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CO-CREATION OF DIGITAL SERVICES WITH AND FOR FACILITIES MANAGEMENT IN CONSTRUCTION PROJECTS

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ABSTRACT

The building construction sector is slowly recognizing the financial opportunities of the growing digital service business for facilities management (FM). Digital FM provides service business opportunities for construction project parties, reduces building life-cycle costs, and increases the performance of the building. However, research is needed to understand how the construction sector parties can create digital services with and for FM.

This paper presents a case study on the co-creation of a digital FM service during the medical center construction project of the University of California, San Francisco (UCSF) at Mission Bay in California. The sub-contractors and the FM team co-created a quick-response (QR) code system for valves on the project. This digital service is now used by the FM team for training purposes and in emergency situations when information on valves and their service areas is quickly needed. In the future, the service will be linked to building information modeling (BIM) to better benefit from BIM in the operations and maintenance of the center. Researchers made on-site observations, conducted 84 interviews, and reviewed archival data in 2012, 2014, and 2016.

Drawing from the case study, this paper provides a framework for successful co-creation of digital FM services within a construction project. The framework consists of three processes. 1) *Dialogue process* is promoted by co-located project parties and early and continuous involvement of project parties, a liaison, and the FM team's experience both in construction and FM. 2) *Trust building process* can be accomplished by providing the FM team with access to project documentation and receiving constructive feedback from the FM team. 3) *The creation of a shared understanding* about the FM's needs and the service providers' ways of satisfying those needs is enabled by project parties learning from each other, FM's empathy skills, risk assessment, and cost transparency.

KEYWORDS: Co-creation, facilities management, digital services, construction project

INTRODUCTION

The building construction sector is an important contributor to many countries' economies and physical surroundings, even though the sector suffers from poor productivity. The sector's business is project-based, employs mainly traditional design-bid-build contracts, and is characterized by low trust between project parties. (Egan, 1998; Dubois and Gadde, 2002a) However, new winds are blowing in the sector. Digitalization provides the opportunity for

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improved efficiency and new service business. For example, robotics and 3D printing already enable the pre-manufacturing of building parts and smart sensors enable better life-cycle management of buildings. Cloud computing and big data analytics offer new service business possibilities. (Kankaanpää, 2015)

The maturity of digitalization in the building construction sector has come in the form of building information modeling (BIM). BIM is a digital representation of the physical and functional characteristics of the building. 3D modeling software can be used to share data during the whole life-cycle of a building (Succar, 2009). So far, BIM has been mainly used during the design and construction phases, although some early adaptors have been able to use BIM for facilities management (FM) (Eastman et al., 2011). However, now BIM is developed enough for wider adoption in the operation and maintenance phase of the building. The technological advances in BIM open up new possibilities for the building construction sector to move towards value-added thinking, instead of just focusing on cost efficiency. Some contractors have understood this potential and started to enter the digital service business for FM. New digital service business opportunities exist when a project considers the life-cycle needs of customers instead of focusing only on the initial design and construction costs. (Leiringer et al., 2009)

The operation and maintenance costs of a commercial building over its life can be many times more than its design and construction costs (Lewis et al., 2010; Becerik-Gerber et al., 2012). Thus, it can be argued that the building owners, users, and facility managers should demand and be offered services that lower and optimize the life-cycle costs of buildings. These services should be digital to receive the benefits of quickly sharing and analyzing lots of data generated by smart sensors. Understanding the daily business of customers is crucial in developing digital services that support the business needs of the customers. Usually, the construction project parties are mainly interested in delivering projects on time and on budget. They are not necessarily interested in understanding the business needs of the customers, i.e., owners, end-users, and maintainers. This phenomenon of engaging in self-interested behavior and passing costs off to future project parties is called broken agency, also known as displaced agency (Henisz et al., 2012). The broken agency is typical in the project-based construction sector because each project phase has different project parties, decision makers, and values.

One way to understand and satisfy the needs of the customers is to create services with them (Blazevic and Lievens, 2008; Ford et al., 2012). However, more research is needed to understand how the building construction sector's parties can create digital services for FM (Becerik-Gerber et al., 2012). This paper addresses this research need by presenting a case study on the co-creation of a digital service with and for FM in the medical center construction project of the University of California, San Francisco (UCSF) at Mission Bay. The Medical Center has been operating since February 2015. The project was selected because a successful co-creation process took place during the construction phase of the project. The paper presents a framework for successful co-creation of digital services with and for FM in a construction project context.

