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Explored Challenges of Adoption and Use of Green Digital Tools in Facility Management

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Abstract. It is argued that a building contributes to the environmental impact at the largest extent during operation and maintenance (O&M) phase and more focus should be put on decreasing the existing building stock's ecological footprint. To facilitate the environmental work, Green digital tools (GDT), for instance BIM can be used. These tools exist but are not widely adopted. Therefore, the aim of this research was to identify challenges hindering adoption and use of digital tools dealing with environmental impact in FM. Qualitative interviews were conducted with FM personnel. Data were analyzed with a literature study and the theory about Diffusion of Innovation. Identified challenges could be sorted into five different barriers namely 1) Technological 2) Economical 3) Legal and contractual 4) Organizational and 5) Knowledge. Important findings include the need for improved information integration, increased awareness of GDT and networking between stakeholders. Further findings were the issue of high cyber-security and unrealized economic value of GDTs. Most of the barriers are closely interlinked, however, organizational barriers were considered the most critical in influencing adoption and use of GDTs. Most FM companies are highly digitized but not using BIM and still find it having too many critical issues to be considered a good investment.

Keywords: BIM, Facility Management, green digital tools, adoption of innovative technologies

1 Introduction

Given the importance of sustainable development and climate change, the Architecture, Engineering & Construction (AEC) industry, just like other sectors, must overcome several challenges to reduce greenhouse gas (GHG) emissions and decrease its environmental footprint (Lu, Wu, Chang & Li, 2017). Existing buildings make up 98% of the building-market and it can therefore be argued that operation and maintenance (O&M) phases contribute to environmental impact at the largest extent (Howard, 2017). Several researchers (Whong & Zhou, 2015; Ghaffarianhoseini, Zhang, Nwadigo, Ghaffarianhoseini, Naismith, Tookey & Raahemifar, 2017a) agree that this phase contributes at the largest extent to the environmental impact and claim that more focus should be put on the post-construction life stages of a building. To facilitate environmental work, more focus should be allocated on benefits and obstacles of using digital technologies, for instance Building Information Management (BIM), throughout the lifecycle. There should also be further explorations about the gap between development and use of these tools (Lu et al., 2017). As the Global Sustainable Development Report highlighted, *"Many technologies already exist, but their deployment [...] is lagging behind due to many technical, economic, institutional, legal and behavioral barriers."* (United Nations, 2016, p. 46).

The facility management (FM) is lagging behind design and construction concerning the adoption and use of BIM. Therefore, research has started shifting its focus towards the O&M phase to explore benefits of using BIM for environmental assessments throughout the whole life-cycle of the building (Ghaffarianhoseini, A.; Tookey, J.; Ghaffarianhoseini, A.; Naismith, N.; Azhar, S.; Efimova, O.; Raahemifar, K. 2017b). Lu et al., (2017) believe more focus is needed on mapping practitioners' needs. Since much of the new technology and frameworks today get stuck in a primary phase where they are developed for a certain project but afterwards tend to have little or no use for the engineering industry (Issa & Anumba, 2007). The FM sector and BIM vendors have also started recognizing environmental values of a BIM-based FM (Lu et al., 2017). FM practice is already highly digitalized as a consequence of the advanced building automation systems for monitoring energy consumption, still there are benefits of developing methods for further asset management tasks, for example to connect inbuilt material inventories with environmental databases with the help of BIM models (Talamo, 2016).

The Diffusion of Innovation theory by Rogers E. M. (2003) is widely used in academic articles. To understand the diffusion of digital innovations in construction industry, several researchers focusses on a specific area, such as the interfaces between the firm and the industry, the firm and its clients, or the firm and the technology providers

(Shibeika & Harty, 2015). Others emphasizes the importance of the evolving relationships between the stakeholders (Lindgren, 2016) or measure the time lag between awareness and first use of BIM (Gledson & Greenwood, 2017).

Examining literature concerning digital tools and ecological sustainability produces results concerning innovative technology or proposed BIM frameworks carried out during case studies. Fewer studies are carried out mapping the FM practitioners' perception and their acceptance of digital technologies. Gao and Pishdad-Bozorgi (2019) states that examined case-studies are assumed to be generalizable to the entire O&M phase, but it is important to map underlying FM principles to understand benefits of digital tools. Especially towards BIM adoption, there is no one-size-fits-all solution. There is a need to map FM demands on data delivery and identifying areas for improvement (Gao & Pishdad-Bozorgi, 2019). Theories and studies already exist to explain adoption of innovation in general, however, it is still important to find the reasons why or why not FM practitioner adopt innovative technologies. Gao and Pishdad-Bozorgi argues that there is a question about what creates the gap between available technologies and using them in the FM practice. Therefore, the aim of this research is to identify challenges hindering adoption and use of digital tools dealing with environmental impact in FM.

The aim is achieved by qualitative interviews with FM practitioners. The rest of the paper is structured as follows, *chapter 2* presents a summary of the Diffusion of Innovations theory (DoI) and a literature study concerning adoption barriers, *chapter 3* describes the method of the study in detail, *chapter 4* summarizes respondents reasoning about challenges in adopting and using Green Digital Tools, this is followed by discussion in *chapter 5* and lastly, conclusions in *chapter 6*. From this point on the term *Green Digital Tools* (GDT) will be used as an umbrella term for digital tools in FM enhancing environmental sustainability. In literature, other terms are used including Green Building Technologies, FM enabled BIM, BIM and Green BIM. Due to the special complexity in BIM for FM, BIM will also be named exclusively in this report.

2 Theoretical Framework

The first part of this chapter presents a summary of the Diffusion of Innovations theory (DoI). DoI aims to explain how innovations are adopted. 2.2 presents a summary of identified barriers from a literature study and is sorted by the authors into five categories 1) Technological barriers, 2) Economical barriers, 3) Legal and Contractual barriers, 4) Organizational barriers and 5) Knowledge related barriers.

