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Preface of the publisher

21. Journal for Facility Management: Science meets Practice

After one and a half year of COVID-19 a sort of new normal has come to place. The world is still fighting the pandemic but also concentrating on the other challenges. One of the most important one is the climate change. At the same time as the IFM congress the UK hosts the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow. COP26 summit is to accelerate action towards the goals of the Paris Agreement. Also the EU is putting new legislation like the Regulation (EU) 2020/852 “on the establishment of a framework to facilitate sustainable investment, and amending Regulation” (ESG) in place. As buildings cause around 40% of all CO2 emissions they are coming more and more in the focus of these actions. At EXPO Real, the largest real estate fair in the German speaking countries, almost all reviews concentrated on ESG. But is this really a new topic? The IFM carried out the first studies on the interrelation of FM and sustainability in 2011, 10 years ago. These studies were permanently updated. For a long time this aspect was rather neglected. A friend, Facility Manager of an international company, told me recently: “I was talking to my bosses continually about sustainability and projects to optimise the ecological footprint of our real estate. But they did not really take up on the ideas. Now the are forced to do something immediately. Their stakeholders are forcing them. Now they are in a hurry!”

If the top management would have set steps earlier they now could show their vision and far-sightedness. Another friend did so and his shares are now skyrocketing. At the moment the IFM is prototyping a cost-efficient easy way to implement IoT, big data solution, at the Viennese Castle. A way that is effortless to retrofit in existing buildings and enables the monitoring of all type of energy usage. It links this also to the usage behaviour and well-being. This prototype is based on the previous research done at the IFM.

Why did we include well-being and room climate parameters? Already in the 1970s research was done on the interaction of room climate and the well-being and performance of people. This research continued but was also not really taken up by top management, only looking for cheap workplaces, not taking into consideration the impact of the work environment on their employees. Today, human experience and the war for talents asks the management suite to concentrate on these topics.

All these ideas and topics ask the real estate industry to act really sustainable, not only in respect to the energy usage, but also in respect to the social component of sustainability: the impact on the human being.

These examples also show that industry could profit very much from intensive exchange to research. Top management is very often busy with its day to day business. Science has the mission to look in the future and can therefore be a source for innovation. But academia can only offer – The c-suite has to take the opportunities. Our publications are mainly free of charge and present validated results. This journal is such a source. Many of the papers presented use cases that are ready for usage in your daily business and can make the difference in the future. Take up on this opportunity!

This issue of Journal für Facility Management provides you with far-sightedness into the following topics:

- Facility Management Development Trends in South-eastern Europe: The Case of Turkey
- Decentralized Management Framework for heterogeneous Devices in FM
- Developing A Standard Workflow for Drone Roof Inspections

The first paper deals with the fast development of FM in South East Europe and especially in Turkey. The main findings of the study revealed that institutionalization of FM business in both public and private sectors should be developed as well as outsourcing of services, agreement design and determination of performance indicators.

The second paper deals with the rapid technological development of smart building appliances. Combined with the huge amount of device manufacturers and different submarkets for smart devices this leads to difficulties for the integration of different systems. The Web of Things (WoT) protocol is the most promising approach for communication. Based on the relevant literature, this paper presents a framework architecture that augments the WoT protocol with decentralized authentication and authorization capabilities based on biscuit tokens. The baseline protocol workflow enables the integration with existing management systems.

The last paper also deals with new technologies like Unmanned Aerial Vehicles (UAV), or "Drones". Drones have been used by Facility Managers (FMs) in the post occupancy stages to monitor and inspect the condition of various building envelope systems, as a part of protecting the building assets of people, processes and technology. This paper provides a standardized protocol that FMs can utilize in conducting low-slope roof inspections.

At this point, I want to thank all international researchers who sent us numerous abstracts and papers for the double-blind review. The decline rate was kept high with more than 50%. This high-quality research enabled us to increase the quality of the IFM journal over the last years. Thanks for your help and we are looking forward for your future support. I also want to thank the members of the editorial and the scientific board for their terrific work. They supported me in reviewing first the abstracts and then the full papers and gave a lot of input to the authors.

The high decline rate, the high reputed members of the editorial and the scientific board and the supporting universities ensure that the articles are not only having a high scientifically quality, but also that practitioners can put them into practice easily.

I also want to thank my team, especially Barbara Gurdet, Antonia Heil, Christian Lau and Lisa Thrainer. Without their personal engagement, the journal would not be available in this high quality.

I wish you all the best from Vienna, an enjoyable read, a lot of input for your research and/or for your daily work. I look forward to a lot of new abstracts and papers for the next call for papers for the 15th IFM congress 2022.

Yours,
Alexander Redlein

Head of Editorial Board

To my family Barbara, Caroline Sidonie und Alexander David

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Vielen Dank an alle KollegInnen des IFM für die Mithilfe bei der Organisation!

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Facility Management Development Trends in South-eastern Europe: The Case of Turkey

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Abstract

In Turkey, facility management (FM) appears to be developing at high rate in last two decades. Unlike in Europe, this situation stems from the delays in the development of standards and the acceptance of FM as a profession in the field by private and public institutions. However, the current FM market in Turkey has been developing gradually with the significant increase in the share of employment. This study aims to gain a qualitative understanding of the complexities in the FM sector and developing a mature FM market across Turkey. Various data has been collected through in-depth, semi-structured interviews and official records from the relevant institutions. The research results represent the perceptions of various stakeholders employed in several businesses and research institutions, regarding its key challenges and opportunities of the business environment in FM organizations, FM supply market, professional bodies, FM education, and FM research. The main findings of the study revealed that institutionalization of FM business in both public and private sector should be developed as well as outsourcing of services, agreement design and determination performance indicators. The market analysis provides valuable information for decision makers and FM organizations.

Keywords: Facilities management, FM markets, practices and development trends, Turkey

1. Introduction

The increasing role of FM, the profession is defined in many different approaches. Almost every definition underlines the aspect of an integrating approach which covers a combination of people, processes, place, and technology is highlighted. However, the importance of the relationship between the supporting services and the core business functions is not always distinguished in FM literature (Smit, 2008). In the cause of incorporating the concept and the process of space-human relationship, the relationship between space-labour productivity, and the separation of jobs according to talents and competences, support services for subordinate jobs in enterprises had enabled the emergence of the FM profession (Erentürk, 2016). According to Noor and Pitt (2009), FM is a management of business that focuses on human-oriented services in residences, taking care of customer needs and aims at customer satisfaction, devotes on its time, energy and resources to these goals and purposes, produces customer-oriented solutions, and knowledges and applies to international and national regulations as well. Cotts and Lee (1992) define FM as the activity of the organization to coordinate between work, physical workplace, and employees. Kohnstamn and Regterschot (1994) defined FM as the integrated management (planning and control) of locations, services and tools that contributes to the organization operating in a variable environment to achieve its goals and to be effective, efficient, flexible, and creative (Remoy, 2010). Becker (1990), on the other hand, considers FM as the process of coordinating all the work related to the design, planning and management of buildings, systems, equipment, and furniture in order to achieve competitive success in a rapidly changing world. Currently, the Urban FM extends the role of FM towards improving health and well-being in the urban environment (Temeljotov Salaj and Lindkvist, 2021).

The global FM industry is growing rapidly in almost every country, and the FM market continues to grow in the public and private sectors. The swift growth in outsourcing of FM services in public and private institutions has enabled the establishment and implementation of international and professional standards of FM and over time had enabled the FM profession to be recognized as a preferred career. Reporting on trends and growth of the European FM sector was quite prominent some years ago where important studies have emerged to try and map the size and scope of the European industry, e.g. Redlein and Poglich (2010), Teichmann (2009), Tucker and Cannon (2017), Stopajnik and Redlein (2017), Tucker et al. (2018). The research on FM maturity level in Europe showed the differences among different parts of Europe, especially in South-East Europe (SEE) as being less developed (Tucker et al., 2017, Anonymous, 2020b). This has elevated the interest to compare the result with the trends to date and to see what kind of disparities with other parts of Europe exists and how much COVID-19 situation stopped the progress.

An analysis of the development of the FM market in Turkey and making an assessment based on situation analysis will constitute and set an interesting example in the FM avenue. In this research, the development of the FM market in Turkey, its current situation, the opportunities offered by the market, and the difficulties and shortcomings were evaluated based on expert opinions. The results of the study include the development of FM practices in Turkey and the determination of the problems experienced in the process and the presentation of solutions for the future move based on these findings, which are considered important in terms of creating a model and setting best practices for developing countries which are facing similar scenarios and characteristics. In addition, it will be possible to discover the prevailing market situation in Turkey, provide general and useful information about the domestic market concerning FM; these information's can be relevant to companies and experts, operating at European and global level, on exploring the country market, setting standards and strategies for new companies' and growth for both domestic and foreign investors in Turkey's market, which can be among their target markets.

2. Methodology

The purpose of the research is to take an inductive, constructivist approach to gaining knowledge from currently general statistics, collected data through in-depth, semi-structured interviews and critically analysing the perceptions. It is emphasized that there are not enough field studies on the development process and current state and maturity concerning the FM field in Turkey (Tanrıvermiş et al., 2019). Under these circumstances, this study was carried out by evaluating the data obtained by making in-depth interviews with the participants and experts in the field, who have an important role in the field of FM education, training, and research, facility, and management companies in Turkey about the current situation, difficulties, and practices in the industry. By using interviews and the key informant, method, the different aspects of the FM sector in different areas, the development of FM organization, the FM supply market, the FM professional organizations, the development trends of FM training and research were discussed, and it should be noted that country markets have been evaluated using this approach in previous FM studies (Tucker et al., 2018). Care was taken to ensure that the interviewees were either practitioners or education/training experts in the field of FM, and the employees more than 10 years experiences in FM companies determined around 250 people and 45 experts from different public and private institutions were involved and participate in the online interviews. Discussions with experts; interviews with experts were conducted as online meetings due to the pandemic conditions, and a general evaluation based on the results of these interviews was made in this study. In addition, the current situation and potentials of the Turkish FM market have been depicted through the evaluation of the administrative records regarding the facility and real estate market, as well.

With the examinations conducted at sectorial levels, answers were sought to the basic questions about what the factors that motivate FM in Turkey and the size of the development potential of the market. The experts interviewed describe the current situation and give the output and possible future forecasts. The main question of the study is to evaluate the historical development and current situation of FM in Turkey and defining legal and institutional problems and human resources inadequacy that constrain the development trends of the sector. In the FM sector, the analysis of the supply market and especially in determining the FM supply and demand activities in the country, explaining the current situation in the first place, and developing possibilities for the future predictions and scenarios are useful for decision-making bodies. In the education, research and professional organizations part of the study, outputs related to FM supply and demand activities in the country are provided. The development of education and research activities in the country in terms of FM education and FM research has been examined.