ENABLING DIGITAL FM

Building owners tend to focus on the initial design and construction costs of a building, even though the operations and maintenance costs of a commercial building over its life-cycle are much higher than its design and construction costs (Becerik-Gerber et al., 2012). BIM data used during the design and construction phases of a project would be beneficial also during the operations and maintenance of the building. In order for FM to get the most benefit from BIM, it must be integrated into the existing computerized maintenance management system (CMMS) which the FM staff uses in their daily work. A comprehensive CMMS supports a variety of operational and maintenance tasks, such as the management of assets, work, contract, inventory, procurement, and workforce. (Lewis et al., 2010) A recent study concluded that in the future BIM data can be automatically transferred to the CMMS (Korpela et al., 2015).

It should be noted that the facilities operations and maintenance work do not only impact the owner's costs but also the performance of the building itself. Thus, it is important to understand how data entered into the BIM supports the operation and maintenance tasks. (Arnold, 2012) The integration of the CMMS and BIM has a lot of potential to reduce the life-cycle costs of operation and maintenance work. For example, in an emergency situation of a water leak, BIM can help locate the problem area quickly and identify shutoff valves. (Loveland and Paradis, 2013) BIM can also help the FM staff by providing information on product equipment, warranty, and maintenance (Becerik-Gerber et al., 2012).

A study conducted in 2010 revealed that the use of BIM in FM is still limited (Becerik-Gerber and Rice, 2010). Volk et al. (2014), argue this might be due to the low participation of FM in national and international BIM development and implementation efforts. There are also difficulties in interoperability between the CMMS and BIM. Some of these difficulties can be avoided by planning ahead. For example, parties can use the COBie (construction operations building information exchange) standard for entering BIM data that the FM needs. However, COBie needs to be introduced during the early phases of a project to ensure that the project parties will use it during the design and construction phases. (Loveland and Paradis, 2013; Korpela et al., 2015)

The use of COBie standard goes hand in hand with a BIM execution plan. A BIM execution plan defines the appropriate uses of BIM throughout the project lifecycle and communicates opportunities and responsibilities for project parties. Several ready-made BIM execution plans exist. For example, BuildingSMART alliance has been active in developing national BIM standards. Ideally, all parties agree to the use of the BIM execution plan in the project contracts.

Another approach to ensure that data entered into the BIM will support FM is to involve FM representatives - such as the facility manager, the head of maintenance, and the head of IT and telecommunications systems - in all phases of the construction project. These experienced FM representatives are able to provide critical first-hand knowledge that will support other project parties in their effort of satisfying the life-cycle needs of the building. For example, the FM representatives can provide information about how to best access certain pieces of equipment above the ceiling. (Loveland and Paradis, 2013) If maintenance access is poorly designed, the building will be more expensive and complicated to maintain. However, in practice project owners sometimes do not know who is going to operate and maintain the building. This hinders the involvement of FM during the construction project. Another challenge is that traditionally construction firms consider FM as the recipient of the end-product, and not as one of the value co-creators during the project. (Liu et al., 2014)

VALUE CO-CREATION IN A CONSTRUCTION PROJECT

Value co-creation is an approach to involve FM representatives and understand their business needs. Also, value co-creation is one of the most important antecedents of innovation (Ramaswamy, 2010). Co-creation is a process where personal interaction takes place and where meaningful knowledge between parties is shared. Thus, the co-creation process is reciprocal in nature: both the customer and the supplier receive value. (Grönroos, 2008) The role of the supplier is to produce the resources which the customer uses in his/her value creation process. The role of the customer is to manage the process of value creation. The supplier can influence the customer's process of value creation by coordinating its resources in various ways when interacting with the customer. Thus, the supplier can serve as a value facilitator and a co-creator of value, but not the main creator of value for the customer. (Grönroos and Ravald, 2011)

A recent study on innovation barriers in the construction sector concluded that customers should be involved as early as possible in the design and construction phases to facilitate innovation implementation at the project level (Wei and Lam, 2014). More value can be created by a collaborative effort between the customer and other construction project parties. This collaboration requires that the construction project parties interact with each other more frequently during the construction project. However, value co-creation has not yet been thoroughly studied in the construction context in order to understand how the construction project parties should interact. (Liu et al., 2014)

So far, research shows that a lack of adequate trust between the client and contractor reduces sufficient communication and hinders co-creation on construction projects (Liu et al., 2014). This poor communication endangers trust between the project parties. In construction projects, trust can be embedded in interpersonal, intra-firm, and inter-firm relationships. Usually in a construction project, the relationships are of the intra-firm type in the beginning of the project. During the execution of the project, the relationships become inter-firm and develop finally into interpersonal as the project proceeds. Interpersonal trust underlies all the three forms of trust, and thus should not be neglected in research efforts on trust in construction. (Ceric, 2015)

