Relationship of emerging technologies and their influence on Facility Services

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ABSTRACT

Purpose: Macro economic studies estimate that in general 47% of all jobs will be automated due to digitalization (Stopajnik und Redlein 2017), (Chotipanich 2004), (Selinger, Sepulveda und Buchan 2013), (Čas, Rose und Schüttler 2017). Around 10% of all employees in the EU as well as in the US work in the Facility Services (FS) industry. FS will be notably affected by the megatrend digitalization as it consists of an immense number of routine tasks. As current studies only analyse the macroeconomic changes, this paper aims to answer the following more detailed research questions: Which smart building technologies are relevant for FS? Which services will be affected? What is the relationship between smart building technologies and the services they affect?

Methodology: As a basis for the current research 50 German Speaking Facility Managers were asked about the technical and economic feasibility of new technology in the FS sector. Based on a qualitative pre-study identifying the smart building technologies relevant, the authors carried out a quantitative literature analysis. This analysis included not only publications about the usage of smart building technologies in the FS industry, but also considered use cases on the technologies identified as relevant in other industries. In total 520 cases were analysed. Based on the literature review a research database was set up to explore in detail the relevant technologies and the affected services. The next research step was to analyse the relationship between services and technologies that effect these services.

Key Findings: This paper outlines the relevant technologies and services, and also the relationship between services and the technologies affecting them. It shows that services like Maintenance and Operation and Safety are highly affected by automatization.

Intended impact of the study on either research, education, or practice: This study shows the status quo of smart building technologies within Facility Services and how they influence each other. The results are the bases for in depth research about the relation of technology usage and services. It also provides practitioners support to select the proper technologies and use cases to optimise their service provision.

Keywords: evaluations of smart building technologies, internet of things, artificial intelligence, data mining and machine learning, augmented and virtual reality in buildings.

1 INTRODUCTION

Several international consulting companies like EY recently published reports on the progress of digitalization in the real estate industry (Herrenkohl, et al. 2017). All of these stated that the industry is not really taking care of, nor properly preparing itself for the changes (Nagl, Titelbach und Valkova 2017). Two years ago, the TU Wien started a research project to analyse the impact of digitalization on the real estate and Facility Management industry. According to the research, digitalization has impacts in two main areas:

1) The changes in the core business, like new ways of working, modify the demand for infrastructure and services changes dramatically.

2) Emerging technologies like Internet of Things (IoT), Big Data and Artificial Intelligence (AI) allow for disruptive and much more efficient ways of service provisioning. Therefore, the service provision itself is changed by digitalization.

This paper focuses on the second area: the use of new technologies to optimize FS provision.

Another fact is that in Europe as well as in the US around 10% of all employees work in this sector. Therefore, the outsourced FS industry is the 4th-biggest industry regarding employment in the EU (Stopajnik und Redlein 2017). In Europe in 2016, around 14.5 million people work in this industry. In the United States, more than 9 million workers are employed in this sector. Due to the demographic changes and the lack of skilled people, the application of smart building technologies like IoT, AI, and Machine Learning (ML) becomes an important factor (Selinger, Sepulveda und Buchan 2013)

Many studies are analysing the impact of digitalization on work processes. These studies assume that digitalization will have the greatest effect on routine-tasks. They predict drastic changes and so shifts in skills will be required (Nagl, Titelbach und Valkova 2017) (Stopajnik und Redlein, Current Labour Market Situation and upcoming Trends in the European Facility Service Industry 2017) (Frey und Osborne 2013). The study of Frey and Osborne (2013) determined the probability of computerization for over 700 occupations in the US. They estimated that 47% of all jobs would probably be substituted by computers. The background for their study was an analysis of the technological progress in Machine Learning and mobile robotics. Furthermore, the study of Stopajnik et al 2017 (Stopajnik und Redlein, Current Labour Market Situation and upcoming Trends in the European Facility Service Industry 2017) pointed out the huge impact of digitalization on the FS Industry. Typical FS activities (Österreichisches Norminstitut 2007) are more likely to be automated than other activities. E.g. for installation, maintenance, repair work Frey and Osborne determined a 50% probability of automation, janitors and cleaners have a probability of 66%, and the probability of being substituted by computers for first-line supervisors of housekeeping and janitorial workers is 94%. (Stopajnik und Redlein, Current Labour Market Situation and upcoming Trends in the European Facility Service Industry 2017) (Frey und Osborne 2013).

