Journal
für
Facility Management
Wissenschaft trifft Praxis

Heft 17/2018

ISSN 2520-5404

Journal für Facility Management

Heft 17/2018

ISSN 2520-5404

www.ifm.tuwien.ac.at

Preface of the publisher

17. Journal for Facility Management: Science meets Practice

During the last months, I have visited several important business conferences. They focused on innovation, digitalisation, sustainability, networking and cooperation. Most of the presentations were looking for solutions for the following challenges:

- How sustainability does pays off?
- How to retrieve employees?
- How to foster innovation?

I got many innovative ideas for my research and teaching, but I also recognized that, the colleagues did not mention real estate and facility management in any way in their presentations. When I approached them, or mentioned in the discussion possibilities of RE/FM, they were not aware of the possibilities.

It seems that our community was not successful to spread the information how we can enable core business. Real Estate and Facility Management is not to optimise single services, it is about the support of the core business by defining the demand of infrastructure and services and sourcing it. It is not about fulfilling the services. It is about enabling the core business to adapt to the changes due to digitalisation by providing optimal workplaces. Workplace management is to empower employees, foster communication and therefore innovation.

The article of this issue gives an insight how RE/FM can succeed in this strategic area:

- Facility Management in Small and Medium-Sized Enterprises: Importance, demand, willingness to outsource and supply - quantitative study
- MultiMapping and urban FM
- Facility Services: Impact of new technologies
- Digitalization & Facility Management: Energy Flexibility of Existing Buildings

The first paper deals with the paradoxon that especially the smallest companies want to outsource the whole facility services. In their growing phase, they would like to get a full serviced work environment to concentrate on their core business. But the facility service providers consider this market as not large/profitable enough. Need technologies may provide new approaches.

The second paper discusses a more active role of Facility Management (FM) to participate in the development of urban area with aim to build competitive and healthy surroundings with a high quality for residence, business and spare time. An active role of FM is seen as co-creating

the place together with estate owners or users in many perspectives, such as creating better environment or better services (exp. assistance/services for elderly people), to contribute to a desirable urban area throughout its whole lifecycle.

The third paper deals with the impact of new technologies on the facility operation. Studies estimate that in general 47% of all jobs will be automated due to digitalization. FS will be more affected as it consists of more routine tasks. Based on literature review the paper present the relevant emerging technologies like IoT, AI, ML and their technical and economic feasibility in the Facility service industry.

As future energy systems will require buildings to be able to manage their energy demand and generation in dynamic ways, the fourth paper presents technical implementation of such energy flexibility in existing buildings. The objective of this paper is to sketch a digital perspective of energy flexibility in existing buildings and city quarters based on on-going work in different research approaches. The research results show that buildings can support future energy systems not only in the optimization of grid utilization, but also in reaching national carbon dioxide goals. The suggested solutions can be used directly by practitioners.

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 kept high with more than 50%. The high quality research handed in 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 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 Lisa Grasl MA und DI Christine Hax. Without their personal engagement, the journal would not be available in this high quality.

I wish you all the best from Vienna, an enjoyable reading, 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 11th IFM congress 2018.

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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Science meets Practice I:

Strategic Facility Management

Facility Management in Small and Medium-Sized Enterprises – Importance, Demand, Outsourcing and Supply

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Techno-Z Verbund GmbH

Abstract

This paper analyses the understanding of and demand for facility management (FM) services within the group of small and medium-sized enterprises (SMEs), as well as the willingness to outsource facility services (FS) and presents this in relation to the supply situation for SMEs.

The enterprise size, development phase and enterprise's locality were considered as distinguishing criteria during the analysis using qualitative interviews with 11 Austrian SMEs.

The results pick up on an in itself paradox phenomenon. With the group of SMEs, it was mainly the smallest, i.e. micro enterprises (including a one-person enterprise (OPE), that not only have a great interest in and understanding of FM but also see a corresponding demand. The supply aspect does not correspond to this situation by any means. Providers tend to currently approach larger SMEs with integrated offers as it is presumed that there is more demand and also a better reception here. However, it is precisely these larger SMEs that are more likely to tend towards "do-it-yourself".

Growing enterprises generally have a greater awareness of FM, a higher subjective demand for FS and greater willingness to outsource FS than mature enterprises.

Enterprises based in rural regions have to offer special services in the battle for well qualified employees. The issue of sharing FS and optimising costs is important there and in micro enterprises in particular.

Keywords: Facility Management, Demand, Outsourcing, Supply

1. Einleitung

1.1. Motivation

Kleine und Mittlere Unternehmen sind einer der entscheidenden Treiber für Innovation. Sie bilden das „Rückgrat der Wirtschaft“ (Smith and Fingar, 2003). Sie stellen in der EU ca. 99 % aller Unternehmen und bieten ca. 65 Millionen Menschen einen Arbeitsplatz.

Diese Größenordnungen lassen erkennen, welches Potential für FM bei den KMU in Österreich vorhanden ist. Aus diesem Grund untersucht diese Arbeit das Verständnis für FM und den Bedarf an FS innerhalb der KMU, sowie die Bereitschaft diese auszulagern und stellt dies in Relation zur Angebotssituation.

1.2. Problemdefinition

FM hat zur Aufgabe, die betriebsnotwendige Infrastruktur eines Unternehmens kostengünstig zur Verfügung zu stellen. Bisherige Studien am Institut für Managementwissenschaften, Fachbereich Immobilien und Facility-Management der TU Wien (Hizgilov 2011, Redlein 2015) lassen die Behauptung zu, dass FM bei großen Unternehmen bereits Status Quo ist. Im Gegensatz dazu hat FM im Bereich von KMU zum Teil einen geringen Stellenwert. Dieser Umstand ist bemerkenswert, da der zweitgrößte Kostenblock nach den Personalkosten die Infrastrukturkosten sind. Eine laufende Steuerung und Optimierung dieser Kosten bergen ein entsprechendes Effizienzsteigerungspotenzial (Redlein 2015, Hizgilov & Redlein 2011, Hauk 2006 und 2007).

Von KMU wird das durch den Einsatz von FM gegebene Erfolgspotenzial (Kostensenkung, Produktivitätssteigerung, strategische Wettbewerbsvorteile) nur unzureichend genutzt. Sie haben einen hohen Eigenleistungsgrad und wollen die Dinge selbst erledigen (Cigolini et al. 2011, Pfeiffenberger 2014, Markt und Mittelstand, das Wachstumsmagazin 2015, Salzburger Nachrichten 2017). Gründe dafür sind lt. Einschätzung der Anbieter z.B. mangelnde Transparenz am Anbietermarkt und Unklarheit über Bedeutung und Nutzen von FM bei den KMU (Pfeiffenberger 2014). Roberto Cigolini, Giovanni Miragliotta und Margherita Pero vom Department of Management, Economics and Industrial Engineering des Politecnico di Milano haben eine Untersuchung über das Outsourcing-Verhalten von KMU in Italien in Bezug auf FS durchgeführt (Cigolini et al. 2011). Das Ergebnis war, dass weniger als 5 % der befragten Unternehmen sich in einer Geschäftsbeziehung mit einem Lieferanten, der mehrere FS (sog.

„integrierte Services“) anbietet, befinden. Dieses Ergebnis bestätigt die bisherige persönliche Einschätzung des Autors. Ein weiterer Aspekt der Problematik ist, dass KMU nicht gleich KMU ist. So wurde z.B. die Entwicklungsphase eines KMU (Wachstum oder Reifestadium) als mögliches Differenzierungskriterium innerhalb der Gruppe der KMU erkannt und in der empirischen Analyse mitberücksichtigt (Lu Zheng 2012, Dettwiler 2006).

1.3. Hypothesen

1. Es herrscht Unwissenheit bei KMU über die Bedeutung von FM als Managementansatz und dem daraus resultierenden Nutzen.
2. KMU haben keinen Bedarf an FS.
3. Während bei großen Unternehmen das Outsourcing von FS Standard ist, neigen KMU dazu, die Leistungen selbst zu erbringen.
4. Es fehlen maßgeschneiderte integrierte Service-Angebote seitens der Anbieter.

1.4. Methodisches Vorgehen

Gegenständliche Arbeit stellt die Kernergebnisse einer quantitativen Studie dar.

2. Quantitative Studie

2.1. Methodik

Es wurde eine Befragung von KMU im Großraum Salzburg (400 km-Radius in DE/AU/CH) von N=110 Unternehmen mit Hilfe eines Research-Partners im September 2016 durchgeführt. Die Unternehmen wurden für die Auswertung in verschiedene Gruppen (Größe/Verortung/Entwicklungsphase) unterteilt. Die Qualifikation der Teilnehmer für die Umfrage fand in zwei Schritten statt: (1) Vorselektion durch den Dienstleister und (2) Qualifikation im Fragebogen. Im Folgenden werden die Schritte im Detail beschrieben:

2.1.1. Vorselektion des Panelanbieters

Für die Rekrutierung der Umfrageteilnehmer wurde ein international tätiger Paneldienstleister beauftragt. Der Paneldienstleister selektierte Personen vor, welche: (1) entweder als Geschäftsführer oder im Top-Management-Level ihres Unternehmens beschäftigt sind und (2) den Unternehmenssitz im Umkreis von maximal 400 Kilometern um Salzburg (ausschließlich in D-A-CH) haben.

2.1.2. Klassifikation im Online-Fragebogen

Um die Zielgruppe weiter zu schärfen, wurde nach weiteren Kriterien aussortiert: (1) Branche, (2) Unternehmensgröße, (3) Entwicklungsphase, (4) Verortung.

2.1.2.1. Branche

Im Online-Fragebogen wurden zunächst die Personen qualifiziert, die angaben, dass ihr Unternehmen eine Büroorganisation ist. Hierfür wurde jeder Teilnehmer gefragt, in welcher Branche sein Unternehmen tätig sei. Die folgenden Branchen (vgl. www.wirtschaft.at/service/jobs 2018) wurden als Büroorganisationen eingestuft: Beratung/Consulting, EDV/IT, Grafik/Design/Gestaltung, Personalwesen, Rechnungswesen/Controlling/Buchhaltung, Verkauf/Kundenbetreuung/Service, Bildung/Training/Coaching, Logistik/Lagerwirtschaft, Finanzwirtschaft/Bank, Gastronomie/Hotellerie/Tourismus, Marketing/Kommunikation/PR, Pharma/Gesundheitswesen/Soziales, Rechtswesen, Technik/Ingenieurswesen,

Wissenschaft/Forschung. Sofern der Befragungsteilnehmer keine dieser Branchen ausgewählt hat, wurde er disqualifiziert.