Research on co-creation in construction projects argues that "the quality and quantity of value co-creation are determined by the relationships and interactions between a client and construction firm" (Liu et al., 2014:126). The probable inhibitors of value co-creation in a construction project originate from goal incongruence and performance ambiguity. Goal incongruence refers to the different goals of the project parties, whereas the performance ambiguity refers to the inability of a project party to assess the performance of the other project parties. For example, low-performance ambiguity from the contractor's perspective means that the performance specification is detailed enough to know what is expected of the contractor. In this case, the clients know what they want from the project, and are able to communicate it in the contract. Low goal incongruence, on the other hand, means that the customer and the contractor can work collaboratively as they both share mutual goals. To minimize the inhibitors, the project parties should create a collaboration platform that encourages interaction and relationship building between the project parties. (Liu et al., 2014)

According to Prahalad and Ramaswamy (2004), the building blocks of value co-creation between a provider and its customers are dialogue, access, risk assessment, and transparency. These four attributes constitute the DART model of co-creation. *Dialogue* refers to communication between the parties and shared learning. Dialogue implies that the co-creation process involves social interaction. It is important that the parties have *access* to the tools and data in the design and production process. The provider should perform a *risk assessment* on the co-created service and inform the customers about all risks associated with them. Finally, *transparency* means that the provider informs the customers about the costs and profit margins of the co-created solutions. (Prahalad and Ramaswamy, 2004) The DART model has been developed in the business to consumer context, but the case study of this paper aims to test its efficacy in the context of a building construction project.

RESEARCH METHODOLOGY AND APPROACH

Next, we describe our research methodology and approach. First, we describe the context of our case study. After that, we describe the processes of data collection and data analysis.

Case Study Context

We conducted a case study on the co-creation of a digital service with and for the FM in the construction project of the UCSF Medical Center at Mission Bay in San Francisco. We aimed at understanding how a successful co-creation takes place. The unit of analysis was the collaborative activities between the FM team members and other project parties during the co-creation process. The researchers chose a case study strategy because it allowed the examination of the co-creation process in the project, which is a temporary phenomenon and difficult to separate from its context (Yin, 1989; Eisenhardt and Graebner, 2007).

The construction project of the Medical Center was a great success. The 1.5 billion dollar project was delivered on schedule and under budget. The Engineering News-Record selected the project as the best health care project in California (Blair, 2015) and also as the best of the best health care project (Blair, 2016). The project gained LEED (Leadership in Energy and Environmental Design) Gold certification. The design of the Medical Center started in August 2007, construction ended in August 2014, and the Center opened to the public in February 2015. The 878,000 square feet Medical Center is comprised of a 289-bed children's, women's and cancer hospital, outpatient building with a helipad, and an energy center. The delivery of the construction project resembled an Integrated Project Delivery (IPD) – often referred to as "IPD-ish" - where the project parties work as one team and make decisions collaboratively but do not share a relational contract (Ashcraft, 2012).

Building a hospital is a complex project and requires the expertise of several different parties from separate disciplines. The main project team consisted of a public owner organization, a construction management consultant, architect, and the general contractor. Altogether 29 organizations were involved in the project. The project included a joint financial incentive for better performance. Early in the project, the owner, and the general contractor decided to co-locate all project parties in a big trailer to ease the challenging coordination of collaborative work of the complex hospital construction project. The co-location of project parties provided an ideal collaboration platform for co-creation. At the beginning of the project, the project parties decided that BIM would be mainly used for coordinating mechanical, engineering and plumbing (MEP) design. This case of co-creation occurred between the FM team and MEP teams. From the FM's perspective, the Medical Center consists of 3,500 rooms which include the assets of mechanical, electrical, plumbing, fire protection, telecommunications data, and pneumatics. For example, a mechanical system includes assets, such as valves, pumps, fans, boilers, hot water tanks, and air conditioning equipment. Altogether, there are 38,000 assets, and each asset has seven attributes, such as description, location, manufacturer, and model number. ("Case study on UCSF Medical Center at Mission Bay", 2016) Thus, the operation and maintenance of those assets is not a trivial task but requires the use of CMMS. Recently, the UCSF Facilities Services started using Maximo, a CMMS product by IBM which consists of a module for asset management ("Asset Management Module", 2015).