The existing studies show the changes by digitalization on the whole FS industry and whole economy, but not on the necessary tasks of employees or new technologies for companies (Stopajnik und Redlein, Current Labour Market Situation and upcoming Trends in the European Facility Service Industry 2017) (Stopajnik und Redlein, The Development of the Outsourced Facility Service Industry in Europe 2017) (Frey und Osborne 2013). So they cannot be used for an estimation of the changes due to digitalization. Especially the proof of the feasibility of technologies in the area of FS cannot be done (Nagl, Titelbach und Valkova 2017). But an estimation of relevant technologies is necessary to determine how these technologies will change the industry. The paper is based on the results presented at IEEE. The research objectives of this paper are to provide an updated evaluation of the relevant smart building technologies. The research questions are:

1. Which smart building technologies are already widely used?
2. Which services are mainly affected by these emerging technologies?
3. What is the relationship between smart building technologies and the services they affect?

2 Methodology

There are currently three major research paradigms: quantitative research, qualitative research and mixed-method research. The characteristics of qualitative research are induction, discovery, exploration, and theory/hypothesis generation. The researcher acts as the primary "instrument" of data collection and qualitative analysis. The major characteristics of quantitative research are a focus on deduction, confirmation, theory/hypothesis testing, explanation, prediction, standardized data collection, and statistical analysis (Johnson, Onwuegbuzie und Turner 2007). Quantitative and qualitative methods have particular lacks of strengths (Johnson und Christensen 2007) . The authors used the research method "Mixed Research". It is a type of research in which qualitative and quantitative methods, techniques or other paradigm characteristics are mixed in one overall study (Johnson und Christensen 2007). Its logic inquiry includes the use of induction (discovery of patterns), deduction (testing of theories and hypotheses) and abduction (uncovering and relying on the best of a set of explanations for understanding one's results). The goal is to draw from the strengths and minimize the weaknesses of both research methods (quantitative and qualitative) in single research studies and across studies. Taking a mixed position allows researchers to mix and match design components that offer the best chance of answering their specific (research) questions (Johnson, Onwuegbuzie und Turner 2007). Based on the Mixed Method Research, this study includes quantitative and qualitative research phases.

The methodology used consists of three research steps.

1) Qualitative pre-study: Based on a literature review, a questionnaire was developed to determine the technical and economic feasibility of the technologies. In spring of 2017 fifty Facility Managers were interviewed to define a list of relevant smart building technologies and give an estimation of their respective feasibility.
2) Quantitative literature analysis: The results of the pre-study were validated and updated by a profound analysis of more than 520 international cases published in scientific journals, in strategy documents of well-established consultancies, and also in companies' white papers. The results were validated to safeguard the data quality.
3) Definition of relationships between services affected and technologies: Using a database the cases were analysed with regard to which services are affected and which technologies were used. This enabled the researchers to analyse the relationship between services and technologies.

2.1 Qualitative pre-study

The fifty expert interviews from the pre-study showed that some technologies (IoT, Mobile Apps, Building Information Modelling (BIM), Robotics and Drones, Big Data, AI including ML) are already technically feasible or will be shortly. According to the experts, Augmented and Virtual Reality will be technically feasible at a later time. The technologies mentioned were the basis for the further analysis and used as categories for the technologies.