2.1.2.2. Unternehmensgröße

Die Befragungsteilnehmer wurden zur Zahl der Beschäftigten sowie zum Umsatz und ihrer Bilanzsumme des vergangenen Geschäftsjahres befragt. Für die Umfrage qualifizieren konnten sich nur Teilnehmer, die gemäß der Definition der Europäischen Kommission (ABl. der EU Nr. L 124/36 vom 20.05.2003) zur Gruppe der KMU gehören:

Unternehmensgröße	Anzahl Beschäftigte		Umsatz €/Jahr		Bilanzsumme €/Jahr
kleinst	bis 9	und	bis 2 Millionen	oder	bis 2 Millionen
klein	bis 49		bis 10 Millionen		bis 10 Millionen
mittel	bis 249		bis 50 Millionen		bis 43 Millionen

Tab. 1: Unternehmensgröße (eigene Darstellung nach ABl. der EU Nr. L 124/36 vom 20.05.2003)

Sofern der Befragungsteilnehmer laut seinen Angaben in keine dieser Unternehmensgrößen fiel, wurde er disqualifiziert. Um sicherzustellen, dass bei geplanter Fallzahl von mindestens N=100 Teilnehmern eine angemessene Verteilung zwischen den Unternehmensgrößenklassen herrscht, wurden für die Unternehmensgrößen (Einpersonenunternehmen/ Kleinstunternehmen / kleines Unternehmen / mittleres Unternehmen) entsprechende Quoten gesetzt. Sofern eine Quote für eine der Gruppen erreicht wurde, konnten nur noch Befragungsteilnehmer der noch offenen Unternehmensgrößen am Fragebogen teilnehmen.

2.1.2.3. Entwicklungsphase

Beim Differenzierungskriterium Entwicklungsphase wurde die Entwicklung der Mitarbeiterzahl mit der Entwicklung der Bürofläche verknüpft. Die vollständige Aufzählung

der Grenzen findet sich in folgender Tabelle:

Wachstumsphase, wenn:											
Unternehmensgröße	Option 1				Option 2				Option 3		
	Wachstum Mitarbeiterzahl (mindestens)		Wachstum Bürofläche (mindestens)		Wachstum Mitarbeiterzahl (mindestens)		Wachstum Bürofläche (mindestens)		Wachstum Mitarbeiterzahl (mindestens)		Wachstum Bürofläche (mindestens)
Kleinstunternehmen	100%	UND	10%	ODER	50%	UND	20%	ODER	keine notwendige Steigerung	UND	30%
Kleine Unternehmen	40%		10%		20%		15%		keine notwendige Steigerung		20%
Mittlere Unternehmen	20%		5%		10%		10%		keine notwendige Steigerung		15%

Tab. 2: Kriterien zur Einteilung in Wachstums- und Reifephase

Für Kleinstunternehmen bedeutete dies zum Beispiel: mind. 100%ige Steigerung der Mitarbeiterzahl UND mind. 10%ige Steigerung der Bürofläche ODER mind. 50%ige Steigerung der Mitarbeiterzahl UND mind. 20%ige Steigerung der Bürofläche ODER mind. 30%ige Steigerung der Bürofläche. Sofern auf ein Unternehmen (nicht EPU) keine der Optionen zutraf, wurde dieses als Unternehmen in der Reifephase ausgewiesen.

2.1.2.4. Verortung

Die Verortung wurde nach EUROSTAT-Kriterien (EUROSTAT 2011) in „urban“ = „high-densitiy“ und „ländlich“ = „urban/rural“ eingeteilt: „urban“ – Einwohnerzahl mindestens 50.000 UND mindestens 1.500 Einwohner pro km², „ländlich“ – Einwohnerzahl weniger als 50.000 ODER weniger als 1.500 pro km².

2.1.3. Facility Services

Die Teilnehmer wurden nach FS Produktgruppen und Einzelservices nach EN 15221-4 (2011) befragt.

2.1.4. Aufbau der Analyse

Die 4 Hypothesen (siehe 1.3.) werden anhand der Datensätze (1) empirisch analysiert und (2) einem einseitigen t-Test unterzogen.

2.2. Hypothese 1 – Es herrscht Unwissenheit bei KMU über die Bedeutung von FM als Managementansatz und dem daraus resultierenden Nutzen.

2.2.1. Empirische Analyse

Die Unternehmen wurden befragt, wie vertraut sie mit dem Begriff „Facility Management“ sind. Für die Interpretation wurden die Angaben 1 und 2 „(sehr) vertraut“, sowie 4 und 5 „(gar) nicht vertraut“ in „Top 2“, respektive „Bottom 2“ zusammengefasst.

Der Großteil der KMU ist grundsätzlich vertraut mit dem Begriff FM. Lediglich 30% der befragten Unternehmen gaben eine 4 oder 5 an.

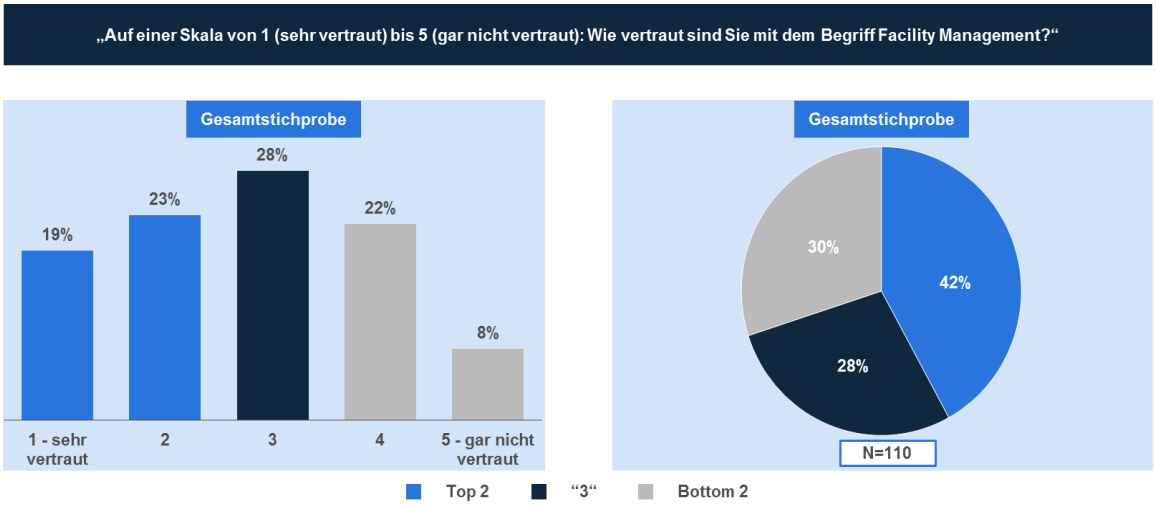


Abb. 1: Vertrautheit mit FM gesamt

Kleinstunternehmen scheinen am besten über FM informiert zu sein – insgesamt gaben 50% an mit dem Begriff (sehr) vertraut zu sein („Top 2“).

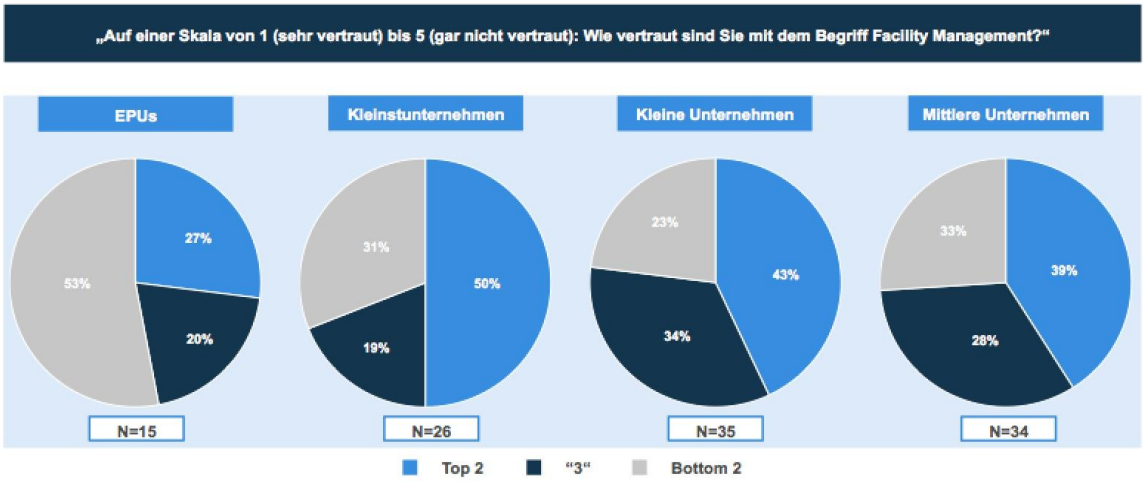


Abb. 2: Vertrautheit mit FM nach Größe

Die Hälfte der befragten Unternehmen, welche sich in der Wachstumsphase befinden, gaben bei der Vertrautheit eine 1 oder 2 an.

Größtes Unwissen über FM herrscht bei ländlichen Unternehmen, welche zu 33% eine 4 oder 5 angaben.