Data Collection

Three researchers collected longitudinal data to understand how the FM team collaborated with the other project parties during the project and how that collaboration affected the co-creation process of the digital service. Multiple data sources were used to increase the validity of data (Yin, 1989): observation, interviews, and background archives. Observation took place at different project meetings held on-site and during the parties' daily work routine. The researchers took a passive observer role rather than an active role to minimize their impact on collaboration (Marshall and Rossman, 1995). The observation and interviews at the site allowed the identification of key interviewees and access to rich empirical data. The interviewees represented several organizations, and they were chosen using snowball sampling (Biernacki and Waldorf, 1981). Five interviewees did not allow the recording of the interview. The researchers also took photos to memorize the context later during data analysis. Background data from project documents stored in the database of the project were also examined.

Our data originates from three points of time: 2012, 2014, and 2016. In the fall of 2012, we studied the design and construction phases of the project. At that time, the project was constructing the exterior skin of the Medical Center. We stayed at the site for three weeks and observed the practices taking place between the project parties. We video-recorded eleven project meetings and conducted 41 interviews. We aimed at understanding how the project parties collaborated. In the spring of 2014, we studied the commissioning phase of the project for four weeks and conducted 35 interviews. We aimed to understand the effects of involving the FM team in the project. It was during this period that the digital service co-creation between the FM team and the MEP teams emerged from project interviews. In spring of 2016, we conducted seven in-depth follow-up interviews with the FM team during the operation and maintenance of the facility. We confirmed details of the co-creation process and observed the outcome of co-creation after project completion. Table 1 presents data collection methods and data.

Data Analysis Process

The interview data analysis followed the recommendations of Miles and Huberman (1994). First, the interviews were transcribed verbatim. Second, the transcriptions were read through to get a preliminary understanding of data collected. Then, the transcriptions were encoded twice and analyzed using qualitative data analysis software, Atlas.ti. The first analysis round included higher-level codes, such as FM, problems in the project, integrated way of working, development ideas, and project peculiarities. These codes emerged from data. The second analysis round focused mostly on the quotes marked with the code FM. Also, the four attributes of the DART model were used as codes. The researchers categorized the quotes into sub-codes, such as the needs of FM, problems faced by FM, collaboration with other disciplines, and benefits of involving FM in the project.

The rich data was analyzed using systematic combining (Dubois and Gadde, 2002b) and abductive scientific reasoning (Danermark et al., 2002) to understand the involvement of FM in the project and the co-creation process of the digital service. In this interpretive research, the analysis progressed as a continuous dialogue between the theoretical pre-understanding and empirical data collected at different points of time (Mantere and Ketokivi, 2013).

Table 1. Data collection methods and data collected in different phases of the project

Data collection method	**Construction phase in 2012**	**Commissioning phase in 2014**	**Operations phase in 2016**
Observation on site	- 10.9.-28.9.2012 - 11 meetings (~15 hours) - 40 pages of field notes	A tour at the nearly completed Medical Center on the 14th of May 2014	A tour at the operating Medical Center on the 5th of February 2016
Audio-recorded, semi-structured interviews	12.9.-28.9.2012 41 interviews (~1530 min): - 7 owners - 5 architects - 4 construction management consultants - 20 general contractors - 5 sub-contractors	16.4.-14.5.2014 36 interviews (~1050 min) - 6 owners - 6 architects - 2 construction management consultants - 6 general contractors - 15 sub-contractors - 1 fire marshal	5.2.-23.3.2016 7 interviews (~280 min): - 4 facilities engineers - 2 facilities managers - 1 facilities director
Archival documents	Organization charts, meeting minutes, communication plans, cost and scheduling plans, quality control plan, and BIM execution plan	A survey on positives and negatives of an IPD-collaborative approach, KPI data (submittals, RFIs, change orders), and Internet articles	Internet articles and interviews with construction professionals in journals, such as Healthcare Design Magazine and The Engineering News-Record

CASE: CO-CREATION OF A DIGITAL FM SERVICE

Next, we describe the case. First, we provide a short description of the co-creation process. After that, we present the case analysis on the enablers for successful co-creation. Finally, we provide two barriers for co-creating digital FM services.

The Co-creation Process

Three MEP sub-contractor companies were involved in the design and construction of the three buildings of the Medical Center. The sub-contractors had the contractual obligation to deliver a set of valve drawings, label the installed valves and deliver a valve matrix to the owner. The matrix lists each valve by the system, their location, and normal position. Traditionally, when the valve drawings are delivered to the FM team after project completion, the FM team spends a lot of time looking at drawings to interpret which service area the valve serves. Quickly finding the information on the spot can be critical in emergency situations such as a water leakage. The information is also needed during preventive maintenance tasks to ensure patients' safety. For example, when closing a valve, the FM team must be careful they do not accidentally turn off a patient's oxygen tube by mistake.