2.2 Quantitative literature analysis

To validate the technologies defined as relevant in the pre-study, a quantitative literature analysis was carried out. The goal was to analyse and evaluate international use cases of smart building technologies already implemented or to be implemented in the near future within different Facility Services. The goal was not only to forecast the impact of digitalization in the FS sector, but also to provide best practice use cases. Due to a high sample of more than 520 international cases an objective perspective and a valid data basis was ensured.

The authors analysed:

- scientific studies published in peer-reviewed journals,
- strategy documents (scientific & strategy consultancies),
- white papers and business project descriptions (incl. press articles, promotion reports, project descriptions from councils and communities).

In order to take into consideration the rapid development of smart building technologies, it was accepted that publications of technology companies and journals are important sources, as they are very up to date, whereas scientific papers need a longer time till they are approved. All publications date from 2010 to March 2019. A lot of cases originated from sources like IEEE Xplore digital library, Harvard Business Review or Researchgate. This procedure resulted in n = 520 records.

To broaden the scope and to make it possible to forecast future developments, reports from other industries using the technologies identified as relevant in the pre-study were also included in the analysis. This was done to enable Relocating: changes of the location and production methodology (Hammer und Champy 1993), (Servatius 1985), (Kröger 1994). The "Grounded Theory" (Glaser und Strauss 1967) was used to systematically analyse the reports and identify codes (Strübling 2014), (Corbin und Strauss 1990). First, these reports were open coded. Then similar codes were clustered into categories. As the EU standard 15221-4 is the only standard accepted by more than one country, the occurring FS categories were aligned accordingly. The smart building technology categories were coded at a very detailed level first and then clustered into the technologies derived as relevant from the pre-study.

For each of the sources the following data were collected:

- ID
- Short description
- Client and supplier of case
- Current FS in which it is applied (Österreichisches Norminstitut 2007)
- Smart building technologies used
- Link to reference
- Date of publishing

Then the data was inserted in a Microsoft Access database in order to compare the different types of reports in a traceable and transparent way.

Fig. 1 shows the data structure of the database. Beside the main table 'cases' including the attributes mentioned above, four other tables are in use. The table "services" and the table "technology" were set up as own tables. This was done to enable a m:n relation. That means several services and/or technologies can be linked to one single case. During the grounded theory based analysis of the cases, it was ensured that this m:n relation of services and technologies is used properly. That means after the coding it was safeguarded that all services that were identified in the case are supported by all technologies identified and vice versa. This enables the authors not only to determine the relevant smart building technologies and the effected services due to the use of emerging technologies, but also to conclude which services are affected by which technologies. The last table validity was used to cluster the type of publications according to their validity. Scientific papers were rated the highest followed by strategy documents. White papers were rated lowest.

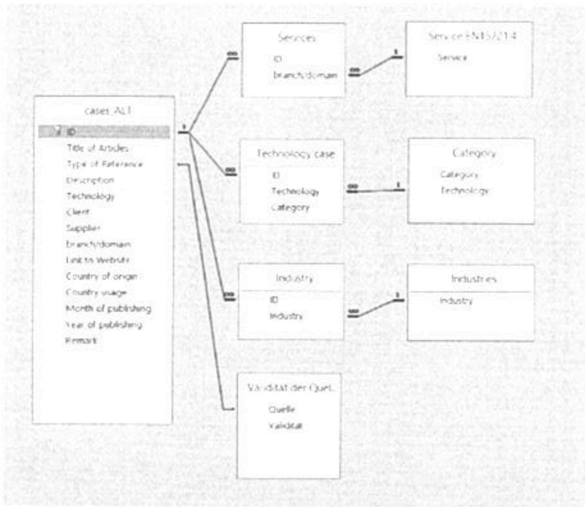

Figure 1 Structure of database

2.3 Definition of relationships between services affected and technologies

As a last step, the database was used to cross-reference which technologies were in use and which Facility Services they were applied in. This enabled the researchers to analyse the relationship between services and technologies.