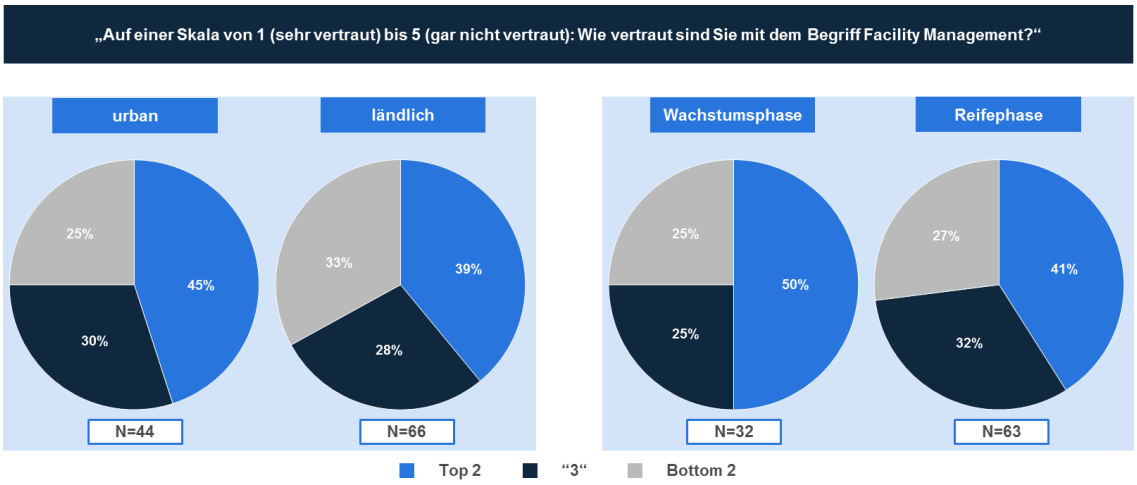


Abb. 3: Vertrautheit mit FM nach Entwicklungsphase und Verortung

2.2.2. t-Test Hypothese 1

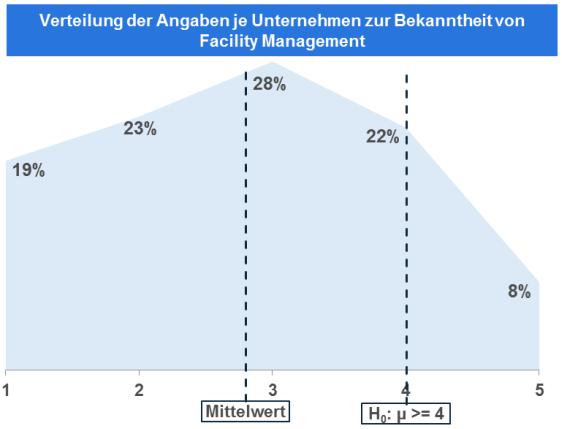
Für den t-Test wurden die Daten der Frage zur Vertrautheit mit dem Begriff „Facility Management“ herangezogen (1 und 2 stehen für „(sehr) vertraut“, sowie 4 und 5 für „(gar) nicht vertraut“).

Die Nullhypothese 1 „der anzunehmende Wert für die Antwort auf die Frage nach der Bekanntheit von FM beträgt 4 oder höher“ kann auf dem 5%-Signifikanzniveau sowohl für die Gesamtstichprobe (siehe Abbildung 4), als auch für jede Untergruppe (Größenklassen, Verortung, Entwicklungsphasen) abgelehnt werden.

Die Ergebnisse des Hypothesentests auf Basis der quantitativen Erhebung bestätigen die grundsätzliche Ablehnung von Hypothese 1 „Es herrscht Unwissenheit bei KMU über die Bedeutung von FM als Managementansatz und dem daraus resultierenden Nutzen“. Nichtsdestotrotz ist durch die Mittelwerte zu sehen, dass es Unterschiede gibt: z.B. haben kleine Unternehmen im Durchschnitt ein besseres Verständnis von FM als Ein-Personen-Unternehmen.

Einseitiger t-Test der Nullhypothese, dass der anzunehmende Wert für die Antwort auf die Frage nach der Bekanntheit von Facility Management 4 oder größer ist[1]

Ergebnis für die Gesamtstichprobe	
Beobachtungen	110
Mittelwert	2,77
Varianz	1,50
t-Statistik	-10,52
kritischer t-Wert	1,66
H_0: μ >= 4	abgelehnt



1) μ0 = 4; H0: μ >= μ0 ; H1: μ < μ0; 5%-Signifikanzniveau

Abb. 4: t- Test Hypothese 1 gesamt

2.3. Hypothese 2 - KMU haben keinen Bedarf an FS.

2.3.1. Empirische Analyse

Grundsätzlich kann festgestellt werden, dass im Moment vor allem die kleinsten und mittleren Unternehmen den abgefragten FS die höchste Relevanz beimessen.

EPUs sind gesondert zu betrachten, weil davon auszugehen ist, dass sie zumindest zum Teil Ein-Personen-Unternehmen bleiben wollen. Diese Unternehmen verfolgen oft gar nicht vorrangig den Aufbau einer Unternehmensorganisation so wie die restlichen KMU. Das lässt sich aus der überproportional niedrigen Relevanz bzw. dem überproportional niedrigen Bedarf, der sich aus der quantitativen Umfrage ergeben hat, ablesen.

Die Befragten bewerteten die Frage auf einer Skala von 1 (sehr wichtig) bis 5 (nicht relevant). Dargestellt ist der Achsenausschnitt zwischen 4,2 und 2,3.

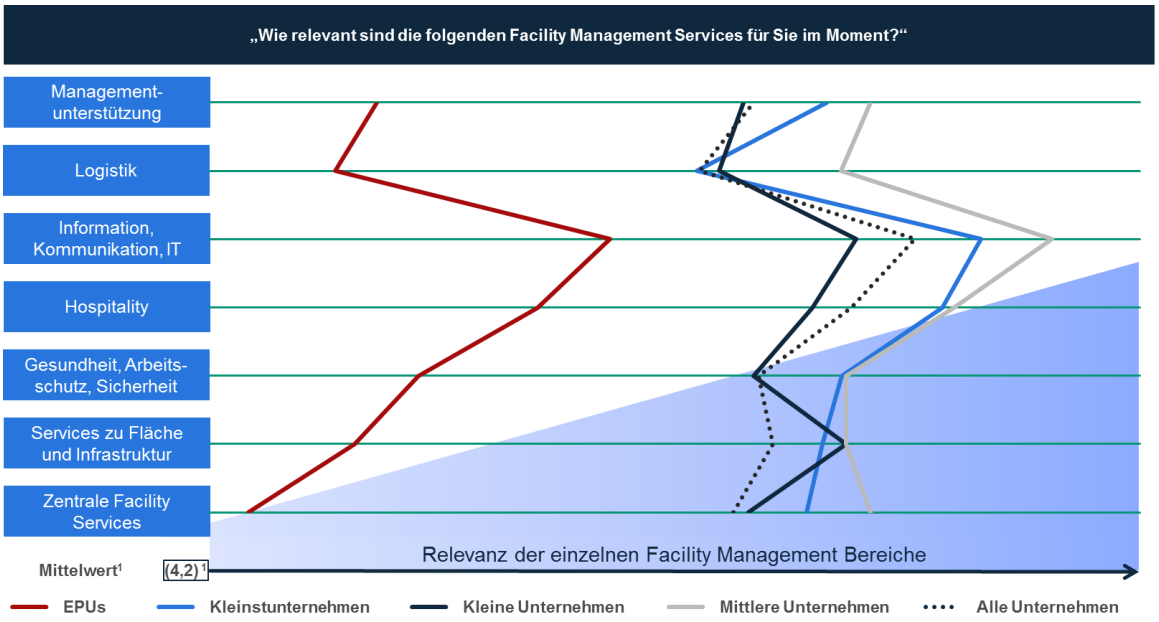


Abb. 5: Relevanz der FS Produktgruppen gesamt

Unternehmen in der Wachstumsphase haben in allen Bereichen einen überdurchschnittlich hohen Bedarf an FS.

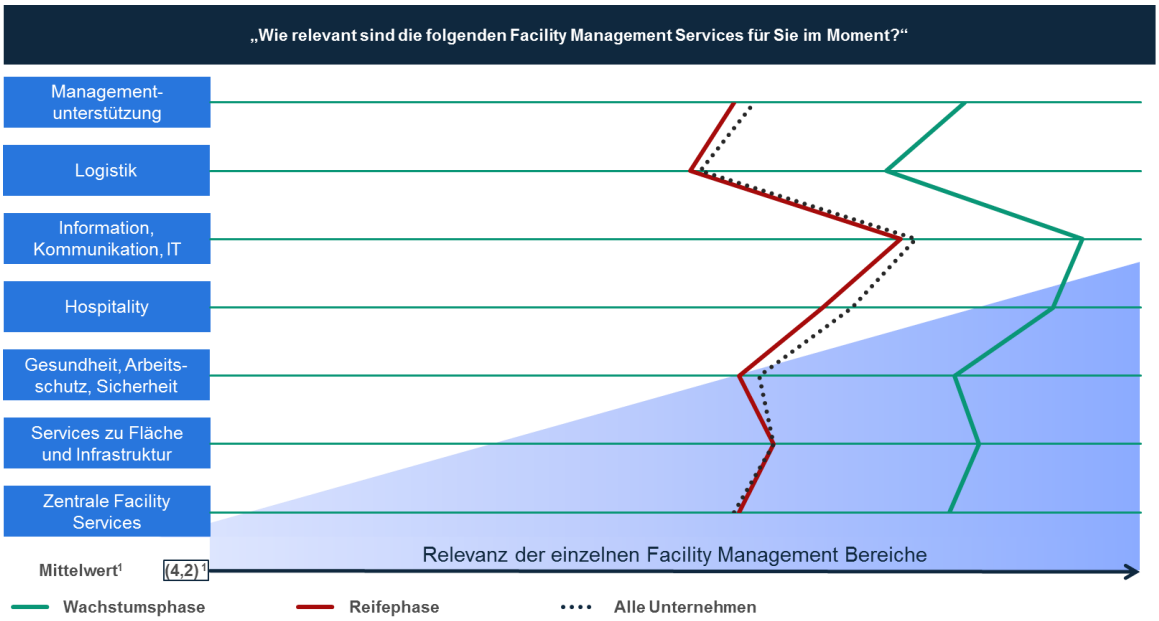


Abb. 6: Relevanz der FS Produktgruppen nach Entwicklungsphase

Die Unternehmen im ländlichen Raum haben mehr subjektiven Bedarf als solche im urbanen Umfeld.

In den Bereichen „Information, Kommunikation, IT“ & „Hospitality“ weicht die Relevanz zwischen urbanen und ländlichen Unternehmen am stärksten ab.