On one day during the construction phase of the Medical Center, one FM team member (a chief facilities engineer) started doing research on the Internet and found out that the valve matrix information could be printed into a quick response (QR) code. He envisioned that the MEP sub-contractors could put this QR code on each valve. When the FM team members would need information on a particular valve, they could scan and read the QR code with their mobile device to quickly access the needed information, such as the service areas of the valve. The idea of a digital FM service to quickly and easily access valve information was born.

The FM team member told the MEP sub-contractors about FM's need to quickly access valve information. The FM team and the MEP sub-contracts started to further develop the idea. The implementation of the idea required co-creation between the project parties, especially the FM team members, general contractor, and the MEP sub-contractors. The project contracts did not specify the creation of the digital FM service, so the project parties had to voluntarily give their working time to this collaborative effort without being directly compensated for it. The FM team provided a spreadsheet with all the required information needed in the QR codes. The sub-contractors printed their unique QR codes which they put on each medical gas and energy valve in all three buildings of the medical center. During the implementation process, the parties had to solve many technical details, such as what kind of a QR code sticker material would best last on a valve.

After the successful co-creation of the digital FM service, the FM team has used the service regularly in the maintenance work of the Medical Center. The team uses the service for training new facilities engineers to operate the facilities. The team also uses the service in emergency situations to quickly find critical information on the valves' service areas. Overall, the FM team considers the co-creation and its end-result successful:

> *"It [co-creation] was a great effort... It [QR code system] is helpful because it is a quick link to everything. It gives us more information and it works very well."* (FM team member in 2016)

The Processes of Successful Co-creation and Their Enablers

Next, based on the case analysis we describe three processes that were part of the successful co-creation. Also, we provide the enablers of those processes. The three processes were dialogue, trust building, and shared understanding creation.

Dialogue Process

A medical center has several end-user groups such as the FM representatives, medical staff (physicians, nurses, pharmacists, and clinical researchers), administrative staff, patients, and their relatives. The owner of the USCF Medical Center intentionally involved its different user groups during the design and construction of the center. FM was one of the most involved user groups.

The owner allocated four representatives from the FM group to join the co-located project team during the preconstruction and construction phases. Two individuals represented the management level of FM and the other two individuals represented the facility engineers. During preconstruction, the team consisted of one FM manager and one facility engineer. The following quotes show that the project parties considered discussions and interactions with the FM team critical in order to design and construct a medical center that is easy and cost-efficient to operate and maintain.

> *"In terms of FM integration, that [presence] was instrumental. We would never have had that kind of integration and input added at a point in time that we could actually do something about it. That was unique. It gives us great satisfaction to make sure that people that are going to use the building love the building, because if ... we don't make the end users happy, long term there's a lot more complaints from the users ... a painful process."* (Architect in 2012)

> *"The input of people that are actually going to be living with the solutions and the facilities folks and having them involved as early as, this is really helpful."* (MEP project manager in 2012)

> *"Lots of projects, health care side that you don't really have the facilities, people around that can give you an idea of what they actually need. As a designer, you carry lots of time, you get them your best solution, but that's not necessarily what they need."* (Mechanical designer in 2014)

> *"It is critical for facilities to be involved at preconstruction because so many decisions are being made in that phase. If facilities isn't at the table for those discussions, and suddenly we are at the construction, and we say that this won't work, then it is too late… if you don't see it built; you don't have the real understanding of what you need to do to keep it running."* (FM team member in 2016)

The role of the FM team was to bring the maintenance perspective into the project. For example, the team reviewed the BIM to ensure that FM had access to valves and variable air volume boxes. The reviews were estimated to resolve more than 250 access problems and saved about $2.5 million in prospective rework ("Case study on UCSF Medical Center at Mission Bay", 2016). During the construction phase, the FM team also did a number of factory acceptance testing for generators and transfer switches.