2.1 Diffusion of Innovations Theory

Early studies of Diffusion of Innovations theory explored many different types of innovations and focused on personal innovation adoption behavior. Subsequent developments expanded this effort to examine the diffusion of more complex technological innovations in firms. Recent research in diffusion *is "concerned with innovation processes which unfold not just within firms, but also across projects and markets"* (Shibeika & Harty, 2015, p. 454) enabling the authors of this study to investigate overall trends in the industry.

Everett M. Rogers (2003) developed the Diffusion of Innovations (DoI) theory that gives an explanation of the spreading of new ideas and technology, moreover, provides a categorization of the adopters, namely the innovators, early adopters, early majority, late majority, and laggards as it can be seen on Figure 1 in Appendix. Rogers defines diffusion as *"the process by which an innovation is communicated through certain channels over time among the members of a social system"* (Ibid. p.11). The innovation must reach the *critical mass*, i.e. *"the point at which enough individuals in a system have adopted an innovation, so that its further rate of adoption becomes self-sustaining"* (Ibid. p.344).

Rogers claims that the social system – defined *as "a set of interrelated units that are engaged in joint problem solving"* (Ibid. p.305) - influences diffusion through the different types of innovation-decisions and distinguishes three main form of them, namely optional, (made by an individual) collective, (made by consensus) and authority (made by relatively few individuals who possess power, status or technical expertise).

An additional distinguishing feature in the theory is *homophily* and *heterophily* that are defined *as "the degree to which two or more individuals who interact are similar respective different in certain attributes, such as beliefs, education, socioeconomic status and the like."* (Ibid. p.305) Rogers claims that communication between homophilous parties usually results in more effective interaction.

Perceived attributes of innovation

Rogers describes five attributes of innovation: relative advantage, compatibility, complexity, trialability and observability and acknowledges that the perceived attributes of innovation influence its rate of adoption.

Relative advantage *is "the degree to which an innovation is perceived as being better than the idea it supersedes"* (Ibid. p.229). Rogers emphasizes the importance of the opinion of the adopter rather than the actual benefit of the innovation and claims that there is a correlation between those two factors. As he states, *"the greater the perceived relative advantage of an innovation, the more rapid its rate of adoption will be"* (Ibid. p.15).

Compatibility *is "the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters"* (Ibid. p.240). Innovations with higher perceived compatibility have a more rapid rate of adoption.

Complexity is *"the degree to which an innovation is perceived as relatively difficult to understand and use"* (Ibid. p.257). This attribute is negatively related to the rate of adoption because more complex innovations require the adopter to develop new skills that may take some time.

Trialability is *"the degree to which an innovation may be experimented with on a limited basis"* (Ibid. p.258). Rogers argues that divisible innovations have a more rapid adoption rate because a trial on a partial basis can reduce uncertainty. Trying a novelty may involve re-invention, the process during which an invention is changed or modified to meet the adopter's requirement.

Observability is *"the degree to which the results of an innovation are visible to others"* (Ibid. p.258). Roger concedes that this attribute is positively related to the rate of adoption and regarding technological innovations demonstrates that possessing less observability the software component has a slower adoption rate compared to the hardware component.

2.2 Barriers to Adoption and Use of Green Digital Tools

Today, much emphasis is placed on improving the handover to FM, however, only achieving efficient handover of information doesn't guarantee that information is utilized in a resourceful manner. Another trend today is through the help of GDT, for instance BIM, achieve lower energy consumption during O&M phase (Gerrish et al., 2017). Ghaffarianhoseini et al. (2017b) mentions some use-cases for GDTs like BIM for existing buildings including FM activities, as-built renders, documentation and tracking of information, quality controls, monitoring and assessment. BIM could also be utilized in energy and emergency management and to retrofit planning. One great benefit of having a unity in the information flow throughout the entire life cycle is enhanced quality of information, resulting in better possibilities to make informed decision later during the building lifecycle (Ghaffarianhoseini et al., 2017b). Despite these advantages, challenging barriers still exist in the adoption and use of GDT.

Technological Barriers

A technological barrier hindering the adoption and use of GDTs in FM include the lack of suitable tools (Whong & Zhou, 2015). Lack of suitable tools can be divided into lack of databases, insufficient labeling programs and certifications, there is also a lack of reliable suppliers of GDT (Darko et al., 2017). The adoption and use of GDT is dependent on reliable and user-friendly tools and uncomplicated models (Wong & Zhou, 2015). Among FM practitioners it is important to determine which tools are most suitable for them (Pishdad-Bozorgi, Gao, Eastman, & Self, 2018). Another issue is the need for continuous model maintenance during the building life cycle in order to always keep models updated (Volk, Stengel & Schultmann, 2014), (Dixit, Venkatraj, Ostadalimakhmalbaf, Pariafsai & Lavy, 2019).

The long lifetime of buildings together with the also long adoption time of technologies contribute to complexity in following the outpacing of new GDTs and adopting them to existing buildings (Volk et al., 2014). This can result in interoperability issues between tools (Wong & Zhou, 2015), (Pärn, Edwards & Sing, 2017). Interoperability and compatibility are considered as critical barriers (Whong & Zhou, 2015), (Dixit, et al., 2019). In FM, interoperability problems most often occur between building atomization, BIM and other digital FM tools as well as incompatible file formats become a barrier when adopting and using GDT (Dixit, et al., 2019). There is a need for improved export functions in programs because data exchange between programs are too complex (Sanhudo, Ramos, Martins, Almeida, Barreira, Simões & Cardoso, 2018). A solution could be standardizations of data exchange schemes (Pärn, et al., 2017). Another issue is the use of multiple information sources, such as historical data, data from sensors, inspection records and blueprints (Pärn, et al., 2017). Handling all these data separately are time-consuming and prone to human error and a solution would be to develop systematic processes to capture information (Pishdad-Bozorgi et al., 2018). Gao and Pishdad-Bozorgi (2019) states that the most common technological issue in FM is information accessibility since FM practitioners have more difficult to easy access information of different kind. Gao and Pishdad-Bozorgi continue explaining that another issue concerns the archiving of relevant information instead of utilizing it.