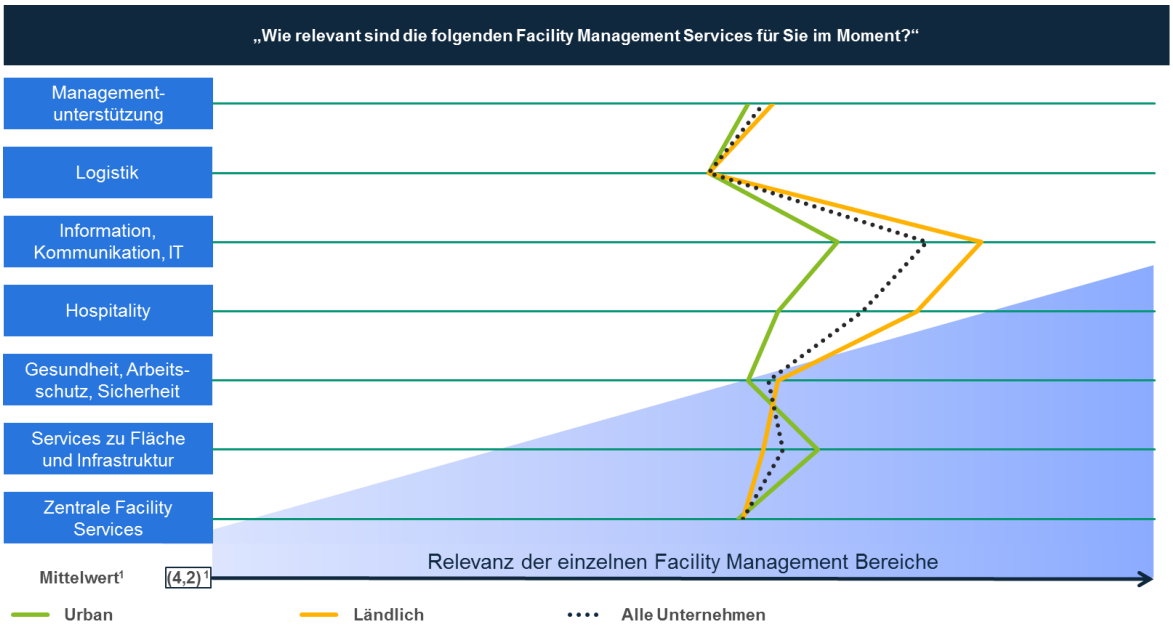


Abb. 7: Relevanz der FS Produktgruppen nach Verortung

Die insgesamt für KMU relevantesten Einzelservices werden wie folgt im Überblick dargestellt:

	1.	2.	3.	4.	5.
KMU GESAMT	Sicherheit und der Schutz der IT	Arbeitsplatzgestaltung und Ergonomie	Reinigung und Betreiben eines Daten- und Telefonnetzes	Kopier- und Druckerdienste	Versorgung mit Energie und Wasser
Kleinst-unternehmen	Arbeitsplatzgestaltung und Ergonomie	Reinigung	Betreiben eines Daten- und Telefonnetzes	Gesundes Essen und Getränke	Entsorgung Abfall
Kleine Unternehmen	Reinigung	Instandhaltung und Betrieb	Sicherheit und Schutz der IT, Versorgung mit Energie und Wasser	Entsorgung Abfall, Vorbeugender Brandschutz	Arbeitsplatz-gestaltung und Ergonomie
Mittlere Unternehmen	Sicherheit und Schutz der IT	Finanzen und Controllingdienst-leistungen	Betreuung des Rechenzentrums und der Server sowie deren Betrieb	Arbeitsplatz-gestaltung und Ergonomie	Kopier- und Druckerdienste, Dokumentenmanagement u Archivierung
Urban	Reinigung	Entsorgung Abfall	Versorgung mit Energie und Wasser	Sicherheit und Schutz der IT	Arbeitsplatzgestaltung und Ergonomie
Ländlich	Arbeitsplatzgestaltung und Ergonomie Sicherheit und Schutz der IT	Betreiben eines Daten- und Telefonnetzes	Empfang, Registrierung und Beratung von Besuchern, Dokumentenmanagement und Archivierung	Reinigung, Kopier- und Druckerdienste	Instandhaltung und Betrieb, Vorbeugender Brandschutz, Finanzen und Controllingdienstleistungen
Wachstums-phase	Finanzen und Controllingdienst-leistungen	Versorgung mit Energie und Wasser	Reinigung, Arbeitsplatzgestaltung und Ergonomie, Dokumentenmanagement und Archivierung	Entsorgung Abfall, Sicherheit und Schutz der IT	Vorbeugender Brandschutz
Reifephase	Arbeitsplatzgestaltung und Ergonomie	Sicherheit und Schutz der IT	Betreiben eines Daten- und Telefonnetzes	Reinigung	Instandhaltung und Betrieb

Tab. 3: relevanteste Einzelservices für KMU

2.3.2. t-Test Hypothese 2

Für den t-Test wurden die Daten der Fragen zur momentanen Relevanz von FM-Services herangezogen (1 und 2 stehen für „(sehr) relevant“, sowie 4 und 5 für „(gar) nicht relevant“) und der Mittelwert für jedes der befragten Unternehmen über alle Einzelitems gebildet.

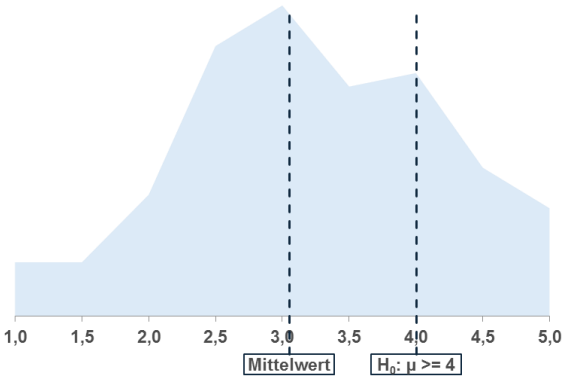
Die Nullhypothese 2 „dass der anzunehmende Wert für die Antwort auf die Frage zur momentanen Relevanz von FM im Durchschnitt 4 oder größer ist“ kann auf dem 5%-Signifikanzniveau für die Gesamtstichprobe (siehe Abbildung 8), als auch für jede Untergruppe (Größenklassen, Verortung, Entwicklungsphasen), bis auf die Ein-Personen-Unternehmen abgelehnt werden.

Die Ergebnisse des Hypothesentests auf Basis der quantitativen Erhebung bestätigen die grundsätzliche Ablehnung von Hypothese 2 „KMU haben keinen Bedarf an FS“. Grund für die Selbstdurchführung sind bei den befragten Unternehmen meistens die Kosten.

Einseitiger t-Test der Nullhypothese, dass der anzunehmende Wert für die Antwort auf die Frage zur momentanen Relevanz von Facility Management im Durchschnitt 4 oder größer ist[1]

Ergebnis für die Gesamtstichprobe	
Beobachtungen	110
Mittelwert	3,06
Varianz	0,85
t-Statistik	-10,72
kritischer t-Wert	1,66
H_0: μ >= 4	abgelehnt

Verteilung der Mittelwerte je Unternehmen zur momentanen Relevanz von FM Services



1) μ0 = 4; (H0: μ >= μ0 ; H1: μ < μ0; 5%-Signifikanzniveau

Abb. 8: t-Test Hypothese 2 gesamt

2.4. Hypothese 3 - Während bei großen Unternehmen das Outsourcing von FS Standard ist, neigen KMU dazu, die Leistungen selbst zu erbringen.

2.4.1. Empirische Analyse

Am ehesten lagern kleine Unternehmen aus. Sie sind bei allen Services an erster Stelle außer bei IKT. Hier sind die kleinsten Unternehmen an erster Stelle.

Gesamt betrachtet besteht zwischen der Auslagerungsbereitschaft am Land und in der Stadt nur 1 %-Punkt Unterschied zugunsten des Landes.

Zwischen wachsenden und reifen Unternehmen sind es insgesamt nur 2 %-Punkte, wobei die Auslagerungsbereitschaft bei den reifen Unternehmen höher ist als bei den wachsenden und zwar immer, außer bei IKT-Services (+5%), Logistik (+3%) und Managementunterstützung (+1%). In diesen Bereichen lagern die wachsenden Unternehmen mehr aus.

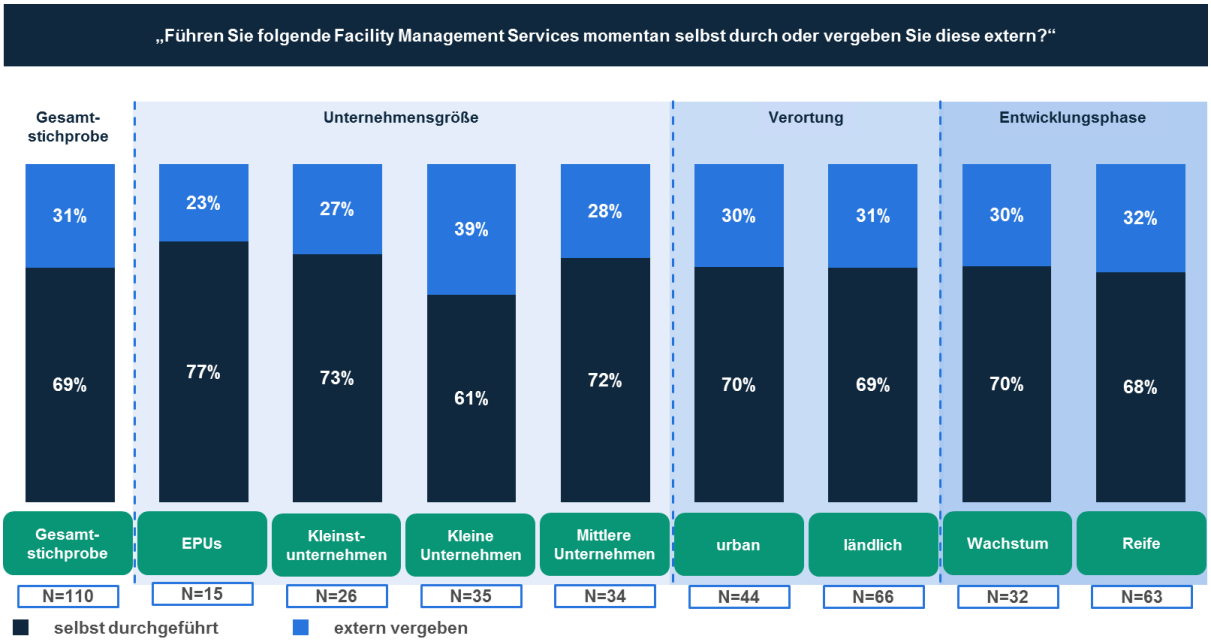


Abb. 9: Auslagerung FS gesamt

Services zu Fläche und Infrastruktur und IKT werden mit 37 % am meisten ausgelagert, (nach Priorität): (1) Entsorgung von Abfall, (2) Versorgung mit Energie und Wasser, (3) Reinigung. Gefolgt werden diese von Services zu Managementunterstützung mit 34 % und zentrale FM-Services sowie Gesundheit, Arbeitsschutz und Sicherheit mit je 31 %.