The FM team attended "daily huddle" meetings in the field and meetings with the owner, architect, and contractors. The FM team tried to follow the design and construction choices the project parties made, and suggest changes if the choices were not adequate from the FM's point of view. One of the FM team members (an MEP project manager) functioned as a liaison between the other project parties and the FM team. His role was to make sure that the FM team could review the design solutions made by the design team. He also helped the FM team and the contractor to collaboratively select the pieces of equipment. He describes his role in the following quote:

> *"The contractors are selecting different equipment, they want to know they have three prices and three pieces of equipment, we sit down and look at the advantages and disadvantages of the equipment because we need to maintain them. We are looking at actual equipment datasheets, and I just point the right people. Different questions come, and my role is to know who to involve."* (FM team member in 2016)

Another FM interviewee told that the inventor (a chief facilities engineer) of the digital FM service idea had both construction and FM experience which helped in the further development of the service. Also, the interviewee told that good personal skills help in getting people to work with you.

> *"He has been in [FM of] healthcare for over 20 years…and involved in construction. He has some excellent personal skills; he had an understanding of what it means to put something into the ceiling."* (FM team member in 2016)

Trust Building Process

When the FM team entered the pre-construction phase, the general contractor and all the sub-contractors were resistant to having the FM team in the project. They feared the FM team would complicate their project work by asking for changes. This fear led to an initial lack of trust between the FM team and the other project parties in the beginning of the project. For example, the FM team did not initially have access to project documentation, such as the designs, project's decision-making structure, meeting schedule, or meeting minutes.

Over time, the project parties started realizing the benefits of the FM team's presence, such as saving a tremendous amount of rework. Co-location and collaboration helped in building interpersonal trust between the parties. As a result, the FM team was given access to project documents. The following quotes describe how the general contractor started thinking how the FM team works and how to effectively collaborate with them which helped in building trust. The FM team also started to provide their view in a constructive manner, which helped to build trust.

> *"There has to be some degree of trust. That doesn't just come from, oh, I just met you; I trust you, we're great. That doesn't come through … some [contractual] agreement. There's got to be some work done. It requires a degree of understanding how people work, what those behaviors are and how to get people to effectively collaborate with one another. I do think the final product of the building is really good in part because the user input and facilities input."* (General contractor in 2014)

> *"By providing constructive, correct input and over time, you start to be more listened to. Your comments carry out a little bit more weight. We started to be trusted by the design team, and that was an important part. If you are able to build that trust as we brought up concerns, it was much easier for them. That didn't happen in the first year. It took one year to build the trust… The biggest part of building trust is that they realized that we aren't going away. You start building relationships with architects, consultants, and subs."* (FM team member in 2016)

Shared Understanding Creation Process

The FM team members and the project parties started to ask questions and learn from each other once a certain level of trust had been built. For example, the sub-contractors learned about the needs of the FM team, whereas the FM team learned about the different ways the contractor and MEP sub-contractors could meet those needs. The contractors taught the FM team to navigate in the BIM, and the FM team used the BIM to show the contractor where the tight spots for accessing pieces of equipment located. The following quotes show that a shared understanding between the FM team and other project parties about the needs of FM and contractors' ways of satisfying those needs started to be created as a result of learning from each other.

> *"I think a lot of times, the subs; they just don't understand how the building is run. [In this project,] the subs would come and talk to us, what you think about this, what do you think about that? At the end of the day, I think we agreed on a lot of things. Anyway, I think the long story is they started to understand the kinds of things we wanted."* (FM team member in 2012)

> *"We had owner buy-in was a big one because they had their staff here, their facility staff to help us make mechanical decisions. I loved it because when we know what they [FM team] like, it helps us design, and when they know what we're trying to do for them, it helps them understand what the hard parts are, what the tight spots are and what they might want to look at."* (Mechanical engineer sub-contractor in 2014)

Construction projects involve a lot of stress. One of the FM team members expressed that the participants need to possess certain personal traits and capabilities in order to be able to work collaboratively in a stressful environment. Participants need to have patience, be well-spoken, understand the collaboration process, and understand other project parties.

Barriers for Co-creating Digital FM Services

Two barriers to co-create digital FM services could be observed when analyzing the case. One of the barriers was the lack of financial compensation for co-creation opportunities that arise during the construction phase of the project. One of the three sub-contractors chose not to participate in the co-creation process because the project did not financially compensate for the additional effort required. The contracts did not have enough contingencies to compensate it.

The other barrier to co-create digital FM services, especially the full potential of using BIM for FM, was the lack of a BIM execution plan at the initial phases of design development. The information retrieved from the QR code could have been put into the BIM if a BIM execution plan had stated it. The FM team is now in the process of integrating the digital FM service with BIM and their CMMS. The project taught the owner and the FM team that it is critical to have a BIM execution plan early in the project to make sure that each project party knows what data to put into the BIM.