Another important aspect is cyber security of GDTs (Lu et al., 2017). Storing data electronically makes it possible for hackers to access sensible information, together with improper information capture these barriers are substantial to solve in order to achieve a widespread adoption of GDTs (Dixit, et al., 2019).

Economic Barriers

The significance of the economic concerns in the AEC industry is widely recognized in the literature (Isaksson & Linderoth, 2018). High market prices and long pay-back periods of GDT are crucial barriers to the adoption (Darko et al., 2017). Likewise, cost of software licenses hindering the use of GDT in sustainable FM practice (Whong & Zhou, 2015), (Gerrish et al., 2017) and both the value and the actual financial benefit needs to be established for GDT, in this case BIM, to be adopted by FM (Pishdad-Bozorgi et al., 2018).

Beyond the abovementioned direct economic impacts, there are some indirect financial aspects described in the literature, such as costs connected to information management and training (Dixit, et al., 2019). An additional issue is uncertainties and risk**s** connected to adoption of new GDT (Darko et al., 2017). The economic risks of implementing GDT are tightly connected to the adoption and use of innovative tools and can cause project delay**s** due to the complex and time-consuming nature of their adoption (Ghaffarianhoseini et al., 2017b).

Legal and Contractual Barriers

Intellectual property is a main issue in adoption and use of GDT. This can be further sorted into licensing issues, complex liability of errors made in models with joint authorship and issues concerning ownership of design and data (Ghaffarianhoseini et al., 2017b). The questions of who is responsible for the accuracy of data and who is the owner of the BIM model are two factors hindering the adoption and use of GDTs (Lu et al., 2017), (Dixit, et al., 2019). This is specially a problem for the FM since information management is not as developed in operational phase as in other phases (Gerrish et al., 2017). Confusion about model ownership and data responsibility together with lack of standards and level of development can obstruct the adoption of BIM and create reduced cyber security and user confidence (Volk et al., 2014). Another issue is data privacy among stakeholders (Dixit, et al., 2019).

In order to reach a higher level of adoption and use of GDTs there is a need of government support and initiatives. Leaders need to realize the importance of GDT. There is also a need for more codes and regulations connected to GDT (Darko et al., 2017).

Organizational Barriers

One of the key issues connected to the low uptake of GDT is considered being organizational ones (Ghaffarianhoseini et al., 2017b). A possible reason can be the conservative nature of the AEC industry (Issa & Anumba, 2007) or the resistance to change old workways among practitioners (Lu et al., 2017) (Aziz, Nawawi, & Ariff, 2016) together with a distrust about GDT (Darko et al., 2017).

Architects and engineers are the largest group using BIM, only a minority of facility managers are using BIM in any way (Ghaffarianhoseini et al., 2017b). Different standards and protocols are used by the diverse stakeholders, which can also act as a barrier for organizations when implementing BIM, despite it proved to be valuable in assisting energy calculations and conducting carbon footprint assessments by reducing cost and time needed (Olawumi, 2019). The different commitment and interest of project stakeholders also makes the adoption and use of digital GDT more difficult (Lu et al., 2017) because conflicts of interests often arise among project participants (Darko et al., 2017). An additional obstacle is the rigid requirements of the certificate authority to take into consideration when applying green building certifications (Darko et al., 2017) but also the lack of interest in green innovations in construction projects can lead to low market and client demands (Dixit, et al., 2019).

Even though there exist some guidelines to help divide responsibility among project stakeholders, the collaboration issue is still one of the main ones regarding the implementation of GDTs (Chong, Lee & Wang, 2017). There is a consensus in academia that clear BIM workflows (Dixit, et al., 2019), more detailed guidelines, metrics and necessary parameters should be elaborated further (Pishdad-Bozorgi et al., 2018). There is a need for established standards and procedures (Pärn, et al., 2017) that could lead to better communication and coordination from early design phases through handover to O&M phases (Gerrish et al., 2017).

Furthermore, the lack of promotion of GDT (Darko et al., 2017) together with still unperceived benefits of digital tools in FM practice (Edirisinghe, R.; London, K. A.; Kalutara, P.; Aranda-Mena, G., 2017) form barriers for a wide adoption of novel digital technologies.

Knowledge Barriers

Researcher can tend to investigate scientifically interesting issues and not industrial grounded needs (Issa & Anumba, 2007) resulting in lack of a clear purpose in how GDTs should be used which hinder the adoptability of GDTs (Gerrish et al., 2017). The lack of knowledge among FM practitioners contributes to the low adoption rate of for instance BIM tools despite the growing understanding among scholars of GDTs and their potential in enhancing environmental sustainability (Wong and Zhou, 2015). Aziz et al. (2016) consider a lack of knowledge about GDTs among practitioners in the building industry. The limited knowledge at field level contributes to the low uptake of GDTs and therefore its full potential is still to be discovered (Wong & Zhou, 2015).

There is a lack of reliable research and education in how to use green building technologies in order to achieve greener buildings and this combined with the practitioners' unfamiliarity with GDT results in low awareness of these tools and their benefits (Darko et al., 2017). Pärn et al. consider that the rapid outpacing and developing of technology is causing trouble in training personnel to keep up to date with the latest tools. Project clients need to have a higher understanding about which semantic information are required during the buildings life cycle to reach a higher demand and supply alignment of FM data. This can be solved by more education in the subject and better management of knowledge (Pärn, et al., 2017). More demonstration projects could also help the learning process and increase awareness of GDTs (Darko et al., 2017).