Am wenigsten ausgelagert werden Services zu Hospitality mit nur 16%, hier v.a. Empfang, Registrierung und Beratung von Besuchern.

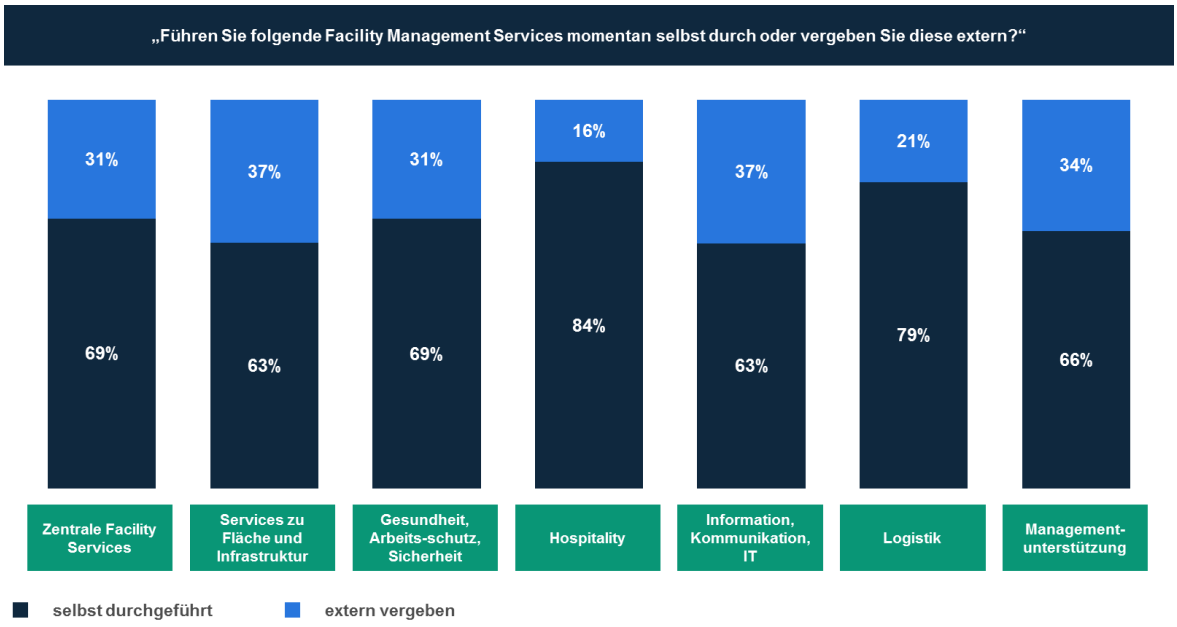


Abb. 10: Auslagerung nach FS Produktgruppen

Hauptgrund für die Selbstdurchführung von FS sind Kostengründe (68%) – allerdings spielt auch das mangelnde Vertrauen in die Anbieter eine Rolle (38%).

2.4.2. t-Test Hypothese 3

Für den t-Test wurden die Daten der Frage zur Selbstdurchführung/Auslagerung von FM-Services herangezogen. Für jedes Unternehmen wurde auf Basis seiner Angaben der Mittelwert gebildet und auf 0 bis 1 (0 % – 100 %) umskaliert. Je höher der in der Abbildung 11 angegebene Mittelwert, umso mehr FM-Services werden ausgelagert.

Die Nullhypothese 3, „Die befragten Unternehmen lagern zu 40 % oder mehr ihrer Facility-Management-Services aus“, kann auf dem 5%-Signifikanzniveau für die Gesamtstichprobe als auch für jede Untergruppe (Größenklassen, Verortung, Entwicklungsphasen) bis auf kleinere Unternehmen und Unternehmen im urbanen Raum abgelehnt werden. Das heißt kleinere und Unternehmen im urbanen Raum lagern zu 40% oder mehr ihre Facility-Management-Services aus.

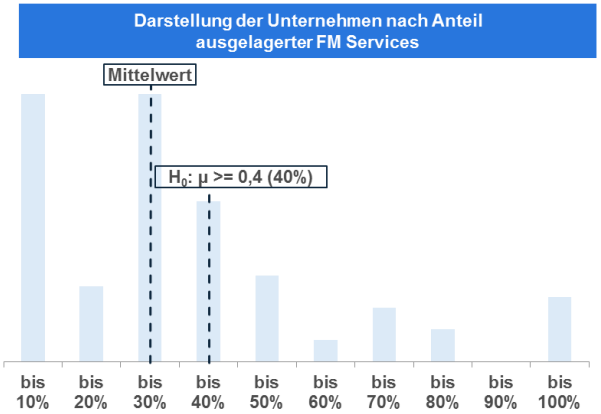
Dass das Outsourcing von FM-Services bei großen Unternehmen zum Standard gehört, kann die quantitative Erhebung nicht bewerten. Letzteres tritt aber in einer Studie des Zentrums für Immobilien und Facility Management der TU Wien (Redlein 2015) zutage. Dieser zufolge liegt

die durchschnittliche Auslagerungsrate aller abgefragten FS bei rund 42%. Dies ist auch der Grund warum der Mittelwert hier im t-Test mit 40% angenommen wurde.

Von den befragten kleinen Unternehmen werden die angegebenen (sehr) relevanten FM-Services zu 39% ausgelagert, bei den urbanen Unternehmen sind es immerhin 30 %. Diese Zahlen klingen im ersten Moment widersprüchlich zum obigen Ergebnis des Nullhypothesentests. In der empirischen Analyse wurde eruiert, ob die einzelnen relevanten FS insgesamt mehr ausgelagert oder mehr selbst durchgeführt wurden. Im t-Test wurde festgestellt, ob die jeweiligen Gruppen von KMU die für sie relevanten Services eher auslagern oder eher selbst durchführen.

Einseitiger t-Test der Nullhypothese, dass die befragten Unternehmen 40% oder mehr ihrer Facility Management Services auslagern

Ergebnis für die Gesamtstichprobe	
Beobachtungen	96
Mittelwert	0,30
Varianz	0,07
t-Statistik	-3,56
kritischer t-Wert	1,66
H_0: μ >= 4	abgelehnt



1) (μ_0 = 4; (H_0: μ >= μ_0 ; H_1: μ < μ_0; 5%-Signifikanzniveau)

Abb. 11: t-Test Hypothese 3 gesamt

2.5. Hypothese 4 - Es fehlen maßgeschneiderte integrierte Service-Angebote seitens der Anbieter.

2.5.1. Empirische Analyse

Ein Paketangebot von FS stellt für die befragte Stichprobe eine absolute Ausnahme dar. Besonders EPUs & Kleinstunternehmen wurden bisher nahezu nie entsprechende Servicepakete angeboten.

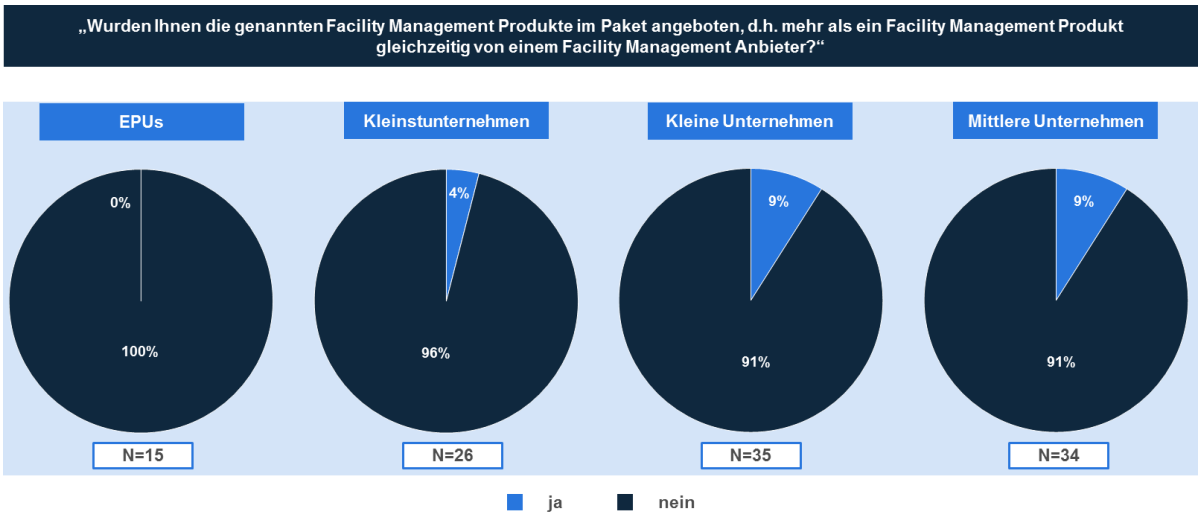


Abb. 12: Integratives Angebot nach Unternehmensgröße

Unternehmen in der Wachstumsphase wurden vergleichsweise häufig bereits Services im Paket angeboten – bisherige Serviceangebote im Paket sind für ländliche Unternehmen / Unternehmen in der Reifephase eine Seltenheit.

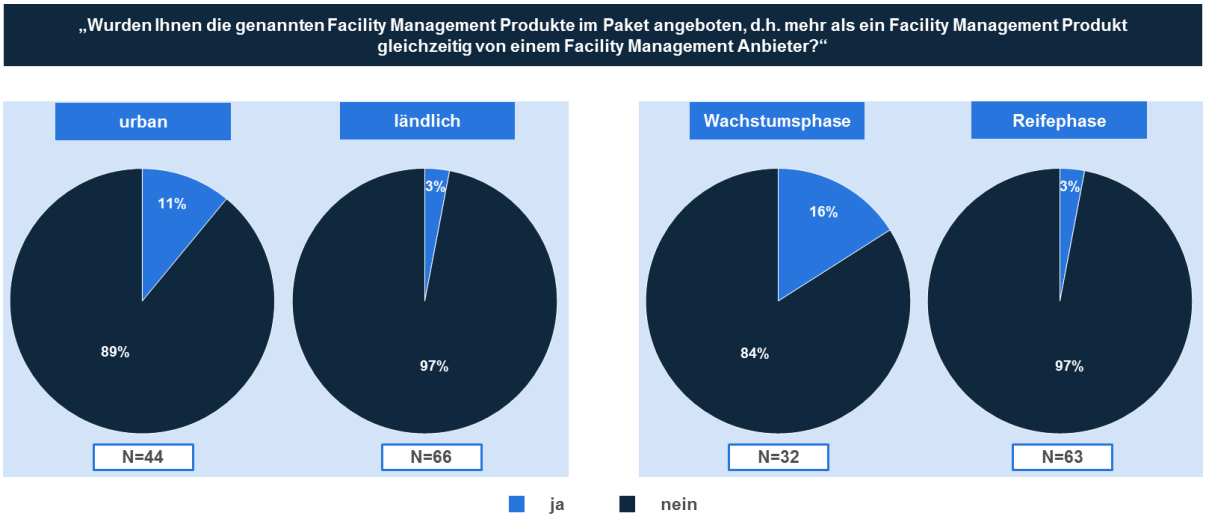


Abb. 13: Integratives Angebot nach Entwicklungsphase und Verortung

2.5.2. t-Test Hypothese 4

Für den t-Test wurde die Frage herangezogen, ob den befragten Unternehmen FM-Services schon einmal im Paket angeboten wurden.