> *"Our biggest regret is not having a BIM execution plan in place at the beginning. When we came, BIM was built for construction coordination, for clash detection, for ease of construction. They didn't build the model for the operations folks down the road. If we*

would have had a BIM execution plan, we would have said hey with this little extra work you could help us a lot down the road." (FM team member in 2016)

"We did not emphasize facility management… We had not done enough research, and it was not marketed well enough about how you could make the model useful for operations." (Owner in 2012)

DISCUSSION AND CONCLUSIONS

Next, we discuss the DART model in the construction project context and refine it based on the case analysis. After that, we provide implications of the study and discuss future endeavors.

A Framework for Successful Co-creation with and for FM

The study aimed at understanding how a successful co-creation of a digital service for FM takes place in a construction project context. The literature on value co-creation suggests that co-creation is a suitable approach for engaging people in the collaborative effort of creating services. The literature also provided a DART (dialogue, access, risk assessment, and transparency) model of co-creation, which has been developed in the business to customer context. Next, we will discuss the four attributes of the DART model and analyze the model's efficacy in the construction project context based on the case analysis.

The project parties were early involved in the project and continuously co-located. This enabled a continuous dialogue between the FM team and other project parties. One of the FM team members functioned as a liaison between the other project parties and the FM team. The liaison was essential in ensuring that the FM team was given a chance to review and comment on design solutions from the FM's point of view. The study points out that the FM team members had both FM and construction experience which was considered necessary in communicating the FM's point of view to other project parties.

The continuous dialogue was essential in building good relationships. The FM team members provided their view and feedback in a constructive manner. This built trust between the FM team and other project parties. The project team gave the FM team access to project documentation, such as designs, the meeting schedules and meeting minutes, to help the FM team find the right meetings to attend and provide feedback on design solutions.

One of the FM team members was considered patient, well-spoken, collaborative, and able to understand the views of other project parties. Zhang and Fan (2013) call these attributes empathy skills. These skills helped in building shared understanding about the needs of FM and contractors' ways of satisfying those needs. This finding adds to the earlier discussion on co-creation in the construction project context by suggesting that the FM team members benefit from using empathy skills in building shared understanding with the other project parties. Also, the fact that the project parties were co-located and made decisions collaboratively provided an ideal platform for different project parties to learn about the needs of each other.

The co-creation of the digital FM service required interpersonal trust between the project parties. This finding seems to support the earlier finding made by Liu et al. (2014) that trust is an important ingredient of co-creation. The continuous dialogue and trust between the project parties seemed to contribute to the creation of a shared understanding of the needs of the FM team and the MEP sub-contractors' possible technical solutions to them. In the case study, an experienced FM team member expressed his need to quickly access valve information, whereas the MEP sub-contractors helped in the technical implementation of the digital FM service. For example, they provided their view on the risks of using certain types of QR code materials on valves. The general contractor informed the FM team about the probable costs generated when implementing the digital FM service. The shared understanding of the FM's needs and MEP's technical solutions to them seemed to boost the co-creation process between the MEP sub-contractors and the FM team members. These findings strengthen another finding made by Liu et al. (2014) that early contractor involvement is important for enabling co-creation in a construction project context. The findings also reinforce the view that the customer, in this case, the FM team, needs to be early involved in the project to facilitate the implementation of the co-created service (Loveland and Paradis, 2013; Wei and Lam, 2014).

In summary, the study finds that the four attributes of the DART model are present in the co-creation process of a construction project. In the study, (1) *dialogue* took place between the FM team and other project parties. The other project parties gave FM (2) *access* to project documentation, such as designs, the project's decision-making structure, and meeting schedule and minutes. (3) *Risk assessment* occurred when the teams provided estimates on the costs of the digital service. The FM team received (4) *transparency* when other teams communicated the actual costs of the digital FM service. However, this study refines DART model based on the case analysis. This study suggests that DART model's *dialogue* is one of the three processes of successful co-creation of digital services with and for FM in the construction project context. The other two processes of co-creation are *trust building* and *the creation of shared understanding about the FM's needs and MEP sub-contractors technical solutions to them*. Dialogue process starts first and continues throughout the co-creation. Trust building starts sometime after the dialogue process has started and also continues until the end of co-creation. DART model's *access* is one of the enabling factors for trust building. Shared understanding creation starts sometime after the trust building has started and continues until the end of co-creation. DART model's *risk assessment* and *transparency* are enabling factors for the creation of shared understanding. As a result, we provide a framework that includes three processes and their enabling factors for successful co-creation of digital FM services in the construction project context. By successful we mean that the co-created digital service meets the needs of the FM team. (Figure 1)