Gerrish et al. emphasize the importance of reaching balance in the amount of information provided from design to FM. Too little information results in reduced usability, too much information on the other hand is a growing problem among BIM adopters, operators need extensive knowledge and experience in extracting and sorting among all that information (Gerrish et al., 2017). Therefore, there is a need to identify which FM information should be included in the BIM tools. Data in the BIM tools are collected throughout the life cycle, and project teams should therefore early on define the information needed to make the tool useful for FM (Pishdad-Bozorgi et al., 2018).

An explanation for the low adoption and use of state-of-the-art technology could be a resistance in letting others closely examine the technology to find flaws, furthermore researcher might have exaggerated the capabilities of the technology and minimized limits of it. Another reason can be improper testing of software at field level and the lack of ability among commercial vendors to bridge the gap between theory and practice (Issa & Anumba, 2007). Gerrish et al. explains that in the academia, it is possible to manipulate variables crucial for FM practice, therefore the examples and cases provided in research has limited feasibility among practitioners. The slow adoption of technologies like BIM proves that there still exist important barriers to overcome among practitioners (Gerrish et al., 2017). More focus is necessary on collaborating with practitioners and scholars in developing GDTs, for example BIM, to decrease carbon and greenhouse gases throughout the building lifecycle (Whong & Zhou 2015).

3 Method

The research method for this study is a qualitative approach. The reason behind using qualitative method and interviews are mainly to reach in-depth reasoning from practitioners. Both connected to which challenges they consider influencing the adoption and use of GDT but also to get well argued thoughts about demands concerning environmental data handling. As the main goal of this exploratory research is gathering ideas and gaining insights into the diffusion of green digital tools in innovative FM firms rather than generalizing from the sample to the broader population, a non-probability sampling method and semi-structured interview technique are chosen. As Williamson (2002) states, *"semi-structured interviews allow users to articulate their specific concerns and needs"* (p. 243) and *"complex responses are more likely because explanation and clarification can be provided to the respondent"* (p. 244).

Companies are sampled by comparing members from two Swedish national alliances. First a national alliance inclined to disseminate and encourage the use of BIM and digital technologies in the building sector among different kind of companies in the project lifecycle. The alliance was founded in 2014 and is driven by the building sector with almost 200 companies as members. The second alliance is a national alliance focusing on enhancing ecological sustainability in the building sector, members in this alliance are also firms working in different phases of the building lifecycle. This alliance is a Swedish part of a global alliance and was founded in 2011, today more than 300 companies are members. Five FM-companies which are members in both alliances are chosen for this study. From the companies the "snowball sampling" is applied to find respondents with knowledge and experience from diverse areas like IT, FM and sustainability. In order of mirror the sample with FM reality, different number of respondents are chosen from the company depending on the size of it. Therefore, company A, the largest, has five respondents and company B and C has one respondent. Company E is considered being a good example of a company in the lead of digitalization and therefore two respondents are chosen. To get an outside perspective of aspects and FM's reasoning, a consultant company is involved. This company is also a member of both alliances and the respondents from the company have extensive knowledge of GDTs and FM.

Limitations of the investigation are only including Swedish circumstances, focus on companies in the lead of both digital and environmental work and focus solely on FM.

3.1 The Companies

Company A owns around 1.5 million square meters, mostly commercial buildings like offices. From this company five respondents are chosen, working both as managers, with environment, with IT and as facility managers.

Company B owns around 400 thousand square meters social properties like schools. From this company one respondent responsible for digitalization is chosen.

Company C owns around one million square meters social property with high security demands. At this company one property manager is chosen.

Company D owns around 2.5 million square meters mostly commercial buildings like offices. From this company two respondents are chosen, one working with IT and one property manager.

Company E owns around 160 thousand square meters social properties both with high security but also for education. From this company two respondents are chosen working as property manager and one facility manager.

Company F is a larger consultant company with great knowledge about environmental impact of the building industry and digital tools, two respondents are chosen, one working with IT and one with FM.

Table 1. List of Respondents

No.	Code	Respondent's role	Role code 0=consultant,1=FM, 2=environment, 3=IT,	Level code 1=strategic, 2=tactic, 3=operative	Length of interview	Experience (years)
1	A1	Property manager	1	2	30 min	18
2	A2	IT specialist	3	2	30 min	7
3	A3	Technical manager	1	3	20 min	1
4	A4	Project manager	1	2	20 min	10
5	A5	Sustainability manager	2	1	50 min	7
6	B1	IT & digitalization director	3	1	40 min	8
7	C1	Property manager	1	1	30 min	4
8	D1	Property manager	1	2	50 min	12
9	D2	Technical R&D director	3	1	40 min	3
10	E1	Facility manager	1	1	30 min	5
11	E2	Property manager	3	1	30 min	20
12	F1	Consultant	0	1	40 min	4
13	F2	Consultant	0	1	30 min	8

3.2 Data Collection

Data are collected by semi structured interviews with respondents at different professions like high and middle level managers, facility managers and experts at environmental work and digitalization. They are all asked the same questions divided into three categories including individual experience, environmental aspects of the company and lastly GDTs for instance BIM. To achieve somewhat of an outside perspective two consultants working with GDTs and FM are also interviewed. One with experience of GDTs is specifically asked about usage of GDTs in FM and one with experience of FM is asked about challenges influencing adoption and use of GDTs in FM.

3.3 Analytical Process

Thematic analysis is used through cross-examining the data from respondents reasoning with aspects from literature. The purpose of the thematic analysis is to identify and categorize aspects influencing adoption and use of

GDTs such as BIM. Empirical data are analyzed firstly by identifying existing aspects which influence adoption and use of GDTs from practitioners' point of view with barriers identified from a literature study. Secondly, by explaining experiences from practitioners concerning adoption and use of GDTs with the Diffusion of Innovation theory by Everett M. Rogers.