3 RESULTS

3.1 Relevant technologies

The results of the quantitative literature analysis regarding the relevant smart building technologies are shown in Fig. 2. The figure shows the occurrence rate of the smart building technologies within all the reports analysed as a percentage of all analysed use cases.

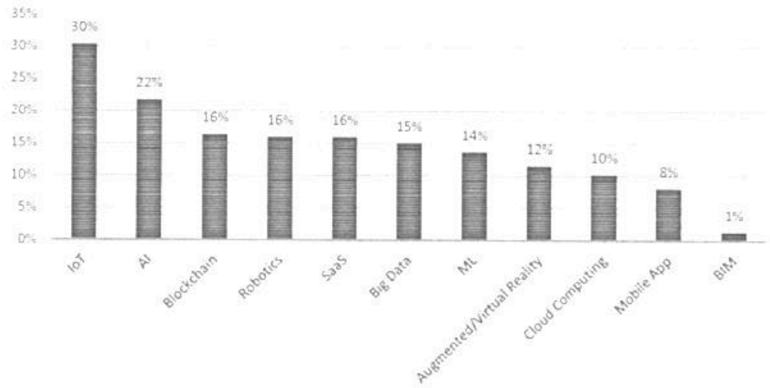

Figure 2 Technologies grouped by category and occurrence within the case studies as a percentage of all use cases analysed (520)

Technologies with less than 26 overall occurrences were left out of the above graphic, as they occur in less than 5% of use cases. BIM was included to show that while the experts stated it to be a prevalent smart building technology, this claim could not be supported by the data gathered. Software as a Service (SaaS) and cloud computing were not within the scope of the pre-study as it is more a way to provide software, rather than a tool in itself. In the following analysis the two software platforms SaaS and cloud computing are not included as they support all smart building technologies, while here only the technologies themselves are analysed.

In all the publications the smart building technology IoT is mentioned the most. The reason for this is the enormous price reduction of sensors and IoT devices within the last years. The availability of self-sufficient devices that produce the energy they need by themselves and can be easily connected to the WIFI of the buildings, also enables the use of IoT (Xu, He und Li 2014).

In general, AI is mentioned very often. In the last years AI/ML tools have made great progress. They are mainly used to analyse the data generated by the IoT devices and identify patterns (Moreno, et al. 2014). The capabilities of Big Data and AI/ML tools in this area has increased. Several device producers like Fujitsu include AI/ML features already in their devices. An example is the automatic recognition of patient statuses, which in case of an emergency informs relevant people automatically (Fujitsu 2014). The availability of AI/ML over SaaS platforms like IBM Watson increased, while at the same time their costs decreased. Robotics take the fourth place in the analysis. Robotics and drones are mainly used to carry out repetitive work. New versions are more flexible and can cooperate with the FS personnel.

Blockchain is mainly in the focus of strategy documents. This technology provides many use cases in the area of FS. AR and VR were often discussed in white papers but not in the other sources. BIM was in the top two mentions regarding feasibility according to the FM experts, but in the quantitative analysis only 7 cases could be found.

3.2 Affected services

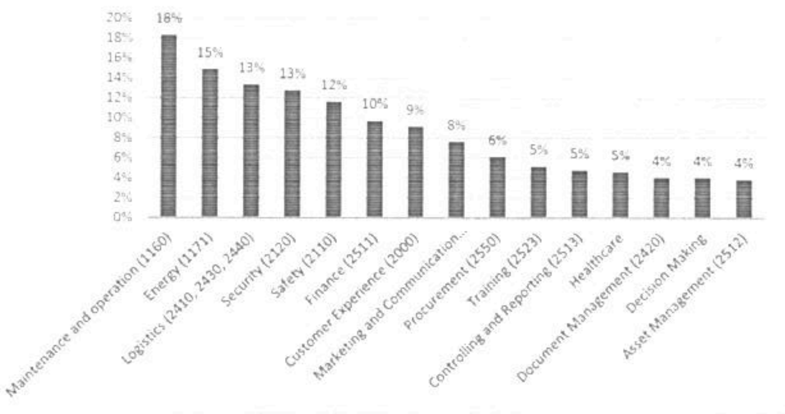

Figure 3. Affected services according to number of occurrences in publications as a percentage of the number of cases analysed (520)