3. Analysis of The Current Situation of Real Estate and FM Requirement in Turkey

It is observed that Turkey's economic size, urbanization and industrialization levels are associated with the size and demographic characteristics of the population. Turkey is considered as a promising FM market in terms of its population and GDP size. The population of Turkey has reached to 83.61 million people according to the data of December 31, 2020; with 50.1% of the total population are men and 49.9% are women (Figure 1). On the other hand, 92% of the total population lives in cities and it has been observed that there is an increase in the population in cities. The annual population growth rate was 13.9 per thousand in 2019 and 5.5 per thousand in 2020 (TURKSTAT, 2021). The share of the 15-65 age group (63,119,163 people) in the total population was 75.49%, the share of the population group under 35 age group was 45.60%, and the share of the 65 years of age and over age group in the total population was 9.51 percent. The fact that most of the country's population consists of young people will cause a high demand for residential and commercial real estate and infrastructure investments in the years to come. On the other hand, the increasing of life expectancy, changing traditions and the increase in the share of the elderly group in the total population will lead to an increase in the demand for the still limited elderly care facilities and, social real estate investments and management. The 75.49% share of the active population in total indicates that there is an acute need for business development and employment opportunities, and significant employment opportunities will be possible through the development of the FM market.

The gross domestic product per capita, which was generally around 10,000 USD in the 2010s in the country, declined to USD 9,215 in 2019 and to USD 8,599 in 2020 with the effect of devaluation and exchange rate regime. According to the World Bank rankings, Turkey had managed to maintain its status of being a middle-high income country. The share of agriculture in GDP in 2019 is 6.4%, the share of industry is 21.8% and the share of the services sector is 71.8%. In contrast to the industrial sector, the services sector takes the place of agricultural sector, which has contracted in the national economy. In the last decade, the share of construction in the national economy varied between 5.3% and 8.5%, and the share of the real estate sector, including FM services, varied between 6.5% and 10.4% (Tanrıvermiş et al. 2019). Despite the macroeconomic instabilities experienced in the last three years, the total added value of finance and insurance activities was increased by 21.4%; the information and communication activities was increased by13.7%; the agricultural sector was increased by 4.8%; the public administration, education, human health and social work activities was increased by 2.8%; the real estate activities was increased by 2.6%; in other service activities was increased by 2.5%; and in industry was increased by 2.0% whereas it is observed a significant decreased of 5.2% in the professional, administrative and support services; the decrease of 4.3% in the services sector; and the decrease of 3.5% in the construction sector in 2020 (TURKSTAT, 2021).

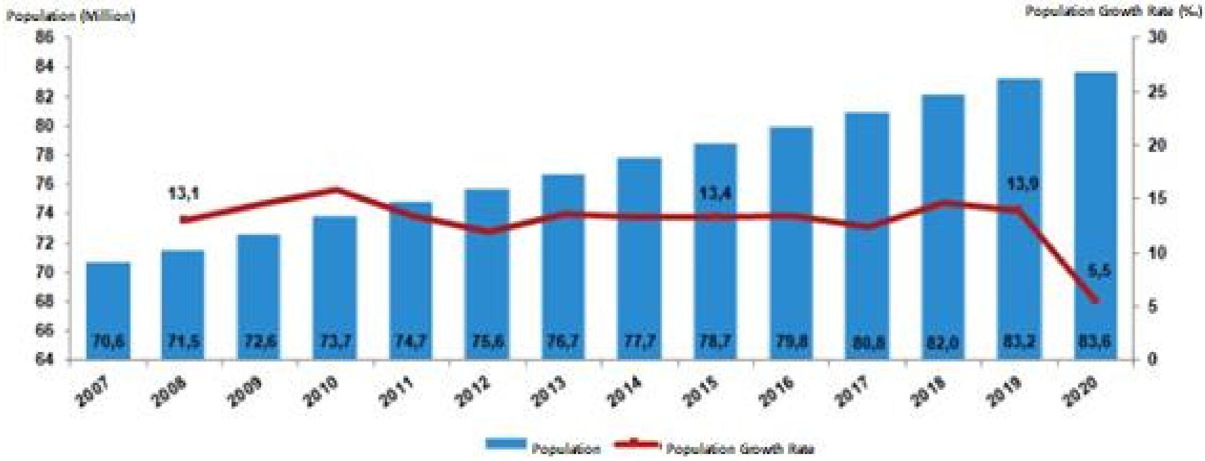

Fig. 1: Population and population growth rate in Turkey (TURKSTAT, 2021)

In terms of FM services, there is necessary to examine housing production and use, commercial real estate market and infrastructure investments. The total number of residences in Turkish cities reached 26 million by the end of 2020. It is observed that 7 million units of the total housing stock is in risky and it is necessary to carry out a major transformation in the cities. In the last two years, it is observed that due to macroeconomic instabilities, there has been a significant decrease in the number of new project development and construction permits as well as the number of buildings and residences that have received residence permits. While the number of construction permits remained between 1.0 and 1.4 million and the number of building occupancy permits was between 750 and 825 thousand in 2016-2017, there was a sharp decrease in the mentioned numbers in the period of 2018-2020 (Table 1). Vertical construction was preferred in cities due to the need for rapid transformation and the insufficient land stocks, and the number of high-rise residential and office buildings increased. The share of high-rise buildings (277,244 independent sections produced) in the housing assets rapidly increased to 23.12% in 2020, and the management of high-rise buildings has also become an important and potential field in the business arena.

It was observed that the number of building investments for lodging, office space, wholesale and retail trade, industry, education, hospital, and maintenance activities outside the housing market generally tends to increase until the 2019-2020 period (Table 2). Although there has been a significant increase in the investments made in office and luxurious residence buildings, industrial and storage/warehouse buildings, hospitals, and care facilities in the cities, it was observed that there is still a large gap in the aspect of management of these facilities. Due to the evolving urban life and developments in the service sector, the use of luxury residences has become widespread in recent years, and even the process of transforming some residential buildings into commercial residences (Airbnb like) partially or completely into luxury residences and transitioning to short-term rental activities. The necessity of meeting the commercial and housing needs all together, especially in the central and business areas of cities, has led to an increase in the demand for luxurious residences. It is noteworthy that building licenses for lodging, office space, wholesale and retail trade, industry, education, health, and care have decreased significantly in the 2019-2020 period and new project development initiatives have weakened (Table 2).

Years	Building Permits			Occupancy Permits		
	Number of Buildings	Surface Area (m²)	**Number of House**	Number of Buildings	Surface Area (m²)	**Number of House**
2005	114,254	106,424,587	**546,618**	64,126	50,324,600	**249,816**
2010	141,371	178,776,701	**916,504**	82,407	85,535,260	**431,271**
2015	125,030	220,653,829	**892,791**	110,145	143,070,336	**732,786**
2016	134,099	206,971,538	**1,006,650**	111,382	151,395,780	**754,174**
2017	160,445	281,713,052	**1,377,061**	117,360	161,751,496	**823,952**
2018	101,510	143,819,838	**643,125**	123,776	169,943,417	**870,501**
2019	53,819	70,493,433	**304,544**	93,279	149,264,217	**730,585**
2020	58,865	72,454,226	**357,807**	53,986	86,198,564	**423,733**

Tab. 1: Number of buildings with building permits and occupancy permits in Turkey (TURKSTAT, 2021)

The geographical location and transport infrastructure connections of the country allow for new logistics center of investments and an increase in urban logistics. In addition to the projects developed by local and foreign real and private individuals and organizations, public institutions also focus on infrastructure investments such as city hospitals, airports, and toll roads, and in these projects, various project financing models (such as build-operate-transfer, build-operate, build-lease-operate-transfer) were observed to be more preferred.

Years	**Lodging Buildings**	**Office Buildings**	**Wholesale and Retail Trade Buildings**	**Industrial Buildings and Warehouses**	**Schools, Universities and Education Buildings**	**Hospital and Care Institution Buildings**
2005	1467	1101	5748	3378	830	251
2010	1593	2027	5421	4419	936	228
2015	824	3950	3238	3306	1136	300
2016	1042	2947	3257	4047	1243	266
2017	1376	3826	3684	4412	1510	338
2018	1442	1241	4648	4373	1800	394
2019	842	483	2526	2235	809	235
2020	821	922	3145	3665	502	292

Tab. 2: Lodging, commercial and industrial real estate investments in Turkey (TURKSTAT, 2021)

When the number and capacities of city hospitals, which are widespread in Turkey and considered as an important public-private cooperation project, are examined, it should be noted that there are a total number of 10 city hospitals operating in the country and that the city hospitals with the largest capacity are operating in Ankara. On the other hand, the number of city hospitals to be opened were 8 in 2020 and 2 in 2021. The total bed capacity of the 20 city hospitals, including those to be opened until 2025, has been planned to be 30,815, and it should be emphasized that the existing hospitals have brought about significant success in inpatient treatment and healthcare provision, especially during the pandemic period. City hospitals were built and put into operation with a public-private cooperation model, and in these facilities, 8 to 12 auxiliary services (such as food, cleaning, security, parking, outdoor, laundry, building and medical device maintenance-repair and renovation, waste and energy management) are provided by Special Purpose Vehicles (SPV) and city hospitals have been one of the good examples in which the operational responsibility is shared with SPV through Operations and Maintenance (O&M) contracts executed before the construction of the projects started. It is observed that especially in newly developed city hospital investments, they work with a FM consultant during the project phase and SPV's generally prefer establishing business companies or working with professional FM companies.

The number of airports in Turkey was 59 in total, and by the end of 2020, the number of domestic passengers was 49,740,303, the number of international passengers was 31,875,837 and the total number of passengers together with direct transit passengers was 81,703,685. The number of passengers in 2019 was 208,911,338 persons (Anonymous, 2021d), and the passenger capacity decreased by 61% compared to the previous period due to reasons such as full lockdowns, travel restrictions or prohibitions. A total number of 38 airports operates and offer services in international passenger and freight transportation, and the number of airports operating at the local level is 21. In addition, there are 18 military airports in total, thus, the total number of all airports is 77. The total number of airports will be 86, with 9 airports that are planned to be opened in the coming years and are currently in the project phase or under construction. It is seen that international airports were built and opened for operation with a public-private partnership model, and airport management is also carried out by FM companies.