Die Nullhypothese „dass der anzunehmende Wert für die Anzahl an befragten Unternehmen, welche bereits FM-Services im Paket angeboten bekommen haben, 20% oder größer ist“ kann auf dem 5%-Signifikanzniveau für die Gesamtstichprobe (siehe Abbildung 14), als auch für

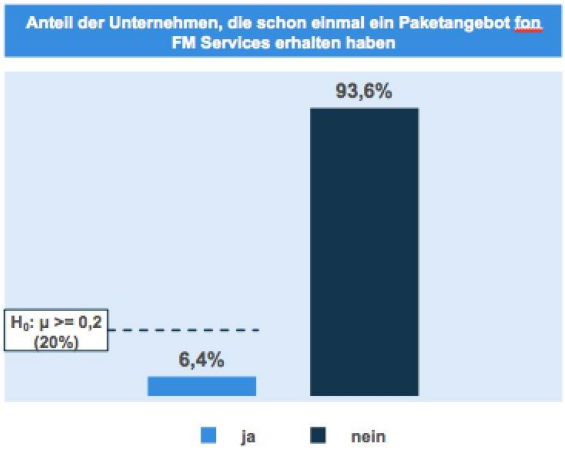
jede Untergruppe (Größenklassen, Verortung, Entwicklungsphasen), bis auf Unternehmen in der Wachstumsphase abgelehnt werden.

Von den befragten 110 Unternehmen wurden nur 6 % in der Vergangenheit FM-Services im Paket angeboten. Zudem gaben 38 % der zur Selbstdurchführung befragten Unternehmen an, dass sie aufgrund von Vertrauensproblemen FM-Services selber durchführen.

Hypothese 4 „Es fehlen maßgeschneiderte integrierte Service-Angebote seitens der Anbieter“ kann auf Basis der quantitativen Erhebung grundsätzlich als bestätigt, bzw. zumindest als nicht widerlegt betrachtet werden.

Einseitiger t-Test der Nullhypothese, dass der anzunehmende Wert für die Anzahl an befragten Unternehmen, welche bereits FM-Services im Paket angeboten bekommen haben, 20% oder größer ist

Ergebnis für die Gesamtstichprobe	
Beobachtungen	110
Mittelwert	0,06
Varianz	0,06
t-Statistik	-5,83
kritischer t-Wert	1,66
H_0: μ >= 4	abgelehnt



1)(μ0 = 4; (H0: μ >= μ0 ; H1: μ < μ0; 5%-Signifikanzniveau)

Abb. 14: t-Test Hypothese 4 gesamt

2.6. Zusammenfassung

Den befragten Unternehmen ist grundsätzlich bewusst, was FM bedeutet und sie sehen einen Bedarf für ihr Unternehmen. Unter den Befragten sahen mittlere und Kleinst-Unternehmen, sowie Unternehmen in der Wachstumsphase die höchste Relevanz bei FS. Nur in dem FS-Bereich „Information, Kommunikation, IT“ wird eine erhöhte Relevanz gesehen.

Die befragten Unternehmen lagern fast ein Drittel (31%) der FM-Aufgaben aus. Bei der Auslagerungsfreudigkeit von FS gibt es geringe Unterschiede zwischen den Entwicklungsphasen oder der Verortung. Bei der Betrachtung der verschiedenen Unternehmensgrößen stechen die kleinen Unternehmen mit einer Auslagerungsrate von 39%

heraus. Nur wenigen Unternehmen wurden bisher FS im Paket angeboten. Nur 6,4% der befragten Unternehmen haben schon einmal ein entsprechendes Angebot erhalten. Die Hypothesen 1 und 2 können abgelehnt werden. Hypothese 3 kann nur für urbane und kleine Unternehmen abgelehnt werden. Hypothese 4 gilt als bestätigt.

Abschließend kann gesagt werden, dass KMU, insbesondere die kleinen Unternehmen, eine relevante Zielgruppe für FS-Anbieter sind, für die ein attraktives Angebot geschaffen werden sollte.

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MultiMapping and Urban FM

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Abstract

Purpose: The paper discusses a more active role of Facility Management (FM) to participate in the development of urban area with aim to build competitive and healthy surroundings with a high quality for residence, business and spare time. FM, as a supporting service in operational phase of built environment (building, complexes or areas), can pursue development from the first start of the use phase until its end. An active role is seen as co-creating the place together with estate owners or users in many perspectives, such as creating better environment (exp. sustainable oriented, against gentrification) or better services (exp. assistance/services for elderly people, financial models for supporting better living conditions, inter-generation models).

Design: MultiMap model is used for measuring building performance (technical, environmental, structural etc.) and with new strategy to use it for urban areas, it is more focused in urban value capture model, modifying forms of management and toward and new services for FM, oriented to a social responsibility. Developing and combining new modules for multiMap will produce criteria of which objects/cities/districts can be mapped and measured already from planning phase and follow the project until the end of the operation phase. This may contribute to maintain a desirable urban area throughout its lifecycle.

Findings: MultiMap model is generic and therefor found adaptable for more than buildings. Urban context is group of campuses and campuses is group of buildings. The complexity is about organizing FM services into Urban FM due to different stakeholders and huge amount of data to be handled.

Research limitations/implications: The presented research is developed for public as well as private sector, as the basic scientific principles are general and relevant for other sectors.

Practical implications: The research covers a need that is becoming more important as the focus on Well-being issues in high dense urban areas are increasing.
Originality/ value of paper: This paper can contribute to develop Urban FM as an increased area for FM organizations.

Keywords: Urban Facility Management, Business models, Value capture

1. Introduction

In most urban areas throughout the world there is three major trends going on; 1) transformation of existing urban areas (with division between industry building complexes, block of flats, office areas, abounded buildings) to integrated multipurpose areas, 2) growing population and increasing living age and 3) needs for decreasing use of nonrenewable energy based transportation. It is expected that 60% of world population will live in urban areas within 2030 (https://unhabitat.org/urban-themes/climate-change/) and increase further up to 68% in 2050 (UN May 2018). Results of earlier research (Rus, 1997, Temeljotov 2004) show that the characteristics of physical microenvironment, especially the residential and working environment can significantly influence the quality of our life. It is also well known and documented (Bjørberg 2009, Bjørberg et al. 2012) that backlog of maintenance has a significant influence on the environment, both indoor as well as outdoor, which will affect the users of the buildings regarding health, safety, social and environment experience.

Norwegian White Paper "Good Building for a Better Society" (2012) stated the importance to create good buildings as a criteria to achieve “well-being” for users in buildings and in urban areas to get a better society. To fulfill this aim it is necessary to focus on life cycle planning. Connection between the design of the built environment, the quality of life of individuals, the social structure of society and business development are closely linked together. Planner-, construction and property industry plays a crucial role in enabling good cities and towns. Comprehensive research, however, shows that development of urban areas must be linked more closely to an understanding of the development of economic sustainability because of social improvements. In the research OSCAR “Value for owner and users of buildings” (2014-2018) it is stated in life cycle planning it is crucial with an integrated early design team with knowledge from the long user phase. In the team competence from users are essential and in that respect there can be four type of users; 1) the organization (core business), 2) employees in core business, 3) Facility Managers (FM) personnel and 4) visitors. Lack of understanding of this connection leads to cities and towns who, to a far lesser extent, got less desirable ability to create value for the citizens, business and society as a whole.

The FM function or campus (schools, hospitals, and universities) has developed from being janitor or caretaker to be a coordinator of all needs for supporting core business. According to EN 15221 – 4 “Taxonomy” FM is divided into “Space & Infrastructure and People & Organization” and is a strategic role to search, facilitate and demonstrate need of a business

organization as a proactive action that helps the business organization to understand their future needs (Valen et al. 2014). All FM activities is important for up keeping “well-being” aspects. Well-being is the balance between economy -, environmental - and social aspects as shown in figure 1.

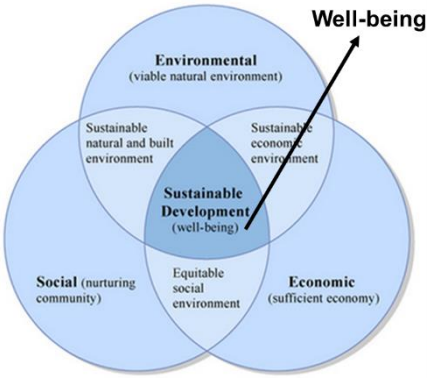

Fig. 1: Well-being as balance between sustainable aspects (Multiconsult)

Urban Thinkers Campus (2014) agreed on several key principles to get well-being, such as the city should be inclusive, has a human scale and is well planned, walkable, and has adequate, accessible, and affordable mobility, economically vibrant, unique identity and sense of place, safe, healthy and be well planned, financed and governed at all levels. In addition the urban areas should provide education and economic opportunities for all, have open and accessible public spaces and it should be madefor and by people.

Documentation of needs for maintenance and upgrading is important to promote and communicate building needs, and aggregating these needs in an objective and comparable measure across the portfolio is a challenge for the Facility Management (FM) organisation. It is important to use models that cover all aspects, which have impact on the core business effectiveness. Urban areas has the same needs, but the big difference from campus mentioned above, is the fact that urban areas has a lot of different core business and stakeholders. To get all stakeholders satisfied FM should provide deliveries such as flexible solutions, well maintained and adaptable buildings and space between them as well as being service oriented towards the customers satisfaction and needs. Urban FM has to comprise the combination of socio-technical skills (Temeljotov et al 2018).

Seen from a transportation point of view, urban areas has three main groups of population; 1) children (to school / kindergarten), 2) grown-ups (work) and 3) elderly people (elderly centres, medical and social care). And all groups goes for shops, cafes, parks etc, as shown in figure 2.