The results of the quantitative literature analysis regarding the affected services are shown in Fig. 3. The analysis showed that use cases not only use numerous technologies but are also applicable to multiple services. The figure shows the occurrence rate of the affected services within all analysed cases as a percentage of the overall cases analysed (n=520). Maintenance and Operation is featured most in the use cases, followed by Energy, Logistics, Security, and Safety. These services partly consist of repetitive tasks and are therefore highly susceptible to automatization.

3.3 Relationship between the services affected and technologies used

In order to assess which services are utilizing which technologies, the two data fields were cross-referenced. This showed which technologies were prevalent in the respective Facility Service categories as defined by EN15221:4.

IoT sensors help to improve energy consumption as they provide an accurate data of the usage and therefore deliver information to carry out optimization. Logistics, Safety and Security, and the customer experience can be enhanced by the use of Big Data, AI and ML. The use of these technologies for customer experience is gaining in importance to create the desired "WOW" effect. Jointly with Blockchain the tools mentioned above optimize Security, Finance, and Procurement. Two examples for this technology in the area of Facility Services that were mentioned often are smart contracts and trusted data about equipment and maintenance.

To further illustrate the relationship between technology and services, two services are analysed in more detail here.

3.3.1 Maintenance

The service "Maintenance and operation" is pointed out to be affected by smart building technologies the most. As shown, IoT is the most important technology affecting this service. IoT devices are used as providers of data about the current status of equipment and the building itself. This data is then delivered to Big Data, AI and further processed by ML to recognize patterns, mainly to support predictive maintenance and to derive actions based on these patterns (Johansson und Vogelgesang 2016). , (Glawar, et al. 2016). In one case, the AI/ML software even includes the scheduling of the maintenance employees (Bonomi, et al. 2012) (Sun, et al. 2016). Therefore, beside IoT, Big Data, AI and ML are also often mentioned. Several new product offers of large FS companies (e.g. Kone, ISS) are based on these technologies (KONE Press Release 2018). KONE has partnered with IBM to make elevator and escalator operations worldwide more efficient by combining AI, Big Data gathered from IoT devices, ML, and cloud computing to predict and - when possible - resolve equipment breaks in order to ease maintenance efforts and gather information about usage and performance (IBM Corporation 2017). This type of predictive maintenance, based on machine status and use data, helps to secure availability, predict failure moments, and identify quality deviations by transitioning some reactive maintenance tasks to more proactive ones (Matyas, et al. 2017) This development shows the increasing importance of AI, ML, and Big Data in combination with IoT devices within Facility Management. Augmented and virtual reality can be used to support and train maintenance employees. Drones and robots help to reduce hazardous and risky tasks for humans, by carrying them out instead. Examples for use cases are mower and cleaning robots (Min Moon, et al. 2015). Several of the cases describe a combination of robots and drones (Wang, et al. 2010). This is why these technologies are also mentioned in the area of safety and security.

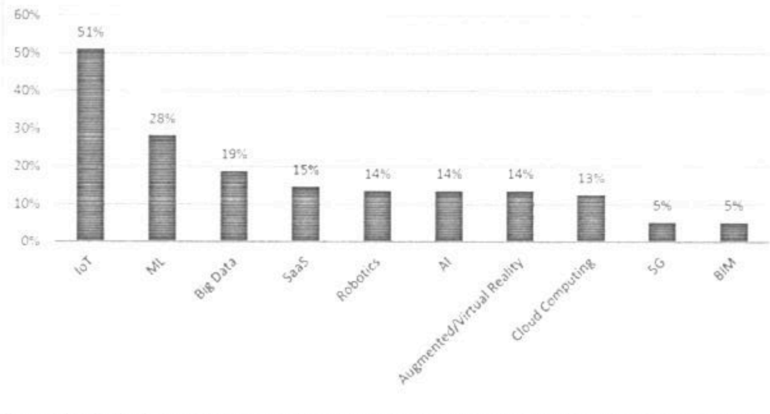

Figure 4. Used technologies according to number of occurrence in publication as a percentage of the number of cases in FS "Maintenance and Operation" (96)