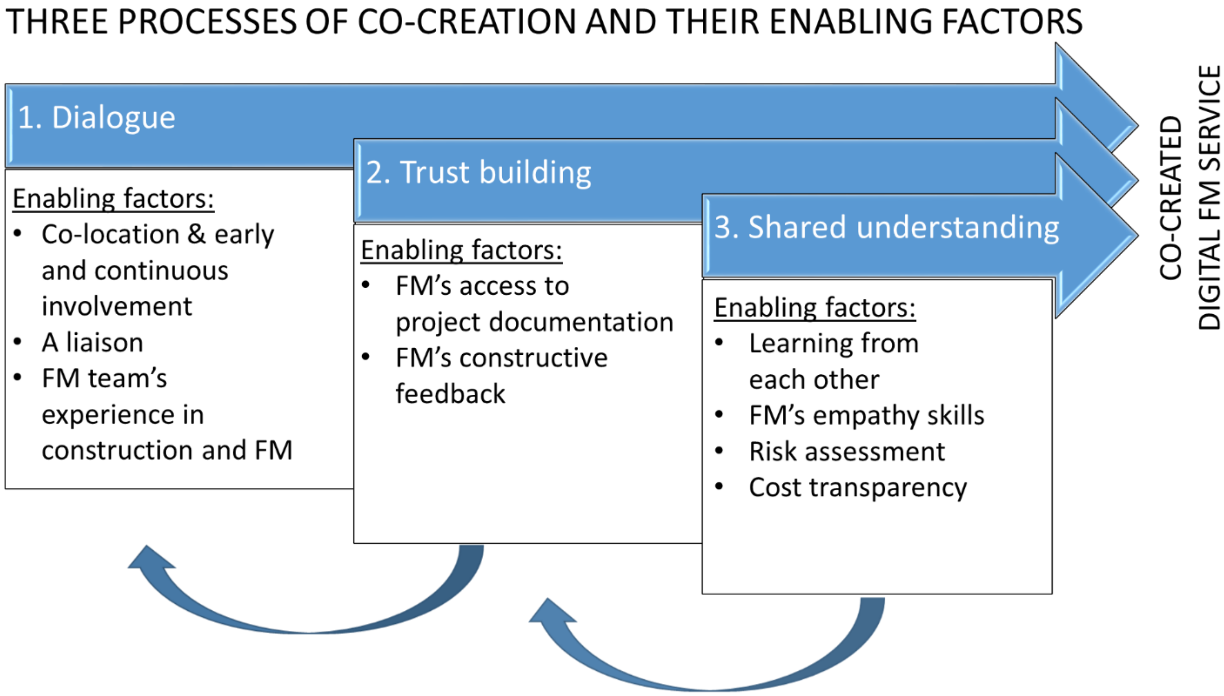

Figure 1. A framework for successful co-creation of digital services with and for FM.

Implications and Future Research Endeavors

This study contributes to the theoretical discussion on co-creation by testing the efficacy of the DART model in the construction project context. As a result, by building on the DART model, the study provides a framework for successful co-creation of digital services with and for FM in the construction project context. The study claims co-creation is not only about the four attributes of the DART model, but co-creation includes three processes: dialogue, trust building, and shared understanding creation. Dialogue and trust creation precede the creation of shared understanding about the business needs of customers and the providers' ways to satisfy them. However, further research is needed to confirm the findings of this single case study. The study implies that the FM team members should have both construction and FM experience to ease the dialogue with the other project parties. In addition, empathy skills help the FM team to build trust with the other project parties.

Regardless of the continuous dialogue and trust built between the FM team and the service providers, one of the service providers could not take part in the co-creation process. The reason was that the contracts did not have enough contingencies to compensate for the additional working hours required by co-creation. Hence, one implication from this study is that it would be beneficial to have enough contingencies in the contract to allow co-creation also financially. Prior research has suggested that an integrated form of an agreement (IFOA) with agile cost shifting creates a mechanism to implement systemic innovations like the digital FM service that cross company boundaries (Hall and Lehtinen, 2015). Future research could study whether an IFOA contract would provide the incentive and the mechanisms necessary to reduce the cost risk burden for project parties to implement systemic innovations with the potential to dramatically decrease life cycle costs.

The limitation of this study is that it only presents a single case study of a successful co-creation. In future work, researchers could compare findings from this case study with findings from another case study where either a successful or unsuccessful co-creation occurs.

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