Themes in this paper are identified from literature study and are grouped as *Technological, Economical, Legal/Contractual, Organizational and Knowledge* based on the work of Dixit et al. (2019) and Volk et al. (2014). Scientific papers on sustainability frequently use the triple bottom lines of the topic as categories, namely the ecological, economic and social factors. On the other hand, literature in AEC often uses the different lifecycle phases of a building for grouping the elements while scientific articles on BIM usually categorize different BIM functions such as visualization, quantity take off or simulation. In this study, five main groups of difficulty areas are created to smooth over the differences of communication used by different disciplines. Furthermore, three components from Diffusion of Innovation (DoI) theory, *the attributes of innovation, the social system and the characteristics of the innovation-decision* are used for the analysis. Additionally, themes are derived from the empirical data to include benefits of working with environmental issues and FM's demands on GDT to give a needled explanation of driving forces in the building industry today and to further give a stronger summary of what attributes GDT need in order to be adopted in FM.

4 Adoption and Use of Green Digital Tools

In this chapter identified barriers as perceived of respondents from the data collection will be presented, divided into the same five categories as in chapter 2, 1) Technological barriers, 2) Economical barriers, 3) Legal and Contractual barriers, 4) Organizational barriers and 5) Knowledge related barriers. Under some of the barriers, attributes from DoI are presented, connected to experience and reasoning from respondents. 4.1 will describe what drives environmental work and how digitalization relates to those aspects and 4.7 gives a sharper summary of demands FM have on GDT.

4.1 Benefits Working with Environmental Aspects

Initiatives to continue developing new ways of working with- and taking more consideration to environmental aspects could be explained by digital trends in society and increased knowledge about global warming. A1 and D2 say that working with environmental factors has become more like "basic hygiene demands" since society has become more aware about climate change. F2 considers that both digital tools and environmental aspects are social trends and enhances each other.

A1, A4, A5, E1 and E2 consider a driving force behind environmental work being internal values. There is a desire to leave as little ecological footprint as possible. According to A5, the company becomes an attractive choice for customers by working with environmental factors and there are economic benefits from working with environmental factors. E1, E2, D1, D2 and A4 say environmental work makes it easier to get funding's, green financing and green bonds. B1 and C1 say economy and environment goes hand in hand and there are only upsides from working with the environment. Trends in society and regulations also affect the work. D1 and D2 agrees that working with the environment gives economic benefits, for instance more effective operation, lower rent and higher market value. Not working with the environment can cause loss of competitive advantages. Working with clear goals are important otherwise environmental work could become green washing. D1 and D2 further states more organizations should work together to solve climate change. On the other hand, E1 and E2 explain company E's driving force is mostly based on internal values and they do not see economic benefits by working with environmental factors. Instead, they emphasize the importance to have rental contracts with clear environmental goals since rental contacts can run for a long time. However, even though there are initiatives to develop new ways of working there are still challenges to adopt and use GDTs, including the following barriers:

4.2 Technological Barriers

Of the technological barriers listed from literature, most of the respondents agree that integration like interoperability and compatibility are important in the adoption and use of technologies. Many respondents agree that lack of integration results in "information silos". To enhance adoption and use of GDTs, cross-integrate information from multiple sources are important and will give richer information flows. D1 sees a barrier that different stakeholders are using different systems which lower possibilities to integrate information. A1 and B1 also consider the different information sources as problematic.

A1 thinks the process to certificate buildings is too complicated and takes too much time. Common for all companies is that they take energy, materials and carbon dioxide-emissions into consideration in their work. F1 stated that even though a building is certificated it does not mean it is ecological sustainable but rather that environmental information exists and is gathered about the building. A5 doesn't consider LCA methods being reliable and speaks about how easy it is to manipulate LCA values. B1 states that company B uses sensors to gather environmental data. B1 further states that it's more complex working with existing buildings when it comes to environmental aspects, for new constructions established standards can be used.

Some participants (A1, A4, B1, C1 & D1) consider the outpacing of GDTs (in this case BIM) being rapid, the change of software is frequent and have much shorter lifetime than a building, which causes trouble in adopting tools for the whole building stock. D1 argues though that tools can be developed during time and can always be improved whilst implemented. Regarding BIM technology, the consultants (F1 &F2) had different opinions about how it should be adopted. F2 suggested using step-by-step method and work merely with data actually needed, F1 recommended collecting as much information as possible to maintain the possibility of a later utilization. A constant question among all FM respondents is to find reliable and user-friendly tools.

When asked about what they do with information they receive from the project phase, A3, A4, A5, C1 , E1 and E2 say their companies do not use data after they receive it which confirms F2's suspicion that information in FM are archived rather than utilized. Updating the received information is difficult and improper information capture is also a problem among respondents. Respondents from company D uses a non-BIM digital tool to control environmental aspects. The data is verified monthly but updating can be difficult. There is a need for more standards related to procedures when collecting and updating data. Respondents in company F consider it is important to make archived data accessible.

When asked about BIM adoption, many respondents (A1, A2, C1, E1 & E2) state that cyber security of tools and databases are important. Especially for FM companies with rental contracts for facilities with high security and privacy. E1 and E2 explain that Company E uses databases to maintain control over materials but have problems about storing information due to high demands on security. Data systems need to have high security so no one can hack them. The forthcoming regulations about data security from the Swedish government contributes further to complexity concerning handling sensitive data. Some (A4, E1 & E2) consider BIM needing too much model maintenance to become an efficient tool.

Looking to *relative advantage* from DoI, green BIM technology is regarded as an instrument for construction planning tasks rather than a support for data handling and controlling in O&M activities (A1, A4, A5, B1, C1, D1, D2, E1, E2, F1, F2), which means that its advantage is not realized. Concerning *compatibility*, the experts (A1, A2, A3, A4, A5, B1, C1, D1, D2, E1, F1, F2) often expressed their unpleasant experiences with quickly changing technologies and administrative requirements causing trouble to personnel to find the needed piece of information in the archives and claimed that "*sometimes it is more convenient to make a new inventory or assessment than to find the old documentation*". In other words, many experienced FM practitioners consider data losses as necessity in the light of the building's long lifecycle versus the rapid technological and administrative development.