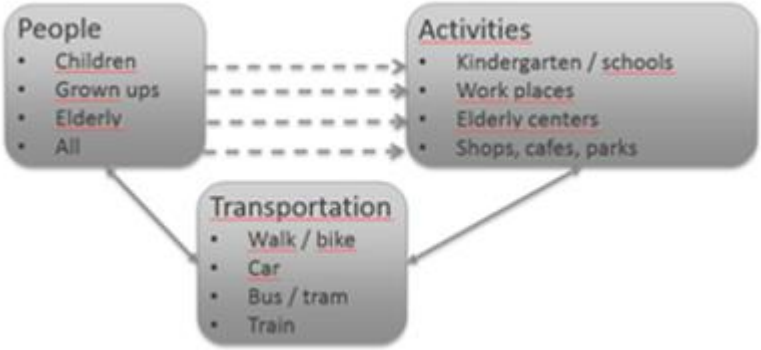

Fig. 2: Population groups and their activities and transportation (S. Bjørberg, Multiconsult)

During life time people are going through all three groups and they have changing social needs, see figure 3.

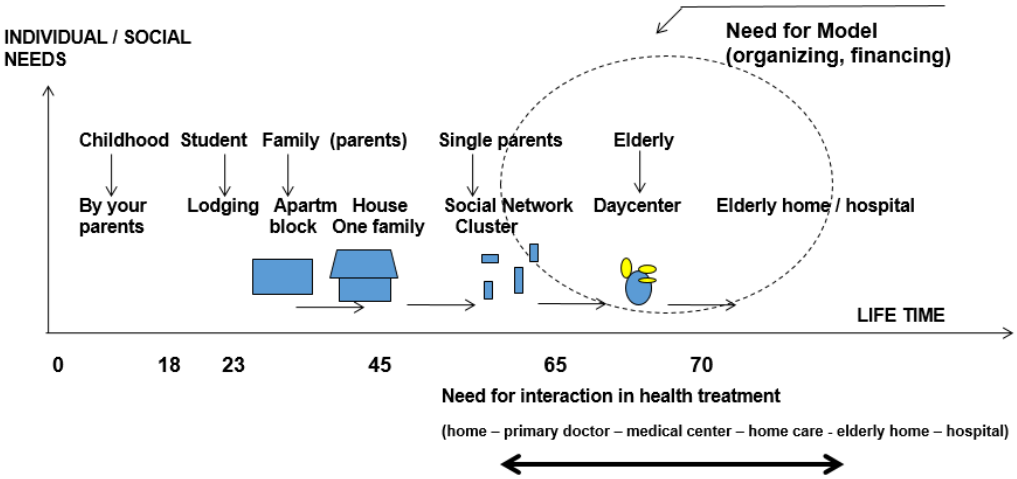

Fig. 3: Life Cycle Social Needs model (S. Bjørberg, Multiconsult)

Transportation is seen as a hierarchy with at least three levels; 1) come fast, 2) come often and 3) come slow and all time. The system should integrated in urban context as shown on figure 4.

Urban FM should be able to take care of buildings, campuses and urban areas to upkeep the well-being aspects and develop new business models. But to take action FM must assess all type of conditions to make plans on long and short terms. Mapping the area from the perspective of an existing state of art in urban area, potential for future development and evaluating the gaps from social, economic, and environmental sides, are important for the analysis of every area. Combination of data mapping and value contribution should turn out to be effective tools for gathering and analysing large amounts of information. The way of classifying information gives opportunity to aggregate data to create comprehensive key performance indicators (KPIs), and with new technology to visualize results to obtain effective way of communicating complex information. Comparison assessed data (performance) and demands will give answer on upgrading needs.

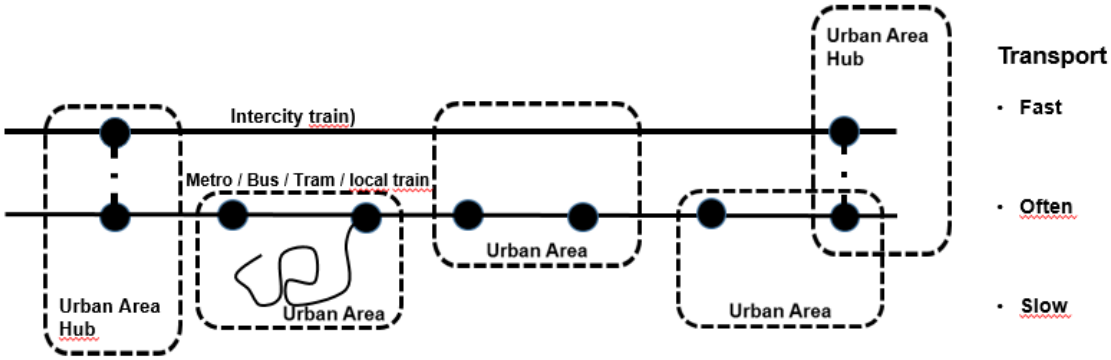

Fig. 4: Transport hierarchy integrated in urban context (S. Bjørberg, Multiconsult)

The new role and concept of Urban Facility Management should expand from typically business or public buildings to apply to the public, targeting urban neighbourhoods and should be seen as a position of knowledge, authority and trust in the urban community. This new role asks for broader access to detailed information, which should be structured in a communicative way for all stakeholders.

2. Methodology / approach

In 1997 Oslo City Council asked for an estimate of upgrading costs and value of their total building portfolio of approximately 4 million m². Due to short time for the assessment of technical condition and the size of the portfolio, the multiMap method was developed. Huge amount of data should be gathered, systematized and communicated. The methodology were based on classification and key words helping matrixes to get structured information from FM people knowing the buildings.

In addition to the technical condition, there has been an increasing focus on how buildings affect the core business effectiveness over time. Changes and new needs in the core business will lead to new performance requirements. Today multiMap consists of several modules, which give information of a building/-portfolio regarding the portfolio performance and potential for future use (see Figure 5), and several other modules is under development.

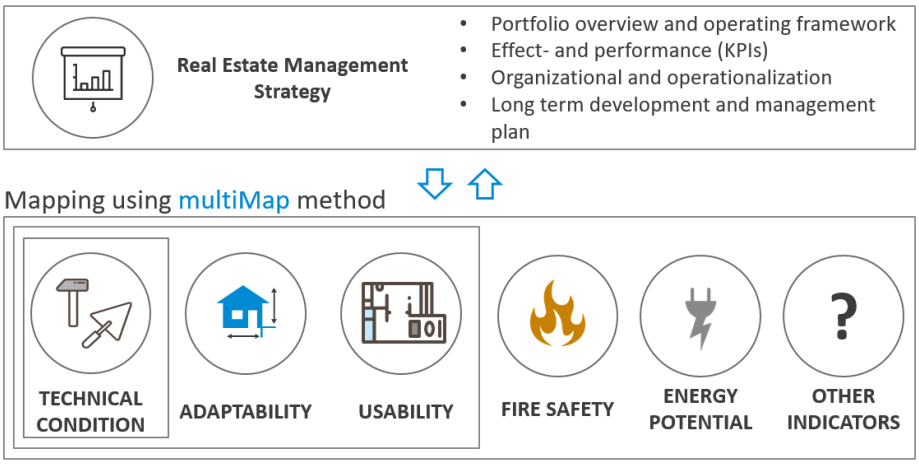

Fig. 5: Different modules and module packages in MultiMap (Ref.: Multiconsult)

Totally, the tool has been used for approximately 30M m² (GFA) of buildings, but since the model is generic, it has also been used on roads and nautical installations in Norway.

Norwegian Standards (NS), such as NS 3424 "Condition Assessment of Construction Works" (2012), NS 3451 "Table of Building Elements" (2009), NS 3454 "Life Cycle Costs for Building and Civil Engineering Work" (2012) and NS 3457 "Table for Building categories" (1995), was taken into use. The first one, NS 3424, is the most central. It uses condition grading between 0 and 3. Condition grade 0 is equivalent to the best grade (new construction), and condition grade 3 corresponds to the lowest grade. Table 1 gives a general description of the condition grades in the standard.

Condition grade	Description
0	No symptoms
1	Slight symptoms
2	Medium-strong sympt.
3	Strong symptoms

Tab. 1: condition grades due to Norwegian Standard NS 3424

Building portfolio is divided into building types (schools, offices, hospitals etc.) and building elements (roof, façade, HVAC etc.). To systematize information for an objective assessment, matrixes / forms, including guidance, are developed. An example of a descriptive matrix is shown in table 2.

FUNCTIONALITY - INTERNAL LOGISTICS				
Parameters	Grade 0	Grade 1	Grade 2	Grade 3
Functions	The facilities contains the functions the organisation (user) needs, now and in the known future. No complaints from users.	The facilities contains to a high extent all necessary functions the users need in todays situation.. Only small amount of functions located in other facilities/building.	The facilities lack some essential functions, resulting in regularly use of other fasilities/buildings.	The facilities does not give room for necessary functions. Large amount of essential functions located in other facilities/buildings. High amount of complaints/dissatisfaction from users.
Area/space	Suffisient area (m2) to support necessary functions satisfactorily, now and in the known future.	Suffisient area for todays functions.	Amount of space (m2) is little. The spaces is small and well suited for the different functions. Low space/area efficiensy.	Acute need of more space in order to perform necessary functions.
Design and shape	Design and technical solutions is a very good support to the core activity, today and in the known future. The internal logistics is good and the core activity can operate effectively.	Design and technical solutions is a good support to todays core activity. The internal logistics is good and does not hinder effective operation for the core activity.	Design, shape and technical solulons is inexpedient. Essential functions is ineffecively located.	Design and technical solutions is inexpedient. Internal logistics is bad and results in ineffective operation of the core activity.

Tab. 2: Example on an explanatory matrix, part of the Usability matrix. (Ref.: Multiconsult)

Use of BIM tools, like Onuma Planning System together with Google Earth, provides the possibility to model buildings in 3D and adding information directly to the model itself. This provides maps and possibility to synthesize building and location. In figure 6, as an example, technical condition is presented using colours on the building models surface. Each colour represent one of the condition degrees. This way of presenting results makes the information very easily understood. It is also possible to add information on different levels, like building site, municipality, county and country.