Among the most important investment areas in the residential and commercial real estate sector in Turkey are shopping malls (SM's), high-rise office and luxurious residence buildings, condominium and qualified (branded) luxurious residential areas. The market segment dominated by the holistic approach in FM has been the investments in shopping malls, especially in mixed projects. In this regard, shopping malls are followed by office, residence, and mixed real estate facilities. Although housing projects have an important share in the activities of FM companies in terms of scale, it is a segment where the penetration remains at a very low level considering the total housing stock and market potential. The total number of houses is 26 million and 12% of the total number of independent sections produced in 2000 and 23% of those produced in 2020 consists of buildings with 10 or more floors. According to the data of the Association of Shopping Centers and Investors (Council of Shopping Centers), the number of shopping malls was 454 in 2019, decreased to 447 at the end of 2020 with the reasons such as closure and transformation of some of them (Table 3). When the distribution of shopping mall investments by provinces is examined, Istanbul has the highest number of shopping malls with 147 SM's, followed by Ankara with 48 SM's and Izmir with 20 SM's (Anonymous, 2021b). It has been determined that the indoor and leasable area of the existing shopping center investments are growing rapidly, the amount of leasable area per 100 thousand persons continues to increase (Table 3), and the investments cannot be made in relation to the population size of the cities and the size of the leasable shopping center investments. It is envisaged that in the near future in Turkey, especially in big cities, the existing shopping malls will go through a transformation process, and in this framework, street retailing will gain importance and priority again in the post-pandemic period (Tanrıvermiş, 2020).

The FM sector in Turkey has begun to be recognized as an area that creates a lot of employment and is needed in almost all commercial, industrial, and lodging facilities. Considering the examples of developed countries and the development of FM in the world markets, it has been determined that FM in Turkey is at the beginning of the development process and institutionalization has not yet been achieved to a large extent. Instead of managing the FM services were separately under sub-headings such as cleaning, security, technical and landscape, it is accepted as the main goal of the developing sector to manage all these services in an integrated way and to offer combined benefits to customers (TRFMA, 2021).

Years	Number of SM's	Leasable SM Area (Thousand m^2)	Population	SM Leasable Area per One Hundred Thousand Persons (m^2)
2007	145	4,063	70,586,256	5,756
2008	189	5,093	71,517,100	7,121
2009	207	5,800	72,561,312	7,993
2010	232	6,533	73,722,988	8,862
2011	264	7,615	74,724,269	10,191
2012	296	8,229	75,627,384	10,881
2013	326	9,247	76,667,864	12,061
2014	346	10,023	77,695,904	12,900
2015	364	10,799	78,741,053	13,715
2016	390	11,359	79,814,871	14,232
2017	429	12,611	80,810,525	15,606
2018	453	13,453	82,003,882	16,405
2019	454	13,508	83,154,997	16,244
2020	447	13,591	83,614,362	16,254

Tab. 3: Shopping Mall (SM) investments and population relations in Turkey (TURKSTAT, 2021)

There are 40 – 50 national FM companies and many small family business service providers (cleaning, catering, security and IT) which are engaged in the FM sector in Turkey. However, there are also around 10 international companies such as JLL, ECE, ISS and so on. Although the data on the sector are not accurate, the number of employees of 29 companies that are members of TRFMA is around 110 thousand. It is accepted that approximately 9% of the employees in the FM sector are employed by TRFMA member companies. Most of the employees in these companies are paid minimum wage and the personnel expenses in the facilities are approximately 50% within the total FM expenses. Consequently, it is stated that approximately 1 million people are employed in the FM sector and the market volume is approximately 15 to 18 billion USD (TRFMA, 2021).

For assessing the domestic market general situation and future perspective, qualitative analysis realized with the selected experts employed in public and private institutions. The main objective of the interviews is outlined the descriptive side of the supply and ignored demand sides. The main issues emphasized by the interviewed 45 experts in relation to the current situation of the Turkish FM and the areas to be improved can be listed as follows:

i. The requirement to develop the facility management market in the public and private sectors: In public institutions, FM services are carried out by public employees, and it is considered that there is a significant gap in the public sector in terms of outsourcing and provision of FM services. In both public and private institutions, the services and experiences of professionals specialized in FM and the strong FM institutions working in this field are needed to a great extent.

ii. Insufficient coverage of facility management and service contracts: It is observed that the scope of the service contracts used in many facilities is insufficient and their content is generally not compatible with international FM standards.

iii. High expectations of owners and users from facility management and structural problems and low-quality service of facility management companies: As the luxury housing constructions increased in the country, the expectations of consumers have also increased. An extra demand for comfortable living spaces has been added to the desire to have a safe living space, which is seen as the most important of the needs. Buildings equipped with the highest level of technological infrastructure, socialization areas, shopping centres located in the lower parts of the buildings have created areas of potential management need for FM firms, and the increase in service demand in this area has not gone unnoticed by foreign companies and investors.

iv. Post-pandemic situation and the increasing need for facility management services in retail trade and service sectors, especially in the post-COVID19 period: Retail trade, tourism, office spaces and related sectors were among the most affected ones in the COVID19 pandemic period. Travel restrictions resulted in a 61% decrease in the number of passengers transported by air in 2020 compared to the previous year, and occupancy in hotels, offices, and shopping centres remained low. On the other hand, tourism continues to be one of the hardest hit sectors by the COVID-19 pandemic, particularly for Turkey. Government in Turkey have taken measures to ease the economic shock to households and businesses, but longer-term the industry will need to adapt to a post-pandemic "new normal."

v. Enforcing the requirement of urban facility management practices particularly in commercial business areas, condominiums and urban transformation project areas: In cities, the provision of local services at the district and neighbourhood levels, public transportation, street-alley management and the provision of services that affect the quality of life at the neighbourhood scale are still carried out by municipalities and public institutions, and there is a need for improvement of FM in this area. Especially in urban transformation projects, the application generally covers the transformation of slum areas and it is ignored that the right holders who previously resided in these areas had relatively more freedom-based lifestyles.

vi. Insufficiency of qualified human resources: The analysis of the administrative records and the results of the interviews show that the management of the facilities that require high costs and involve high risks can be long-lasting and successful if only they are carried out by experts and professional companies who have been trained in this field. With the increase in institutions that provide undergraduate, graduate and doctorate programs and certificate education in this field in Turkey, it will be possible to train qualified and specialized experts needed in the sector.

vii. Insufficient and dispersed facility management legislation and failure to identify the responsible and authorized public institution: Due to the widespread use of condominium properties such as multi-storey buildings, commercial and common areas and social facilities, such as sites and plazas, and as complex facilities such as shopping malls, ports, marinas, airports, logistics centres, licensed storage facilities, factories and industrial zones are dealt with in different legal regulations, it does not seem possible for such facilities to be managed effectively.

Institutions or organizations providing education and training on FM did not exist before 2000. It is observed that the number of scientific research and application projects directly related to facility and real estate management issues and the number of international articles and projects originating from Turkey are at a very limited level in Turkish Higher Education Institutions, and existing studies are limited to construction management rather than FM. As it has been established on February 2, 2007, Ankara University Department of Real Estate Development and Management has become the first academic institution to provide education and to plan and carry out research in the field of FM. Facility and Real Estate Management discipline is among of the basic science areas of the department, and many undergraduate and graduate students are currently taking courses and conducting research projects in the fields of FM, facility services market, standards and institutions, project finance, project and construction management, real estate and asset management. In addition to these, the department attaches importance to a combination of theory and practice in the field of FM, has sector professionals in its advisory boards, and shares the developments in the field of FM with the sector employees through regular conferences and workshops every year and contributes to the increasing awareness on the subject matter. The protocol executed between Ankara University Department of Real Estate Development and Management and TRFMA is very important in the cause of setting an example for cooperative activities between universities and other institutions. It stands out as an important step taken for the establishment of the concept of FM and for executing application and research in coordination. Cooperation and accreditation negotiations are ongoing with the International Facility Management Association (IFMA) to ensure international recognition of the programs in facility and resource management, real estate, and asset management by 2021, and the Department has become a member of the European Facility Management Network (EuroFM).

4. Conclusions and Recommendations

It can be asserted that the current situation of the FM market in Turkey is insufficient, but that the FM market has had a faster growth trend in recent years. However, compared to European examples, Turkey FM market still has not made significant and sufficient progress in areas such as institutionalization of the FM market, professional development, establishment of standards, accreditation of professionals and institutions providing services, institutionalization of companies, preparation of FM legislation, design of business and service contracts, preparation and implementation of best practice guides although there are certain studies carried out by the Turkish Vocational Qualifications Authority and Turkish Standards Institution (TSE).

FM is gradually being accepted and considered as an independent profession and a professional field of work in the domestic market, and the requirements of professionalization of FM for commercial facilities and multi-storey and high-rise residences, office and residence buildings, mixed real estate, hospitals, airports, and many infrastructure investments is accepted by almost everyone. Institutionalization of FM companies, structuring of service delivery capacities according to investor and user expectations, harmonization of international standards and licensing of experts and companies in the domestic market is required and the service areas of established companies should be limited to FM services, and in addition, FM companies should only be allowed to provide FM consultancy and facilities services with the scope of specialization.

It is noteworthy that FM associations and integrated FM companies are rapidly established, and foreign companies show great interest in FM in Turkey. It is observed that by regulating the supply and demand sides of the FM market and extending the use of outsourcing in public institutions, it will be possible to ensure both the rapid growth of the market volume of the sector and imposing regulation-related works in a stronger and faster manner. Classification of management companies that integrate space-human-process with single service delivery, performance measurements and standards development, reorganization, and categorization of professional groups with those who provide individual services, those who supply and support

FM companies (such as security, catering, cleaning, software industry, technology companies) will contribute to improving the service delivery and quality assurance in the sector. In the field of FM, there is a requirement to establish a legal and institutional structure for the provision of services, making contracts, developing standards, determining the responsible/authorized public institution, and clearly regulating its duties. It is noteworthy that experts and companies operating in the field of FM are very keen on establishing associations and that associations are disconnected from each other and it is observed that a structure such as a FM council or federation must be established, and national FM policies must be established. It is envisaged that cooperation between the existing academic institutions and FM associations with institutions such as Euro FM, Global FM and IFMA, and especially, cooperation of academic institutions with European and US universities, can significantly contribute to the training of expert staff for the sector and to increase the research and training capacity of in the field of FM. The need for academic institutions and professional companies that will carry out education, research, and consultancy activities in the field of basic FM and advanced facilities, real estate and asset management is increasing day by day. It should be ensured that institutions that will provide FM consultancy are in cooperation with construction and real estate development companies and it should be made mandatory to incorporate FM consultancy services as a team in project development phase of a certain size. For the professional FM understanding to be established in the public and private sector and the sector to create more efficient and effective and more employment, it will be beneficial to licence all people who operate in the sector (real and legal persons) by an umbrella institution and the individuals to be employed in the sector are certified in the context of their authority. As an example of this process, the classification, certification and licensing models made in the field of Senior Level Manager (SLM), Mid-Level Manager (MLM) or SRC certifications in the transportation and logistics sectors can be shown.

