implementation arising from financial barriers (Hawkey et al., 2013) and from those parties worried about new industry logics (Hellström et al., 2015). In our case study, the DSM was conceived almost as a side-effect of providing cost savings, monitoring, and maintenance services via the initial solution. These benefits represented a type of artifact mutability (Gregor and Jones, 2007): unintended, unexpected but positive outcomes of the solution, that can act as value drivers for increasing the implementation extent of the DSM functionality and improving the solution's long-term benefits.

Second, our framework proposes that the perceived utility of the initial DSM solution and the sequencing emergence of complementary value offerings are strongly facilitated by design principles that deal with the organizational aspects of the system. Our results confirm the findings of previous studies showing that sustainable DSM implementations require many interorganizational activities, including communication about actors' activities, motives, and incentives (Palensky and Dietrich, 2011). Our research elaborates on the role of interorganizational activities by showing the necessity of collaborative governance and of assigning leadership to a core actor of the solution; we have also shown that those activities should be

carefully balanced to achieve optimal outcomes. Collaborative governance—in this case, a steering group—is a crucial principle when aligning rules and changing operations among complementary actors in a local DHC implementation.

In contrast to the collaborative governance in the local ecosystem, an assignment of the solution leadership to a neutral core actor outside the traditional DHC value chain is essential in fostering the development of complementary services and thus avoiding the solution from being locked into its initial features in the local DHC settings. The proposed two principles of DSM innovation management extend beyond the existing technological and organizational systems in the DHC ecosystems (Kanda et al., 2016). DSM innovation is a system with complex flows of materials and services (Hall and Roelich, 2016; Päivärinne and Lindahl, 2016), and in these complex systems, locally designed organizational practices can be at least as crucial as product standards and funding mechanisms (Warren, 2014) in ensuring the long-term success of a DSM implementation.

Third, the current study contributes to contemporary research on ecosystem-based coordination by arguing that a different operating scope of ecosystem actors influences their perception of who is included as a (valuable) collaboration partner and who not, which in turn may influence the potential of the solution. In particular, we build on the argument of Jacobides et al. (2018) that at the core of ecosystems lie non-generic complementarities positioned in distinct (somewhat) flexibly re-combinable modules as basis. In light of generic vs. non-generic complementarity, the housing company and the solution developer saw the importance of the energy company and the maintenance company differently. What were seen as non-generic complements in the local setting were thought of as practically generic complements by the solution developer whose focus was on global scaling potential. As the case suggested, because scaling would assume local interaction in every instance of implementation, establishing a locally-based collaborative governance structure can bring this incongruence in light quickly and help otherwise globally positioned actors to adopt a locally appropriate scope of relevant actors. This in turn, increases the potential of the solution in that local setting.

6.2. Managerial implications

The current study shows that the implementation of economically sustainable DSM content in DHC may require heavy alterations to the existing organizational system, including which actors are involved and how communication and operating rules are designed and managed, along with what the business implications of the developed offerings for each actor are. Our study provides concrete action points on how DSM solution developers and property owners can improve their return on investments by establishing an organizational design that leads both to early

benefits for all actors in the ecosystem and a scalable and configurable solution. The findings of the present study can also help governments and local communities in their investments in DSM innovations when it comes to better understanding what kind of organizational configuration is needed to ensure that the solution improves end users' quality of life with reasonable economic efforts. In general, our paper discusses the preconditions and consequences associated with the energy transition needed to reach the goals set for a more sustainable future.

In summary, the current study has three specific implications for managers. First, it is important to assign the leadership of system development to a crucial actor who is not part of the traditional DHC value chain and stands to receive no disadvantages from any solution functionalities or value offerings. This enhances the sustainability of the solution and the potential to include new service configurations that are unbound by previous economic ties between actors.

Second, the solution developer typically has the best understanding of how to implement the solution in the organizational system, but the customer's knowledge is also needed. Management of predictive maintenance requires not only data on the condition of the buildings and systems, but also methods for evaluating courses of action; the customer has the best understanding of these. Therefore, we suggest that collaborative governance should be adopted—for example, through a steering group—to find a consensus on common goals and diminish the risk of innovation being sidelined because of excessive emphasis on technology and a lack of customer and user perspectives.

Third, we argue that the focal organizations should agree on shared operating rules early in the process to avoid potential backlash if the DSM solution does not function properly because of communication problems. Shared and communicated rules prevent operational problems from escalating into conflict between organizations; they also reduce the risk that the initial solution will not be perceived as functional, thus improving the sustainability of the overall innovation.

6.3. Limitations and future research

We analyzed the implementation of a DSM solution within the Finnish real estate and energy sector. Therefore, our study is limited by the specificity of its contextual analysis. We nevertheless believe that although each implementation is bound to have a particular context, it is still possible to outline design principles that are applicable to decontextualized situations. Having provided such, future research should be targeted to yet again contextualizing and testing these principles in other instances of implementation. One useful research strategy would be to carry out comparative case studies between successful and failed implementations.

Furthermore, our analysis reveals the need to strike a balance in organizational design between collaborative governance and the assignment of leadership. Further research could elaborate on this finding by investigating in more depth the role of the focal actor in facilitating and coordinating the development of the system in both its organizational and technological dimensions. We also argue that the innovation ecosystem approach to the DSM implementation that was adopted in the present research may be limited in an interpretation of the role of different norms, cultural systems, and institutions that—both at organization and individual levels—affect the success of implementation. Future research should therefore use other theoretical lenses, such as the practice theory (e.g., Schatzki et al., 2001), to study the correlation between social agents, cultural systems, institutions, governance, norms, and sociotechnical systems in this specific field of demand and supply of energy in buildings.

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Appendix 1. Interview questionnaire

1. Background:
 - a. How long have you worked for the organization?
 - b. In which organizations and roles have you worked before?
 - c. What is your educational background?
2. Describe the DSM solution?
3. What are the solution's stakeholder actors (including customers/suppliers, etc.)?
4. How and when did the DSM solution come into being?
5. Has your understanding of the DSM solution changed during the years (e.g., has the service changed)?
6. How does the DSM solution affect your company's operations?
7. How does the DSM solution affect your company's business?
8. What requirements or other needs does the DSM solution imply for the different actor stakeholders?
9. How do you see that the DSM solution has affected the operations of different actor stakeholders?
10. How do you see that the DSM solution has affected the business of different actor stakeholders?
11. What are the advantages and disadvantages of the DSM solution?
12. Do you know someone who has not been satisfied with the DSM solution?
13. How could the DSM solution be developed?
14. Is there something related to the DSM solution that concerns you?
15. Is there something that you would still like to bring up?
16. Do you believe there is someone in your organization whom I should interview?

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