3.3.2 Safety

IoT affects the service "Safety" to a high degree. Robotics can be used to take over dangerous work from human workers and carry them out instead. These encompass obviously dangerous tasks like defusing bombs which are being automated successfully (Robotics at Penn - Real-World Applications 2014), but also for more covertly hazardous tasks like cleaning the windows at home (Choi und Jung 2011), as well as in high rise buildings (Wang, et al. 2010). Robots are often used in tandem with IoT devices in order to prevent accidents and injuries. In addition to the 3D rule of automatization, robotics can be used for tasks that require extraordinary precision.

stability, and dexterity even in confined and hard to access environments. This greatly reduces the risks for live and health of Facility Service employees.

As mentioned above augmented and virtual reality can be used to train employees and support them in their daily work. AI, ML and Big Data are also important, as they analyse the data gathered from IoT devices, recognize patterns, and use these to predict upcoming events such as machine failures or even more. An example are surveillance systems that automatically can inform security personnel of dangerous and unusual events. An example are cameras that detect when a person leaves its luggage somewhere unattended and goes away. The camera then sends this information per SMS to the security personnel. Another technology that has been gaining in significance is 5G network technology, to further enable sensors as IoT devices.

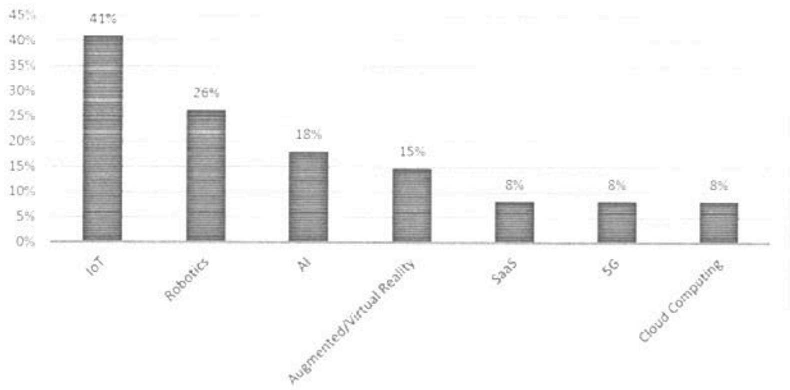

Figure 5 Used technologies according to number of occurrence in publication as a percentage of the number of cases in FS "Safety" (61)

4 CONCLUSION

The quantitative literature analysis showed that smart building technologies are already widely used. IoT use cases are extensively spread. Due to a significant reduction of price and the availability of self-sufficient systems, their usage is widely spread. The literature analysis also identified Big Data, AI, ML and Blockchain as important smart building technologies. Whereas a lot of FM publications stress the importance of BIM, its impact according to the literature research is rather limited. Other technologies are mentioned much more frequently. The data gathered makes it possible to identify the effected services and the relationship between services and technologies. The services mostly affected are Maintenance and Operation, Energy optimization, Safety and Security, Logistics, Finance, and Procurement.

The use cases show that smart building technology not only automatizes certain aspects of various Facility Services but changes the way these services are provided, by shifting actions from reactive to predictive ones.

In contrast to these results, most of the Facility Service companies still use a lot of standard technology to provide FS. Technologies like IoT, AI, ML, and Blockchain develop rapidly, but for now they are mainly used by start-ups or technology companies. "Classical" companies are not yet taking up on these developments. They mainly lack best practice case studies that can directly be implemented in their companies. This postulates the need for further research and the application of smart building technologies in practical use cases to especially prove their economic feasibility.

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