Despite many difficulties and shortcomings, the FM profession and sector were identified to have a greater pace and rapidly developing in the country, and during the COVID19 pandemic, it was determined by many stakeholders that management of the built environment should be a professional business by many stakeholders, and significant progress has been made in this area. Individuals and institutions providing FM services in the construction and real estate sectors are expected to assume higher level of roles and provide specialized services in projects and facilities as “strategic partners” or “consultants”. Demand for the national FM market is increasing day by day and it seems possible to share FM experiences with neighbouring countries. In cooperation with international professional organizations, it will be possible to develop professional standards, to train qualified human resources and to improve their knowledge level and competencies with their employment in the sector. It is also possible to expand the market by outreaching of FM companies operating at national level to other countries, improving networking and cooperation opportunities. There is no administrative and legal regulation related to FM in Turkey yet.

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Science meets Practice II:

Practical Usage of Emerging Technologies in FM

Decentralized Management Framework for heterogeneous Devices in FM

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Abstract

The rapid technological development of smart building appliances leads to changing system interfaces with each iteration of the product development cycle. Combined with the huge amount of device manufacturers and different submarkets for smart devices this leads to difficulties for the integration of different systems into an interconnected Building Automation System (BAS) and further into Building Management Systems (BMS). Existing solutions for device interoperability are lacking in certain aspects. The Web of Things (WoT) protocol is the most promising approach for communication. Based on the relevant literature, this paper presents a framework architecture that augments the WoT protocol with decentralized authentication and authorization capabilities based on biscuit tokens. Furthermore, baseline protocol workflows enable the integration with existing management systems while creating an immutable configuration and workflow history of the building infrastructure. We further discuss how this framework enables new use cases and argue for its potential to decrease operational cost and thus increase building value.

Keywords: IoT, Blockchain, Facility Management

1. Introduction

One of the aspects of Facility Management (FM) is concerned with the provisioning and maintenance of all the systems that are integrated into a building. From the heating, ventilation, and air conditioning (HVAC) system, the lighting and shading systems, infotainment systems to access control and security systems many devices can be part of a building's infrastructure and hence have to be provisioned, configured, and maintained. Additionally, the usage of the individual occupants may have to be tracked to allow for billing. Access to certain systems has to be managed and traced as well. With the introduction of Internet of Things (IoT) devices, many parts of these management tasks could be handled digitally by integrating the devices into a management system.

There are however several hurdles when it comes to the integration of the devices into a general management system. Due to the variety of device types and device manufacturers, there is no common interface to connect these systems. Even more, also the architecture of the individual systems can be diverse. Some work locally, as in the case of traditional home automation systems such as KNX or local automation hubs such as OpenHAB and HomeAssistent. Other systems are dependent on the cloud such as in the case of Nest, Tuya, or similar systems. For this reason, there is the need for a framework, that can bridge the different silos and their different architectures and interfaces while preventing the formation of a new silo with an open, decentralized architecture that facilitates the integration of any technology.

To allow the creation of a management system using such a framework, several capabilities have to be present. The primary goal of the framework is the connection of different device types. This allows for cross-domain interactions. For this reason, a standard communication protocol is necessary to facilitate these interactions. However, the communication and interaction between subsystems have to be governed to prevent unintended access to critical infrastructure. Therefore, the framework has to keep a record of which subsystems are known and what kind of interaction between them is allowed. Furthermore, subsystems could be used by several users with different access requirements and authorization. Hence the framework needs a concept for the representation of devices, users, and access policies. Due to the fact, that the devices need the data on devices, users, and access rights but also other application-specific data to function properly, the framework has to provide a concept for the decentralized storage as well as methods for the controlled update of this information.

This framework can be the foundation of a decentralized, local-first, off-line capable device management system. Such a system would allow many novel use-cases and capabilities. First of all, device on-boarding and configuration can be managed using a single conceptual approach. The overall system state is distributed over the individual devices and thus independent of external infrastructure. This creates a kind of decentralized digital twin, that lives between the local system nodes and is bundled with the building, hence increasing its value. The interaction with centralized systems of record such as Enterprise Resource and Planning (ERP) is possible as those systems can simply act as subsystems themselves.

The interoperability of devices is an important prerequisite to enable the full potential of the IoT (Noura et al 2018). The Web of Things (WoT) is one standard that aims to enable interoperability across IoT Platforms and application domains. The key essence is to use already well-known and established Web technologies like Representational State Transfer (REST), Hypertext Transfer Protocol (HTTP), Constrained Application Protocol (CoAP), and many more to establish a broad basis for interoperability and connectivity over a heterogeneous environment.

The WoT focuses on the standardization of the communication interfaces while leaving aspects such as authentication and security open. This is not an issue for homogeneous systems that can use a centralized system to establish communication authentication. However, for heterogeneous systems this approach is unsuitable. For this reason, a system to manage the identity of the different devices and additionally also the users is required for a secure integration. In this paper, we first present a study of the relevant literature in the following section. The focus of this study lays on the technological gaps in the proposed solutions as well as technologies mitigating the identified shortcomings. Based on these findings, we propose a framework architecture for the integration of IoT devices and systems. The framework consists of WoT gateways that act as bridges to the common data and communication environment. The gateways store the state of the overall system from the perspective of the underlying subsystem i.e. configuration of the gateway itself, the configuration of the subsystem, the identity of the gateway as well as access permissions for devices and users. The data sets contained inside a gateway are synchronized using the baseline protocol, by storing cryptography hashes of the current and previous versions of the shared data on the blockchain. In Section 4, we discuss how this framework enables new use cases and argue for its potential to decrease operational cost and thus increase building value. In the last section, we conclude that the proposed framework has a high potential to solve the described problems but needs to be implemented as future work for specific use cases and subjected to an extensive evaluation.

2. Background

Over the years many Building Automation Systems (BAS) from different vendors were developed. Many of these systems were developed without the focus on interoperability to other vendors or technologies. Therefore, many BAS form an isolated silo, which raises the cost because of vendor or technology lock-in. Furthermore, it must be distinguished between self-operational systems and Web-enabled ones. For example, KNX or BACnet can run isolated from further components like cloud or management tools and provide a standardized communication interface. The integration and commissioning are done by professionals and require a cost-intensive configuration tool and a lot of know-how. On the other side, there are many so-called web-enabled smart home devices like Tuya, Google Nest, Apple Home Kit, or many more, which require Internet access to provide their full potential. Depending on the vendor, they provide limited compatibility with other technologies. Therefore, community-driven BAS like Home Assistant, OpenHAB, or Domoticz emerged which act as an integrator between various vendors and technologies. These community-driven BAS act as a central point where all devices and also automated scenes are stored and configured. This is also the major drawback of these systems, as they represent a single point of failure.

Web of Things (WoT)

WoT was presented in Guinard (2011) and later on adopted by the W3C in its working group. The working group at W3C is divided into different task forces which are working on parts of WoT. In the current state there are five task forces:

- WoT Architecture
- WoT Thing Description
- WoT Discovery
- WoT Security
- WoT Scripting API

These task forces also represent the key building blocks of WoT. In April 2020, the W3C published the first version of the Architecture and Thing Description (TD) as a recommendation and has thus formed a solid foundation for WoT. The key properties of WoT are flexibility, compatibility, scalability, and interoperability. Figure 1 shows the abstract architecture of WoT designed by W3C using these key properties.

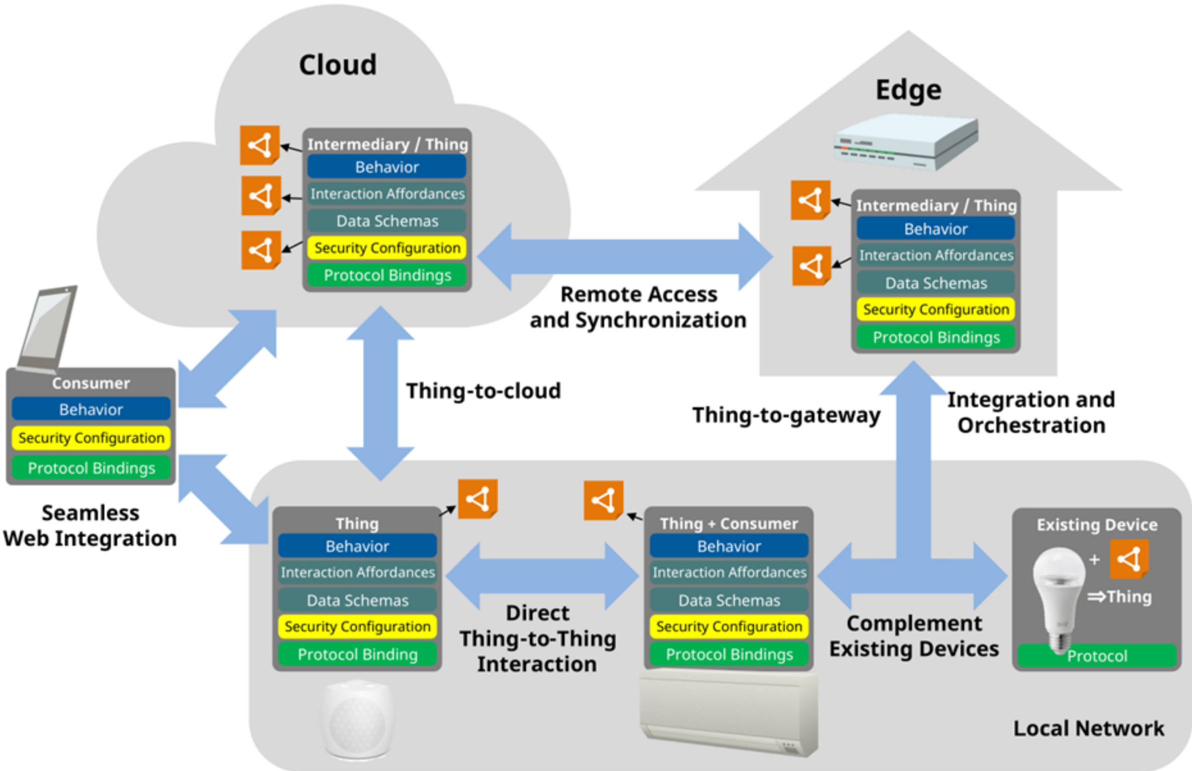

Fig.1: Abstract architecture of WoT (Lagally et al, 2020) (© W3C Software and Document Notice and License (W3C, 2015))

The architecture of WoT is open to integrate every possible device regardless of whether it is WoT enabled by default or uses legacy communication standards. Looking at Figure 1 on the system topological level, one can see how WoT devices interact with controllers, devices, agents, and further Web services. Furthermore, it shows, that WoT allows communication over different domains, such that different buildings can form a group, or different services can be aggregated to provide additional information to the system. This can even be enhanced to form groups that are representing physical cities or parts of them.