4.3 Economical Barriers

Finding the economic value of investing in new digital tools is considered being most important according to A4, A5, B1, C1, D2, E1, E2 and F1. C1 states the need for more personnel resources if for instance adopting BIM tools. However, B1, E1 and E2 contradict each other, B1 considers that there are great economic saving potentials in working with GDTs for instance by energy cost savings, while E1 and E2 state that since occupants are paying for energy, there is no economic value in working with GDTs. A4 and C1 consider that high market prices of tools cause trouble, however, D1 contradicts that as long as there is a reasonable pay-back of the tools, it is plausible to invest in them. A2, A3, A4 and A5 considers the adoption of new digital tools is a slow and costly process. There is a consensus about the costly nature of investments in digital technologies, especially if the improper adoption led to unrealized benefits. Talking about BIM tools in particular, A4 considers it being too expensive and complicated to convert older blueprints etc. to 3D models and doesn't consider BIM being an option for existing facilities but only new ones.

4.4 Legal and Contractual Barriers

Not as many respondents identified barriers within this category. All respondents within company A saw an issue in unclear structure of who is the owner of information and data privacy among stakeholders. A4 further saw a need for more initiatives from the government to reach a wider adoption and use of digital tools. A1, A2, C1, E1 and E2 emphasize the importance of cyber security to protect sensible information concerning the facilities. Most respondents however disagree with the literature that adoption and commitment should be derived more from managers and state that already today much of the adoption and guidelines derive from the top managers in the companies.

4.5 Organizational Barriers

To follow-up environmental work, company A works with long- and short-time goals aligned to UN's global environmental goals, like achieving near zero carbon dioxide-emissions or decreasing energy consumption. Depending on the size of projects, goals are realized by project specific demands. Company B is in the process of creating goals and policy that match the company and the existing building stock. Company A, C, D and E have follow-up meeting of policy and goals and use both external and internal revisions. Respondents within Company A and D consider construction phase contributing to a larger energy consumption and has taken that phase into consideration as well.

A2, A4, B1, C1 and F1 state that the FM industry is conservative and slower than other industries when it comes to adoption and use of digital technologies. A5 however state that FM has become a rather progressive industry. D1 and D2 say that much has happened during the last 10 years. A5 says that more can be done, facility managers have a desire to work with environmental aspects. Still, it is important to adopt technologies in a speed companies can handle. A1, A4, B1, D1, E1, E2, F1 and F2 agree that there is a resistance to changing old ways of working and it is up to each and every one to take responsibility for using GDTs. Some say it is a generational question, while other argues that it is about personality types. Some personalities are more resistant to change, and some are more eager to try new ways. B1 explains that there is a certain skepticism about new digital tools. F1 and F2 have similar views on the different digital maturity levels of FM organizations which influences their capability of communicating their information/data needs concerning construction, retrofitting, refurbishment and renovation projects. However, the consultants had different views on the main reason behind the innovativeness of the organizations. F2 consider the size of the company as the core factor since larger corporations have more resources, while F1 points out the average age of the staff. A1, A2 and A3 make a point considering the importance of the company-size for the adoption. They say, it is easier to adopt new digital tools in a smaller company than in a larger one. A2 sees from experience that adoption becomes more complex in a larger company. A2 also states that there is a low interest among practitioners to take part of new digital tools, for instance by going to exhibition fairs but there is a higher interest to network among different stakeholders. F2 agrees networking interdisciplinary is important to be inspired and see different solutions in adoption of GDTs.

Looking to *Observability* from DoI, some practitioners (A1, C1, and D1) expressed the rare opportunity when they could be inspired by each other. Respondents also talk about a lack of interest in attending exhibition fairs and expressed instead a need for increased networking among companies. This, and the fact that the examined digital tools are intangible and invisible contribute to the slow uptake of green digital technologies. It is also a question of how much time personnel can and should spend on finding new solutions. Some respondents consider a need for better communication, like networking between different stakeholders. Concerning *complexity*, all respondents taking part in the study tend to believe that new digital tools, especially BIM, are highly advanced and complicated instruments and their implementation entail several consequences in the organization such as the need for hiring new personnel with proper skills, the need for reorganization which involves considerably costs for IT infrastructure and training.

4.6 Knowledge Barriers

A3, A4 and B1 consider that the lack of a clear purpose is a barrier in adopting and using new digital tools. A3 sees a problem when adoptions aren't well-planned but rather rushed because it results in resistance among personnel to use the new tools. A4 can't see a purpose of using more tools or adopting BIM for example. D1 and D2 states on the other hand that there is no other desirable solution than increasing the use of GDTs. A1, A3, A4 and A5 agree that it is important to have a positive attitude towards digitalization but sees a problem in the lack of knowledge about how tools should be used. Eight of the respondents (A2, A3, A4, A5, C1, E1, E2 & F2) state the lack of knowledge concerning digital tools and BIM among practitioners as a barrier. There is a lack of knowledge about which tools exist on the market and how to share knowledge throughout organizations. Due to a lack of awareness among practitioners no one has yet figured out how to work with BIM. F2 argues that there is no point in investing in state-of-the-art models with rich information if there is no knowledge of how to use data.

A1, A2, A5, C1, E1 and E2 agree that there is a need to identify which FM information to include in the BIM-model and reach a balance in the information from design to FM. E1, E2 and A5 think as much information as possible should be included in a standardized BIM-model, including for instance data about carbon dioxide emissions. A2 contradicts that FM isn't ready to receive that much information yet. A1 also thinks there is a need to balance information within the organization and agrees that personnel can't handle too much data. F2 state that the demands from the project owner are important and decides which information to include. It is important for FM to realize the difficulty to add information after a project is finished. A2, A3 and D1 want more pilot-projects to learn how to work with digital tools. A5 states that it can be difficult to look at research for good examples since crucial variables in practice can be manipulated in research. In research there is a possibility for instance to exclude certain parameters however, in reality practitioners need to work in parallel with information all the time and can't disregard certain data.