Getting into more detail, the central building block of every device is the Thing Description (TD) which describes the metadata and interfaces of things, where a "Thing" is an abstraction of a physical or virtual entity that provides interactions to and participates in the WoT (Kaebisch et al., 2021). Such interactions are called Interaction Affordances and can be properties, actions, and events. Figure 2 shows an example of a TD, consisting of the metadata about the device itself and its Interaction Affordances. The TD itself is a JSON-LD file, which is both machine and human-readable.

```
{
    "@context": "http://www.w3.org/ns/td",
    "id": "urn:dev:ops:32473-WoTLamp-1234",
    "title": "MyLampThing",
    "securityDefinitions": {
        "basic_sc": {"scheme": "basic", "in": "header"}
    },
    "security": "basic_sc",
    "properties": {
        "status": {
            "type": "string",
            "forms": [{"href": "https://mylamp.example.com/status"}]
        }
    },
    "actions": {
        "toggle": {
            "forms": [{"href": "https://mylamp.example.com/toggle"}]
        }
    },
    "events":{
        "overheating":{
            "data": {"type": "string"},
            "forms": [{
                "href": "https://mylamp.example.com/oh",
                "subprotocol": "longpoll"
            }]
        }
    }
}
```


Fig.2: Thing Description sample (Kaebisch et al., 2021)

Every WoT enabled device has five building blocks, Behavior, Interaction Affordances, Data Schemas, Security Configuration, and Protocol Binding(s), as can be seen in Figure 1. These blocks are also represented in Figure 2, where the thing named `MyLampThing` uses basic security, has one property called status which returns plain text, an endpoint to toggle the lamp power state, and an event interface which can inform other systems in case of an overheat of the lamp.

After generating such a TD, it needs to be distributed to the other devices on the network, and it must be guaranteed that only permitted devices can communicate with each other. This problem is being worked out in the WoT Discovery Task Force. At the time of writing, the discovery part of WoT is a working draft (Cimmino et al, 2021). But even in this state, there are five possible mechanisms to find other devices on the network. These can be separated into local and non-local discovery mechanisms, whereas the first targets local network structures and the second aims at discovery over the Web. Figure 3 shows the discovery mechanisms of WoT.

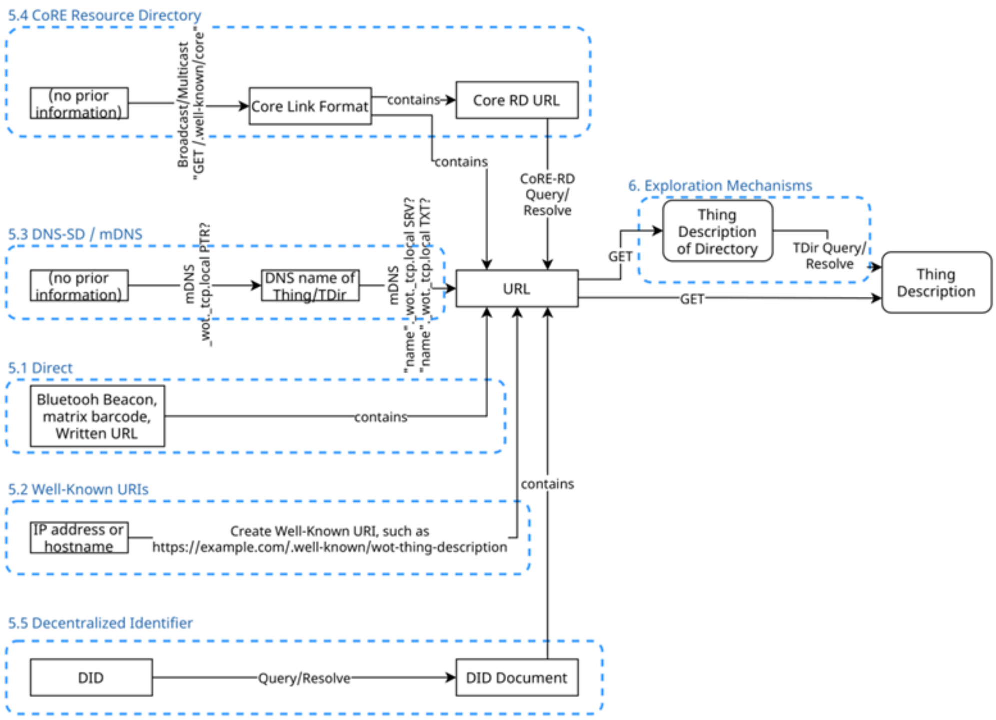

Fig.3: WoT discovery process overview. (Cimmino et al., 2021) (© W3C Software and Document Notice and License (W3C, 2015))

To get a list of devices on the network, there is an exploration mechanism which is a TD Directory. This directory provides the ability to get, search, modify, and delete TD. So that, it is possible to search devices by category or ID. Furthermore, the TD Directory also provides information about authentication mechanisms, this can be Open Authorization (OAuth) or any other provider.

WoT heavily relies on Web technologies so that they also thought on having the ability to dynamically adjust the behavior of devices. Therefore, a similar approach like client-side scripting of the browser was considered by the WoT Scripting API task force. The task force defined a runtime that is executed by a WoT device, like a gateway.

Decentralized State

A major concern in distributed system design represents the handling of shared states. More specifically, communication of state changes and the consensus on the current state are difficult problems in computer science. Depending on the fault and security models, different approaches can be implemented to achieve a shared state. In a centralized system, a single service acts as a reference for all other services. Such a service is often called a system of record. In a decentralized system, on the other hand, multiple services take part in a consensus process to establish a common view of the system state. Many approaches lie in between these two extreme cases. Due to the desired properties of the framework, a decentralized architecture is required.

Blockchains or more specifically Smart Contracts (SC)-enabled blockchains such as Ethereum offer a decentralized consensus together with a strong guarantee of immutability (Buterin, 2014). While changes to the state are proposed via transactions, SCs define the rules for the state changes and determine the acceptance of transactions. Miners group and order transactions compute the new state and publish it in a new block. Each following block confirms the validity of the blocks before. The blocks can only be changed by recalculating the Proof of Work (PoW), which is prohibitively expensive. This makes blocks immutable after a short amount of time (Wood et al., 2014). However, this distributed consensus has certain drawbacks as the state and its changes need to be shared publicly. This has implications for privacy and operational costs. For this reason, only data that is necessary for the evaluation of the SC should be stored on-chain (Eberhardt and Tai, 2017).

There exist many trade-offs for the usage of on-chain vs. off-chain storage and computation. Eberhardt and Heiss give possible strategies for moving data and computation off-chain without losing desired properties of the blockchain (Eberhardt and Heiss, 2018). Baseline protocol, an emerging standard for blockchain-secured data exchange, follows in the same direction. In its draft version, available at the time of this writing, baseline-enabled services exchange data via peer-to-peer communication and submit only references of the data bundled with a compliance-proof to a so-called 'Shield'-SC. A so-called 'Verifier' SC checks the validity of the new state commitment, after which only the new reference is stored on the blockchain. While this approach minimizes the amount of data that needs to be stored on-chain, computation of the verification is off-chained using a zero-knowledge proof system, which additionally improves privacy. Data sharing and cooperation on the baseline protocol are organized in workgroups consisting of several participants. The participants create workflows for the individual business processes. These workflows consist of work steps that define which participant has to provide data under respective conditions to complete the step (Baseline Community, 2020).

Authentication and Permission Management

The WoT standard leaves the authentication and management of access permissions open to individual implementation (Lagally et al., 2020). This is necessary, as different deployments have different requirements. One proposed approach is based on the OAuth 2.0, an open standard that allows the delegation of access rights to services (Hardt, 2012). In its workflow, an identity provider provides tokens to an application that can be used to access services representing the user. Biscuit is a standard for authentication tokens that can be used on OAuth deployments. It allows for offline validation of fine-grained access policies that are encoded in a special logic language. The tokens can be attenuated by the token holder to restrict access even further. This property is very useful when passing tokens from service to service during user requests as it allows to narrow down access policies to the scope of the request (CleverCloud, 2021).

3. Framework

In this section, we present our framework for a decentralized, distributed device management system for diverse IoT landscapes. The framework uses the WoT standard to handle communication between different IoT devices and -networks. Gateway components bridge the gap to the underlying systems if there is no WoT compatibility. These gateways additionally store the overall system state i.e. known devices, users, and access rights, as well as configuration data. State updates are distributed using workflows in the baseline protocol, which creates a common reference point for the current and previous versions of the system configuration.

Nowadays, there are many smart devices already in the market and it is necessary to integrate these devices into our approach, therefore gateways are used which can on one side talk to the non-WoT-enabled devices and on the other side provide a bridge to the world of WoT. These gateways not only care about the right translation between the communication protocols but also handle device configuration and enforce access permissions for communication between the devices.

As demonstrated in Figure 4, gateways in our framework provide access to interfaces of the underlying systems via WoT-properties, -actions, and -events. The access to these interfaces is guarded and they can only be used with authorization tokens using the OAuth 2.0 protocol. This allows for different security policies for any of the device interface points. Administrative users generate biscuit tokens that encode user and device identities and roles. The biscuit logic language is used to enforce authorization rules in the devices. While interfaces related to the control of the devices can be used by simple delegation to the underlying systems, for interfaces that change the configuration of a device, special care has to be taken. Configuration changes should only occur via baseline workflows to ensure, that the history of changes is preserved and changes can only occur according to the proper workflows.

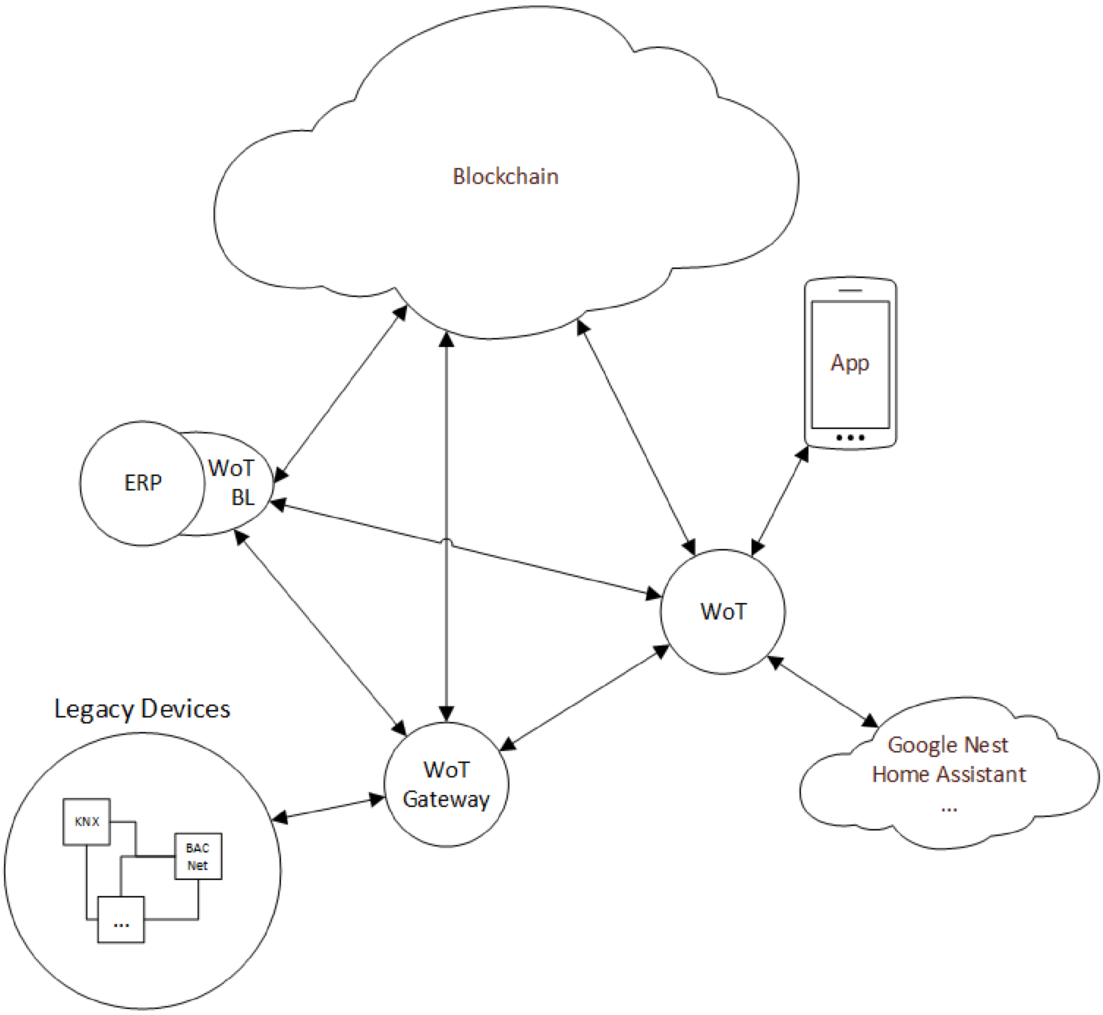

Fig.4: The framework architecture

To enforce that the workflows are followed and that the state reference is stored on the blockchain, the gateway not only checks for the authorization for the interface access but additionally verifies the baseline workflow. If everything succeeds the underlying system is updated and the new configuration is stored in the gateway and depending on the workflows also shared with other systems such as databases. Similarly, state updates related to the configuration of the framework, such as users, devices, or security policies, can only be updated via baseline workflows. These workflows can be arbitrary complex and for example, require the consent of several users or the submission of additional information such as work reports.

4. Discussion

The deployment of the framework allows for many new use cases that are not possible without it. The user, device, and security management establish a foundation for secure user access and device interaction according to the WoT vision. This foundation can be used to implement smart building applications that span systems that could not communicate without a dedicated integration. This has many advantages, as it enables the possibility to add new features to the BAS without a redesign of the system. For example, when a solar power plant is added to a building roof, the availability of local power can be communicated to other systems to trigger energy-intensive processes. Another possibility is the replacement of broken components of an installed system with components from another manufacturer and the integration via the framework. In this way, the established infrastructure can be replaced piece by piece without requiring a complete reinstallation.

The powerful authorization system opens up another set of use cases. The usage of biscuit tokens allows the segmentation of a subset of the interfaces and hence allows the definition of intricate access patterns. This opens up the possibility to give access to certain parts of the system via standardized interfaces. For example, in the case of shared spaces, such as rental apartments or hotels, guests could be given access to the smart home appliances of their rooms. Access to special features such as air conditioning or wellness appliances could also be controlled via the framework and the connection to the blockchain would even allow automating the payment for these services.

However, the biggest advantage of the framework comes from the usage of the baseline protocol for the synchronization of configuration data. Any change to the configuration can be managed using individual workflows. Due to the open architecture of the baseline protocol, other systems of record can be integrated. For example, a repair workflow could be started in the ERP system of the FM, which triggers a repair assignment in a contractor's Customer Relationship Management (CRM) system and additionally grants access to the interfaces of the affected subsystems. After a change of some hardware component, the workflow would then be finalized with the deployment of the new configuration and submission of the contract report together with a payable invoice. While every step of the workflow is committed to the blockchain with a reference to the data, the data itself is stored by the individual stakeholders, ensuring that only minimal data is exchanged and shared.

By using blockchain technology combined with WoT it is possible to generate a historical log of all changes done to the system and of all changes of device configurations in a BAS. This means that any modifications to the BAS are irrevocably stored and can be traced back at any time. From these detailed logs, the condition of the components in the building can be inferred and thus can attest to the actual value of the components and ultimately of the building. Due to the decentralized nature of the framework architecture, it is possible to migrate the data and access rights to a new owner in the case of a sale. No additional infrastructure is needed to interact with the building.

5. Conclusion

The interoperability of IoT devices and their integration into higher-level FM systems is an important aspect necessary for the digital transformation in the sector. Proposed solutions are lacking in certain parts with the WoT protocol being the most promising candidate for device interoperability. However, for a heterogeneous and thus decentralized device landscape user, device and security management is a missing aspect of the standard. Furthermore, it lacks the capability for integration into higher-level systems of record such as ERP and CRM systems.

In this work, we presented a framework enabling the deployment of WoT in decentralized architectures and narrowing the gap between IoT systems and process management in FM. The framework security is based on biscuit tokens which allow for offline authentication of users and enforcement of device access. The known devices, users, the access policies as well as the configuration of WoT gateways and underlying legacy subsystems are managed in baseline workflows. Smart Contracts store cryptographic references to the system state and enforce workflow procedures, while systems only share the necessary data in a peer-to-peer fashion, ensuring privacy. The framework opens up new use cases in FM for configuration, maintenance, and operation that increase building value and help in the digital transformation of management processes. To demonstrate the promising features of the framework, proof-of-concept prototypes for specific use cases in the described area will be implemented and evaluated extensively in future work. Additionally, tooling and concepts for the management of configuration complexity and deployment automation will be investigated further.

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Developing A Standard Workflow for Drone Roof Inspections

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Abstract

Technology use in construction and facilities management has seen an increase over the past decade with new and emerging technologies of Unmanned Aerial Vehicles (UAV), or "Drones". Drones have been used by Facilities Managers (FM's) in the post occupancy stages to monitor and inspect the condition of various building envelope systems, as a part of protecting the building assets of people, processes and technology. Although there have been previous studies using drone-monitoring on roofs, the evidence of a standardized process is found to be very limited. The goal of this study is to develop and provide a standardized protocol that FM's can utilize in conducting low-slope roof inspections. To develop this framework, a detailed analysis of published literature covering the current processes to inspect building envelope systems was used to develop a structure. Additional steps were identified to add to the existing body of knowledge providing a full sequence standardized workflow specific to low slope roof inspections using drones. As a part of the study, two low-slope roofing inspections with drone technology were conducted using the steps from previous studies joined with the additionally proposed steps to create a formalized workflow.

Keywords: drones, workflow, inspections, roof

1. Introduction

The usage of drones can be traced back to the 18th century during the Italian war of independence (Rakha and Gorodetsky, 2018). During those past centuries, the military needs were the major funding sources to develop the use and research of unmanned aerial systems (Rakha and Gorodetsky, 2018). However, technological advancements coupled with International Aviation Authorities' easing of restrictions in the 21st century have allowed for the rise of drone usage with public safety, hobbyists, research purposes, commercial and public sectors for various functions (Aydin, 2019).

Drone use has proved to be both time saving and cost effective as the vehicles are able to quickly access hard-to-reach places manually (Falorca and Lanzina, 2020). As a result, many construction partners are developing and utilizing drones to inspect, monitor, and analyze building infrastructure and activities (Duque et al., 2018). The field of civil engineering has also recently gained increasing interest in the usage of drones for bridge inspections (Duque et al., 2018). Chen et al. (2019) report a growing trend of utilizing camera-equipped drones for carrying out building façade inspections. Short-term and long-term forecasts also show that the drones are here to stay as a utilized asset (Aydin, 2019). Marathe (2019) studied drone usage for maintenance and inspections of long pipeline projects and concluded that drones could be effectively employed for this purpose. All these studies show the growing usage of drones in monitoring, inspecting and analysing the built environment envelope systems. Overall, the use of drone technology in the built environment has been conducted by both in-house workers as well as contractor-consultants.

Roofing systems are one of the critical components of the building envelope because it protects the assets within the building including people, place, process, and technology (IFMA). With this responsibility, is in the best interest of the FM, to maintain its high performance. It becomes even more important to utilize technology in the roofing industry since it is one of the sectors where the workforce shortage is severe (Delvinne et al., 2020). Studies by researchers Schweyer (2020) and Bridgers and Johnson (2006) suggest technology adoption is one of the strategic solutions to overcome this shortage.