Looking to Trialbility from DoI, it is unmanageable to try out how these digital tools would work because the needs are often different for the distinctive building- and project types, likewise, different organizations have specific existing IT environments. Adaption to certain requirements is only possible during the implementation process and it requires significant efforts and investments. Even if a limited trial on a pilot project would lead to positive results, the question about the utility of the tool regarding the whole building stock would remain (A1, A2, A3, A4, B1, D1, F1).

Looking to Communication channels from DoI, knowledge is apparently not reaching potential users and communication channels need to function for knowledge to stream down to potential users.

4.7 Expressed FM Demands

A3, A4, A5, C1, E1 and E2 have in common that the environmental data they receive during handover are not used but rather archived in their internal systems. Company A uses a due diligence packet during handover including environmental inventory, risk analysis, energy declaration, certifications, documentations and drawings. For larger projects, contractors fill in a logbook and hand it over to FM. Respondents from company A and E say the companies don't use the received database over materials in the building. A4 says an issue is trusting that contractors add materials correctly in databases and wishes there would be a way to ensure the database is correct. A1, A2, A4, A5, D1 and D2 aim to compare facilities based on received information but it's difficult to match received documents and structures into internal systems. There is a need for search-and tag- solutions in folder systems and a higher level of integration of information. B1 says company B asks for environmental standards and use the information to reduce consumption of water and energy. C1 says Company C asks for the information they have a possibility to follow-up and if possible, an environmental inventory. D1 and D2 say Company D only demands data for environmental certification during handover.

More data about consumption, historical documentation and material databases are wanted from all respondents to better plan maintenance and new construction. Respondent A3, A5 and C1 see a need for greater integration of information, for instance, by more national standards concerning information structure or stakeholders using the same system. A3 and D2 also see a future for more automation and IoT to facilitate environmental work. A5 sees potential in developing better solutions working with carbon dioxide emission, for instance, applying circular economy in retrofitting and reusing equipment. A5 also finds it important to have more easily accessible data and information in order to understand environmental impact. Today it's only possible, according to A5, to count estimated emissions and not exact emissions. With more information about the facilities it would be possible to count exact emissions for each facility. Respondents in company A store values about energy consumption in a non-BIM GDT and A2 thinks they should add more data to achieve a greater understanding about the facilities. In Company A, respondents uses different systems for different aspects which creates silos of information. BIM is mostly used for new-constructions, A5 considers there are still major issues to be solved before BIM adoption is possible for FM, like costs and updating documentations of existing buildings to models. A5 wants research to focus more on cross integrating information.

5 Discussion

To fulfill the aim of this research, a literature study and semi-structured interviews are conducted to identify challenges hindering adoption and use of digital tools dealing with environmental impact in FM. The literature study reveals numerous barriers concerning the diffusion of both the environmental assessment methods for buildings and the digital technologies utilized for conducting them. Five main categories of the identified barriers are created such as Technological, Economical, Legal/Contractual, Organizational and Knowledge. These subjects are interlinked and closely connected to one other. Especially Organizational, Knowledge and Technological barriers are interrelated. For instance, "information silos" topic is tightly connected to each of them. However, our empirical data supports only a part of the publicized obstacles and predominantly consider difficulties about organizational change. The reason for this can be many folded.

First, since the majority of the respondents are white-collar leaders, they might not have been aware about the technical or the contractual complications in details, instead, they might have been more attentive towards the overall, supervisory aspects of change management. Second, overcoming resistance to change seems to be challenging regardless the size of the company. On the one hand, larger corporations usually have more capital and human resources for implementing innovative technologies than smaller firms have. On the other hand, large, multinational organizations usually have longer decision-path, wider gaps between different professional roles, more complex IT- and legal environment that can be a significant hindering factor when employing GDTs. Third, as some interviewees pointed out, not only organizational culture but also personal skills and attitudes can influence the outcome of change management. There is no consensus whether it is the conservative nature of the AEC industry or the generation gap that causes slow diffusion rate of innovative technology.

It is worth mentioning that respondents with IT background and managers placed the technological and economic issues in focus while the consultant with several-years-long working experience in different FM firms and facility managers considered the organizational change as the major problematic area.

Environmental requirements are getting more common and more complex in the industry. The ability to collect basic measurable data became a "hygiene factor", however, the capability of analyzing these data to gather deeper knowledge and to reach higher ecological sustainability became more challenging. In FM practice, two main areas of application can be identified that influences the environmental impact of a building. These are energy consumption optimization and building logs about environmental assessments of the inbuilt systems, components and building materials. The former area is closely related to building automation and requires real-time data collecting as well as historical data for the analysis, while the latter area is connected to a web-based, third party database about the inbuilt materials for reducing hazardous substances. These data are usually filled in by the contractors and subcontractors, owned by the FM firm or the owner of the building and being "archived" in separate project folders right after the handover. Thus, a project-based information silo is being made instead of creating a building-based information source for decision-making support during reconstruction, retrofitting or refurbishment projects. However, there is a value in preserving this type of information in searchable digital form since it enables a quicker response-time if a potential need arises, such like it was the case of polychlorinated biphenyls (PCBs) in building materials.

An intensive digital transformation took place during the past decades in FM practice. The interviewees related their experience of a large number of software tools supporting their activities, such as computer-aided facility management systems (CAFMs), building control systems, electronic document management systems and energy management systems (EMSs), maintenance management systems (MMSs), integrated workplace management systems (IWMSs), and enterprise resource planning (ERP) systems. Many of the respondents considered these digital tools suitable for one specific task and used them simultaneously, as found from technological barriers it is a question about finding suitable tools, but also about finding economic beneficial tools.