A considerable amount of research has been carried out to investigate the utilization of drones for inspection in the roofing industry. Bodily (2020) compared the roof inspections carried out by drones and conventional methods and concluded that drones are more efficient in terms of time, cost, value, and safety than the conventional methods. Bodily also outlined that there was a notable and feasible cost-benefit savings by the use of drone inspections over much of the traditional manual inspection methods; however his experience was that facilities managers did not have an organized plan of action to utilize this technology. Gajjar and Burgett (2020) documented the detailed comparison between traditional roofing inspection and drone roofing inspection with respect to low slope roofing. Bown and Miller (2018) studied drone use for sloped roof inspections and presented pros and cons for each step. Between the studies of Bodily and Bown & Miller, it can be deduced that low slope roofs are more common in the commercial/industrial arenas while higher "pitched" roofs are most commonly found in the residential fields. The main differences between these two types of structures seems to be the building size and how that affects the equipment setup and takedown times for inspections. The studies also presented viewpoints for improving the outcome of the drone inspection such as having a standard for conducting the inspections across the industry.

The previous research for low slope roof inspections using drones has primarily been focused on identifying the advantages and disadvantages of using drones for roofing inspections. However, studies to develop standard protocol steps or a standard workflow for better outcomes of drone roofing inspection remain to be explored (Gajjar and Burgett 2020; Rakha and Gorodetsky, 2018). Previous research identified a few studies regarding the steps in using drones for bridge inspections (Duque et al., 2018), building thermography (Entrop and Vasenev, 2017) and building envelope inspections (Rakha and Gorodetsky, 2018).

Duque et al. (2018) conducted a study to compare the benefits of bridge inspections using drones with the traditional method. The study recommended a five stage workflow steps to conduct these inspections. The five steps consisted of bridge information review, site risk assessment, drone pre-flight setup, drone enabled inspection and damage identification. The study concluded that there were some limitations with drone use like weather, high wind, overexposure of camera due to sun or snow, obstacles and areas with the Federal Aviation Administration regulation limit.

Entrop and Vasenev (2017) researched to develop a workflow for surveying building thermography. The said workflow was developed through literature review and a series of test flights. The research defined the objects of interest as the object to be inspected or targeted and identified four major steps to carry out the inspection. The four major steps consisted of planning the initial set-up phase, outlining a safe and secure flight area, accounting for photography requirements – momentarily photos or continuous video collection, and designing a flight path for each element within the object of interest. The study concluded with some limitations as the study was not able to observe all possible external variables, including but not limiting to influence of wind, precipitation and temperature difference in indoors and outdoors.

Rakha and Gorodetsky (2018) conducted a comprehensive literature review of studies which addresses the topic of visualization of heat transfer using infrared imaging and identification of standard steps for drone operated energy audit missions. The steps consisted of pre-flight inspection procedure, during flight anomaly detection and post flight 3D CAD modelling developed through the data gathered by the drone. The study concluded that the steps need to be refined by further testing, replication and gathering empirical evidence for development of standardized workflow.

Bown and Miller (2018) studied the use of drones for conducting steep-slope roof inspections. The goal of the study was to compare the drone inspection with the conventional inspection to mitigate the risk of inspector injury and efficiency involved with steep-sloped roofs. The study chose a three-phase path to conduct the drone roof inspections. Phase 1 included the choice of UAV or drone. Phase 2 explored the image quality and drone flying methods. Phase 3 consisted of approaches to optimize the data captured by drone flight. The study concluded that the drone's inspections can replace manual inspections in most of the cases and that the still images and manual control drone is efficient for large roof areas. Additionally, the study noted that current software frameworks were geared more towards 2-dimensional geographical mapping and would not be serviceable for the angular roofing views that are needed for such inspections. The study recommends the drone inspection as an alternate process for an economical and efficient technology-based method that is safer than conventional methods.

From previous research, it can be included that research on developing workflow steps within roofing industry for low-slope drone inspections is very limited. There was no set protocol found that was being used with any group of contractors, researchers or building owners. Therefore, the goal of this study is to add to the existing body of knowledge by developing and providing the standardized workflow that FM's can utilize. Additionally, this research would include the testing, or flying, of such a sequence to verify that it was both possible and feasible. First, the steps that are published in the literature to inspect building envelope systems were used to develop an initial protocol of how such inspections are carried out. Second, various low-slope roofing inspections using a "DJI Mavic Pro" brand drone were conducted using the protocol from previous studies. Lastly, additional workflow steps were identified to add to the existing body of knowledge providing a full sequence of a more standardized workflow which would be specific to low-slope roof inspections.

2. Methodology

As demonstrated in Figure 1, a systematic literature review was conducted to identify previous research on the workflow for drone inspections. A total of eighty-six (86) papers were initially identified based on the abstract of the journal articles. Only peer published articles were selected for the review and literature from thesis, books, online articles and non-peer reviewed articles were excluded. A total of twenty (20) peer-reviewed published journal articles were identified for a full text review to identify the protocol steps for drone inspections. Out of the twenty (20) articles, four (4) journal papers were selected for a qualitative analysis to identify the drone inspection steps. The key steps identified in the qualitative analysis formed the basis of the workflow steps for the drone inspections. The common steps identified through literature review for drone inspections are listed in Table 1. The thirteen (13) keys steps identified were grouped in common themes.

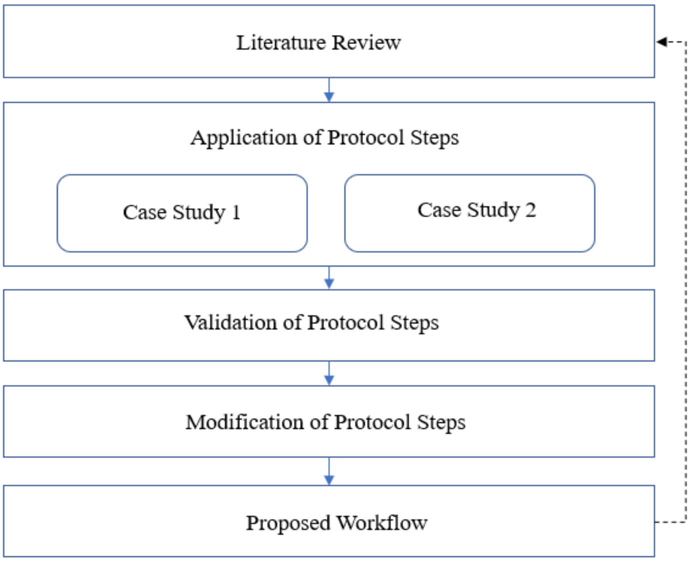

Fig.1: Research Methodology

Theme	Protocol Steps	Duque et al., (2018)	Entrop & Vasenev (2017)	Rakha & Gorodetsky (2018)	Bown & Miller (2018)
Selection	Equipment Selection	X			X
	Site selection	X			
	Site risk assessment	X			
Setup	Drone pre-flight setup	X		X	X
	Initial set-up phase		X		
	Construct flight path to connect all objects of research		X		
	Safe and secure flight area		X		
Inspection	Drone enabled inspection	X		X	X
	Damage identification	X			
Photos	Use of photogrammetric software to recreate the building components	X			
	Photos and Videos storage		X		
	Photo formatting			X	X
Summary Reporting	Summary reporting	X	X	X	X

Tab. 1: Identification of key steps and common themes as per literature review

Based off of the literature review, the above steps were used to conduct roof inspections at the Nauvoo and Independence sites. This was done as a preliminary test to practice following the compilation of protocols listed from existing literature. The DJI Mavic Pro (Fig. 2) was used for this study due to its easy portability, low cost and quick learning speed (72.5 learning hours). For an FM, this model has a reputation for providing appropriate benefit for a nominal investment. As a part of the learning, the operator/pilot was required to obtain the Federal Aviation Administration 107 licensing test for flying in the United States. The total cost of the drone, the accessory and the fees come to about $1,510.

Fig.2: Drone kit for roofing inspection

Case study 1 was performed at Nauvoo Visitors Centre located in Illinois with a roof area of 9,960 SF, shown in Figure 3. The building has a low-slope ballasted roof. The building was selected from the midwest region of the United States, as it experiences all four seasons of exposure and wear. The varying seasons also impact the roof penetrations and consisted of various mechanical units for heating and cooling the building. Case study 2, shown in Figure 4, was performed at Independence Visitor Center located in Missouri with a roof area of 10,010 SF. The building has a low-slope non-ballasted roof. The building was selected from the midwest region of United States, as it also experiences all four seasons, so as to identify any wear and tear on the roof.

Fig. 3: Case study 1 Nauvoo Visitor Center

Fig. 4: Case Study 2 Independence Visitor Center

Testing the literature review protocol consisted of following the general tasks shown on Table 1. This included site selection, equipment setup, general photo & video inspection and summarization of the data collected. Initially, the Nauvoo structure was drone-inspected in this manner alongside several other small structures in the local area. This process was carried out so that the authors could run an initial data validation while becoming cognisant of the process steps of the current studies.

The next step after the validation was the modification of the workflow steps to include a more complete perspective of the inspection intent. That is, to detail all viewable aspects of the roof as well as specific requests from its owners. It was observed that the full sequence workflow steps were not published and hence all the steps had to be combined and modified to fit the needs of the roofing drone inspections. The modified sequence of steps was added to the listed steps into a workflow system and was again tested at the two sites as needed to fulfil the research purpose. Both the buildings and a standardized full sequence workflow steps were proposed to carry out the drone roofing inspections. A detailed comparison of the existing and modified sequences is shown in the Discussion section of the paper on Table 2.

3. Findings

Through the investigational search of drone-inspection literature and the formation of a summary on Table 1, the authors were able to identify the past studies that have contributed to an inspection system for building roofs and other built structures. From this table, it was shown that, although there have been several portions of an inspection workflow proposed by previous authors, a full-length sequence had not been proposed and published. The lacking elements of the reviewed publications were outlined to be the following:

- Details of Actual Video/Photo sequences
- Owner-requested areas of focus within the structure
- Photo formatting and organizing for FM/owner review
- Testing of the full-scale process to demonstrate each sequence and how it fits into the full process

Additionally, the testing of such a full-length workflow was not possible to conduct because it did not exist. For this reason, a 5-step process was derived from the review along with a 4-part subset of steps for the photo and video flight data collection. These steps and subset items are listed below.

3.1. Inspection Field Notes

Similar to a surveying traverse, this step includes the compilation of a data record of items such as the date, weather conditions, general temperature, tools used and approximate time of day that the inspection was conducted. Additionally, names of the crew members involved with the inspection as well as the specific technical equipment (equipment selected) are recorded. Additionally, as a rule of safety, a site-risk assessment is also conducted to address any flight pattern hazards in the localized area. These hazards could be either on the ground or in the air surrounding the structure.

3.2. Equipment Checks

This is a brief inspection of the key flying equipment and an environmental assessment to assure proper safety to the pilot team and surrounding pedestrians. Equipment examination is carried out to assure that propellers are undamaged and free-spinning, battery life of the drone, remote controller and tablet screen are sufficient for the flight. Other components, such as spare parts and connections are verified to be safe and functional before take-off.

As the remote and drone are powered up, synced and lifted off of the ground, an in-flight check of the camera settings is made to assure that it is at the optimal settings for brightness, shutter speed focus according to the current sunlight amounts.

3.3. Drone Enabled Inspection: Picture Sets and Video Footage

The following steps outline the sequence of manually-piloted video and picture sequences that are recorded for observation and inspection. Of the four Picture Sets that are taken with a drone, one is with video footage and the other three are done with simple still shots.

a. Picture Set 1 - Short Video Isometric Swipe

The video footage consists of a short video taken of the whole structure as the drone moves sideways. This allows the inspector to see the isometric shape and roof composition in motion in order to grasp the overall exterior composition of the building. The “fly-around” video only lasts between 5-15 seconds.

b. Picture Set 2 - Top Views

This view is one taken from approximately 25-60 meters above the roof as the camera points directly downward at a 90-degree angle to the ground. Figure 5 illustrates this view from the two case study structures. It serves to give a single holistic shot of the structure and is followed up with several closer “regional” pictures of the various quadrants of the structure. The closer pictures allow for a more detailed summary of the surface of the roof.

Fig. 5: Examples of Picture Set 2 – Top Views

c. Picture Set 3 - Angular Views

This set of pictures takes various high definition “angular photos" of all major penetration points and parapet wall joints to the flat (or pitched) roof. This Picture Set is the most tedious of the data because it includes vent joints, chimneys, antennas, HVAC-related items, parapet walls, etc. Examples of this picture set are found on Figure-set 6, below. Photos are typically taken at about 5-20 feet from penetrations and from 2-4 sides. Occasionally there are environmental items, such as trees, power poles, and miscellaneous cables that make it difficult to get optimal views. However, the overlap of pictures over the areas should cover the necessary surfaces sufficiently.

Fig. 6: Examples of Picture Set 3 – Angular Views

d. Picture Set 4 - Special Requests & Problem Areas

This picture set is initially directed by the owner’s instructions. Special areas such as any roof damage, water ponding, window close ups, nests from animals or insects, mortar joint conditions or gutter conditions are typically requested areas. Figure 7 shows an example of an area where either damage or unfinished repairs have been undertaken. The pilot is also commissioned to document any unforeseen damaged or abnormal areas that are found during the flight inspection.

Fig. 7: Picture Set 4 – Problem area examples

3.4. Data management

Following the traverse of the pilot for inspection, the next step in the process is to compile all of the photos by structure, angle, footage and location. A hard copy of the electronic data (i.e.: thumb drive or hard drive) is given to the owner and the gps-stamped photos are also uploaded to a shared mapping service (such as Google My-Maps or Dropbox or another server-based storage source) so that the data is backed up on a cloud server and map.

3.5. Summary Reporting of Data

As a review of the pictures and video is conducted, a summarized report is created noting any areas that might be damaged, worn down or otherwise noteworthy for further review by the owner of the structure. This will allow for the owner of the structure to be given quick reference on what areas should be considered for further inspection, scheduled maintenance or emergency repairs.

4. Discussion

The literature review comparison of key steps and the proposed workflow steps is presented in this section as shown in Table 2. The identified thirteen (13) key steps were grouped in the five (5) common themes. These are common for both literature review steps and the proposed workflow. However, each major step has a different action subset as marked as a bullet point under each major step as shown below in Table 2. The subset was specifically modified and tested to be followed as a standardized full sequence workflow for carrying out roof inspections with drones.

Step 1 is derived from the literature review with the addition of recording crew members, weather conditions, location information etc. This helps to collect the data in a standard format for all roof inspections andhelps to mitigate the risk of excluding any data point due to human error. Step 2 is also based on the literature review information with the additional adjustments

Steps	Literature review protocol steps	Proposed workflow
1.	• Equipment/site selection and site conditions a. Equipment selection b. Site selection c. Site risk assessment	• Inspection field notes a. Site selection and overview b. Record data-time, weather, tools, crew c. Safety risk assessment for flight pattern
2.	• Setup a. Drone pre-flight b. Initial set-up c. Construct flight path d. Safe and secure flight area	• Equipment checks and set up a. Key flying components check b. Environmental assessment (for proper safety of pilot team/pedestrians c. Equipment examination d. Camera settings
3.	• Inspection a. Drone enabled inspection b. Damage identification	• Drone enabled inspection a. Picture set 1 (Short video) b. Picture set 2 (Top view) c. Picture set 3 (Angular view) d. Picture set 4 (Special request and problem area
4.	• Photo formatting and organization a. Use of photogrammetric software b. Photos & video storage c. Photo formatting	• Data management a. All pictures compilation b. Hard copy exchange and upload on cloud server
5.	• Summary reporting	• Summary reporting a. Review b. Special Notes

Tab. 2: Comparison of Literature Review Key Steps and Proposed Workflow Steps

of the drone camera to be optimized for the lighting levels at the inspection site. Step 3 has the additional sequences with the four different "Picture Sets" that are outlined. These items were not found in any of the literature reviews and were derived from the inspection practice and formulation of the initial round of drone inspections. These sets were also developed through conversation and advice from the owners of the structures and consultations with roof inspectors. These sets included short video footage, overhead views of the full structure, angular views of each of the penetrations and parapet walls and any requested items as well as anomalies or damaged areas. Step 4 is taken to manage the recorded data into a common format for the review by the FM or the owner requesting the inspection as outlined in data management step.

The final summary, step 5, includes a review of the entire process with highlighted special notes of areas of focus. This report can be done on paper, presentation or via video conference. A finalized workflow diagram of this process is shown below in Figure 9.

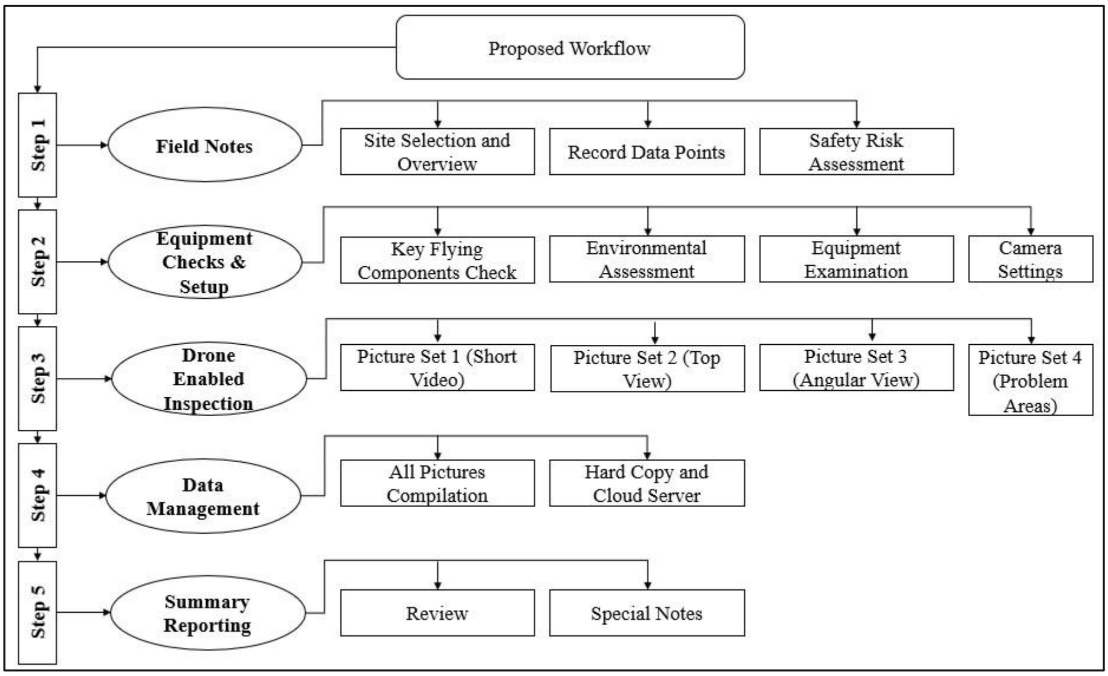

Fig. 9: Proposed 5-step workflow for drone roof inspections

5. Conclusion

In this study, the authors have documented and organized a set of protocols for drone roof inspections with low-slope roofs based on current research with Faculties related work. The literature review suggests that the use of drones is a beneficial alternative for low-slope roof inspections compared to traditional methods. After a thorough review of past inspection studies, it was concluded that there had been several versions of an inspection workflow proposed by previous authors. However, a full-length sequence had not been proposed and published. The lacking elements identified through this study that are added to the workflow are as follows: First, details of Actual Video/Photo sequences taken while in flight. Second, owner-requested areas of focus within the structure. Third, photo formatting and organizing for FM/owner review. Finally, it was necessary to conduct testing of the full-scale process to demonstrate each sequence as a part of the process as a whole.

From this protocol framework, the researchers worked to augment these protocols into a single-set workflow that included any logical missing steps and that could be applied to the drone inspection process. A proposed method of doing the inspection sequence was derived which attempts to cover all the known steps of roof inspections with drones. The 5-step "workflow" was developed from the literature review steps, which were then applied on both sites and were modified to specifically fit the drone roofing inspection workflow. The proposed sequence was tested and validated with two low-slope structures that are in the Midwestern area of the United States.

Although the technology and deregulation of drones has moved forward quickly in recent years, it is only through the testing and innovative practice of facilities managers that the true benefit of its use will be realized. Done use has proven to be a safer, more cost effective and quicker method for many types of structural inspections. However, this progress will only continue as more FM's are willing to invest the time, money and progressive management practices in using drone technology to help with their own properties and building envelopes.

Although this study is limited to low slope roofing systems, the sequence is considered general enough that it can be applied to various roof slope systems as well as other structures such as water towers, silos, cell phone antennae's and other structures. It is anticipated that this workflow can be applied to future inspections as a more standardized approach to roof and structure monitoring with drones.

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