Considering utilizing BIM tools, our study supports the common view that the FM sector is still in the premature phase. As-built models with proper object properties seldom leverages from the construction phase and creating a digital twin of the existing building stock for FM is still problematic. These digital tools are applied by innovative actors mainly in pilot projects for some specific tasks to demonstrate the possible application areas for O&M activities. At the same time, other GDTs are widely adopted and utilized among FM. The main reasons for resistance towards implementing BIM are lack of knowledge about these tools and the associated costs and benefits. This further shows the close interrelation of barriers, in this case between organizational, knowledge and economic issues.

Looking through the lens of DoI, considering both the characteristics of the innovative technology itself (i.e. the content) and the traits of its diffusion process (i.e. the context), it can be argued that even though Roger used the term *compatibility* in a figurative sense and treated the adopter as an individual, this attribute can be applied to many layers in an organizational setting. It can be argued that GDT innovations should be compatible with not only the personal beliefs but also with the organizational norms and routines as well as with the IT- and legal environment to be implemented in an effective way. *Complexity* is an additional attribute that can be related to several aspects/barriers since there are complex organizational (many stakeholders), legal (increasing environmental and cybersecurity requirement) and technical (interoperability).

The empirical data gathered in this study confirm that the innovation-decisions are made collectively by a group of leaders which, according to Rogers' theory, involves a relatively slower adoption rate compared to both optional and authority type of decisions. Optional, i.e. individual decisions can be made more rapidly likewise authoritarian decisions can be made fast. Each organization in our study applied a collective decision-making practice.

We found that there are several experts involved in the processes intended to lower the negative impact of the building stock to the environment. The interviews supported our assumption that the interaction between different managerial positions such as property-, technical-, procurement-, IT-, sustainability- and project management is often challenging. Thus, our data are consistent with Rogers' hypothesis i.e. the multidisciplinary nature of FM activities implies communication difficulties between different professional roles both in intern and extern channels.

6 Conclusions

FM is using multiple GDTs for specific tasks; however, it can be concluded that BIM usage has not reached a critical mass among FM practitioners. There is no consensus among FM practitioners whether BIM is suitable or not during O&M phase. Some companies have started mapping potential benefits of utilizing BIM-models during post-construction phases of a building, however, most FM companies are using other GDTs and find that BIM still has too many critical issues to become a profitable investment. Further explorations about these challenges are needed, both by researchers and FM-industry.

Despite the importance to promote results from pilot projects and collaborations to spread knowledge in the industry, revealing potential benefits and best practice of innovative GDT in FM is difficult because of the complex nature of the industry. For every FM company, different data types from different data sources flow through different channels to reach diverse stakeholders, creating challenges for life-cycle oriented knowledge management in a project-oriented environment.

All aspects of the DoI theory forecast a slow diffusion of green digital technology, especially BIM, in FM practice, so it proved to be an appropriate analytical instrument. The characteristics of both the technology itself and its context predestines a low adoption rate of these pioneering tools. However, the authors believe that this process is not so linear in FM practice as described, rather is a less straightforward, iterative process impacting not simply a chain of suppliers but a whole web of stakeholders.

Social trends, values and economic benefits drives and develops work concerning environmental aspects. In the industry a shift has started from AEC to AECO, which facilitates opportunities to put demands concerning data early on. Further this enables possibilities to develop usage of GDT, however, for FM practitioners it is most important to integrate tools to overcome information barriers.

Future research should further focus on how to better take care of data and information-flows from design and construction to avoid information silos and instead create rich and compatible information storage to gain deeper knowledge about environmental aspects and better plan maintenance and renovations.

Assessment of environmental impact occurs most often in connections with green building certifications, however, the role of the national and international non-governmental organizations (NGOs) and institutions such as Green Building Council is rarely discussed. It is reasonable to assume that their requirements and practice during the certification and audit processes has a huge impact on environmental data handling. Thus, involving them in pilot projects to accelerate diffusion of green BIM tools would facilitate both the digital transformation of the AECO industry and the sectors' body of knowledge in sustainability.

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Appendix

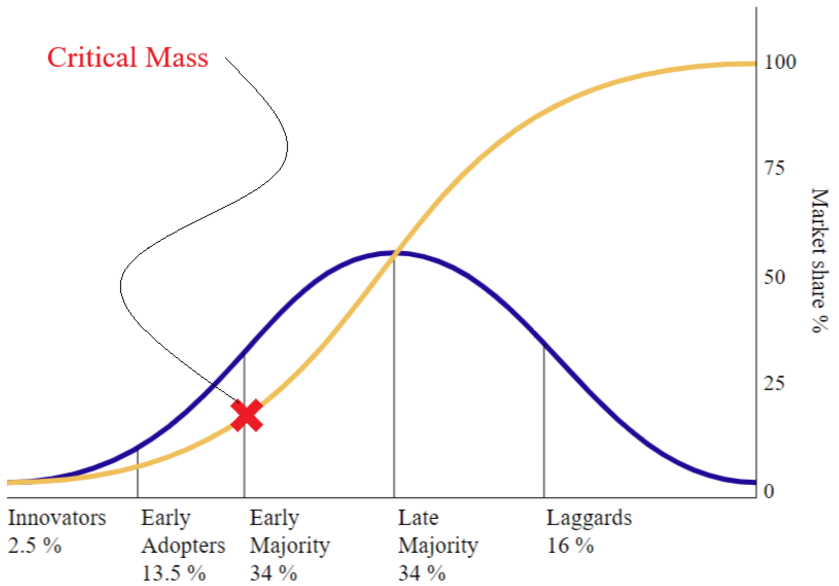

Fig. 1. The Diffusion Process (Based on https://en.wikipedia.org/wiki/Diffusion_of_innovations)