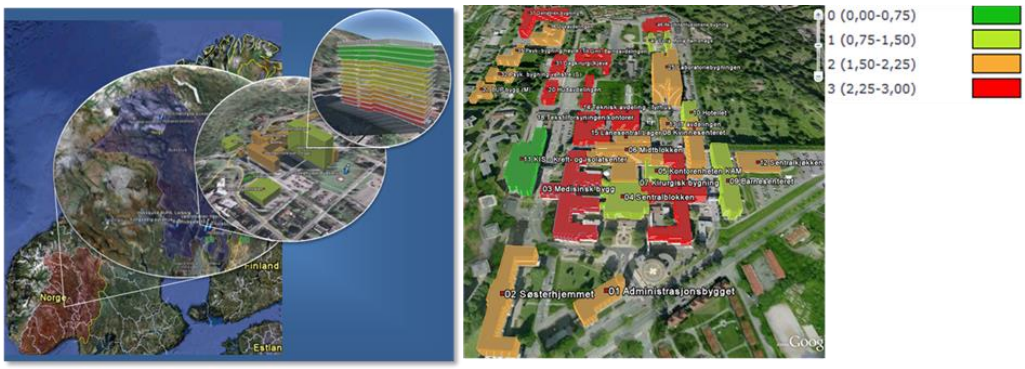

Fig. 6: Presentation of results using Google Earth and Onuma Planning System (Multiconsult)

3. Findings

Since the model is generic also roads and nautical installations in Norway has been mapped. For roads, division is road types and road elements, and for nautical installations, division is nautical types and nautical elements. But for totally Urban FM purposes multiMap should also include definition park types and elements, social aspects and elements etc.

In cooperation with Oslo municipality, agency responsible for parks, Bymiljøetaten (BYM), a module for assessing technical conditions of parks and park elements has been developed. BYM participated with several of their FM resources in the development and structuring of the module. Park types were previously established in the municipality and ranged from Type A (exclusive and high maintenance park) to Type D (more forested parks with less demanding upkeep). Note that pure woodlands and forests are not included in the portfolio. As for existing modules in multiMap, Norwegian Standards are used, if there is one relevant. For the park element structure, NS 3420-ZK "Operation and maintenance of parks and gardens" (2016) were used. For every park element, a cost function was derived, that is based on a few attributes of each park. This cost function is essential in weighting and aggregating the condition grades to a comparable measure across the portfolio.

The mapping process was performed by BYMs own FM resources supported by workshops and Multiconsult staff. Results of the mapping process and compared to other condition analysis were significantly less resource intensive. The complete results are utilized and analyzed internally in the BYM organization for strategic management, communication and resource / budget planning. Due to the flexible structure of the quantitative method, several other analyses may be performed and visualizations produced on demand. This way the message the organization wants to get across may be optimized based on the target group (internal / external, park professionals / laymen etc.).

3.1 Results part 1 – Portfolio overview

Clear and communicative portfolio overview contributes to a greater understanding internally in the organization and externally to political decision makers in the municipality. Challenges and difficulties, as well as the accomplishments and performance, are presented and traced over time. BYM management is segmented into divisions that are largely determined by geographic segments.

There were great diversities in the compositions of the different management divisions' portfolios. Of the 7 management divisions, portfolio m² ranged from 43% of total area to less than 3%. The smaller divisions' parks, however, were significantly more complex and consisted of proportionately more Type A parks. See figure 7 for visualization. This is naturally common knowledge for BYM, but the visualizations and the quantification of this information provides useful tools in gaining a common understanding of the organizations different needs for competence and resources and may be used for more in-depth analysis and external communication.

Type A parks are generally located closer to the city center and are generally more technically complex and with a higher gross technical value (unadjusted for condition). This creates different needs for capital that may not correlate with size. To illustrate this, the gross technical value of parks in different districts of Oslo is compared against gross park m² in the same districts. See figure 8 for illustration. This information is quantified and may be used in the budgeting process.

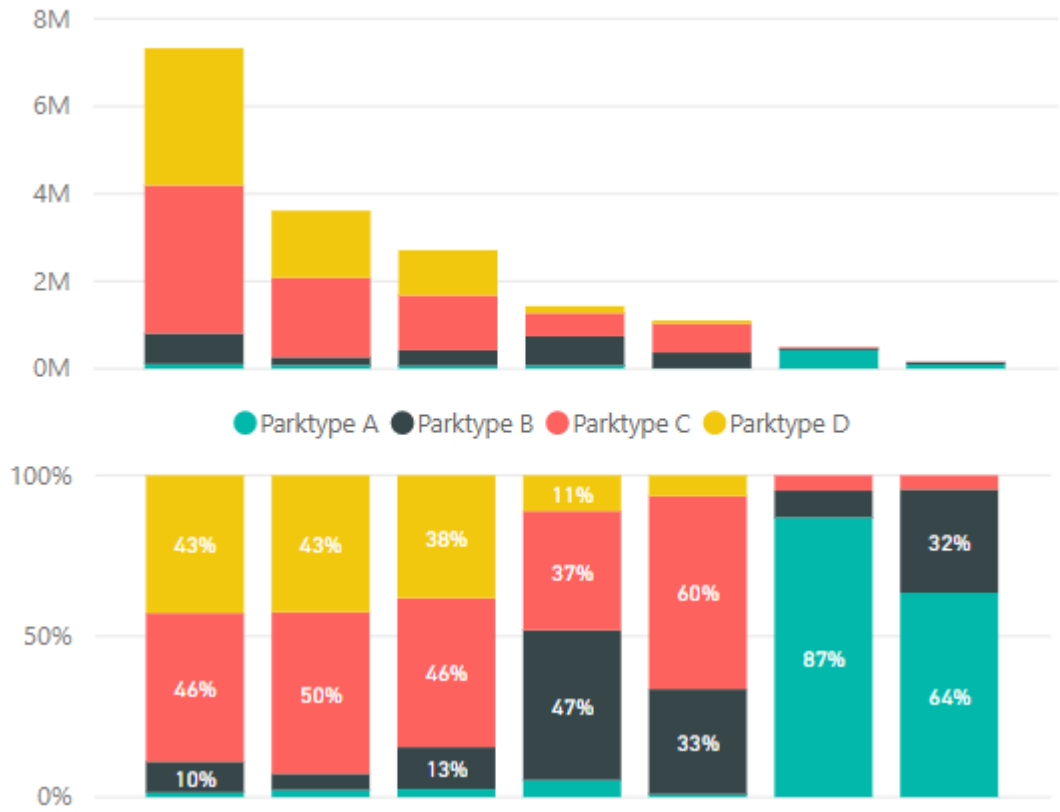

Fig. 7: Composition of FM divisions' park portfolios within BYM (m² and relative ratios)

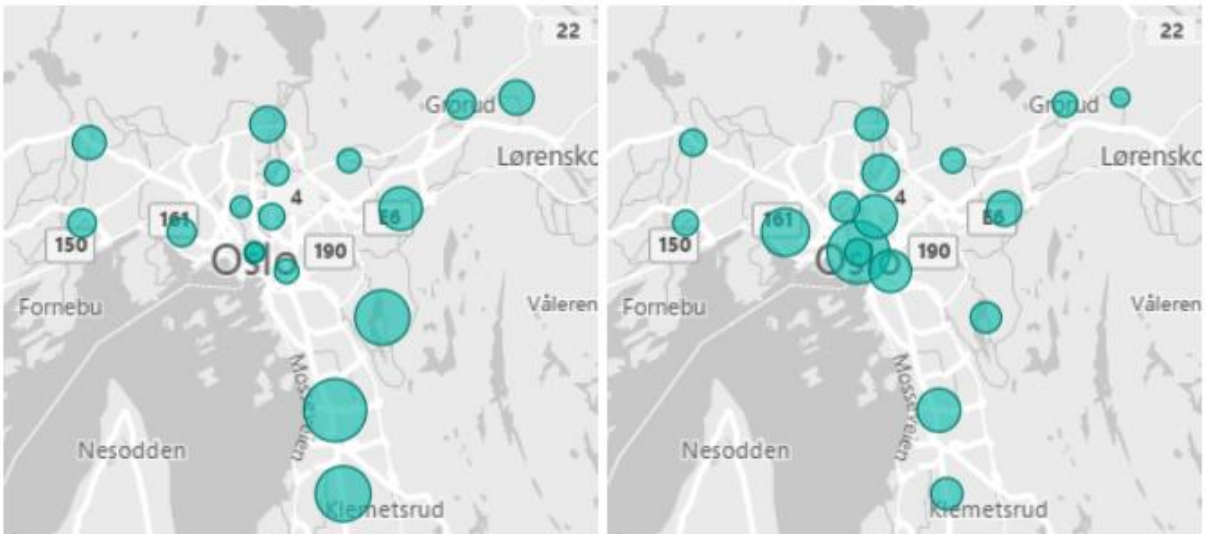

Fig. 8: Visualizations of parks in geographical districts by area (left) and gross technical value (right)

3.2 Results part 2 – Technical conditions

The technical conditions of parks are closely related to degree of upkeep. We have defined maintenance needs as separate from the need for general upkeep (such as mowing grass, shoveling snow, trimming hedges etc.). It is generally defined as maintenance need when a greater effort than normal upkeep is required to restore the element to condition grade 1. The aggregate weighted technical condition grade of the entire portfolio, is presented in Figure 9.

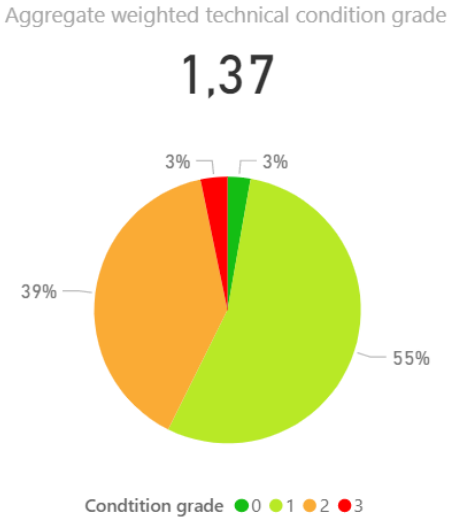

Fig. 9: Total grade (top number) and park area in the different grades (pie)

This grade and data may be separated by management division, geographical district, park types and any other relevant assortments of parks. The interpretation of the result depends on the municipalities ambition levels for certain parks. For instance may Park type A have a lower grade ambition than park type D. We see that over half of the parks are in good to satisfactory condition (grade 0 to 1), almost 40% is in unsatisfactory condition, and 3% is in poor condition. In Figure 10 we see that this distribution varies greatly across geographical districts.

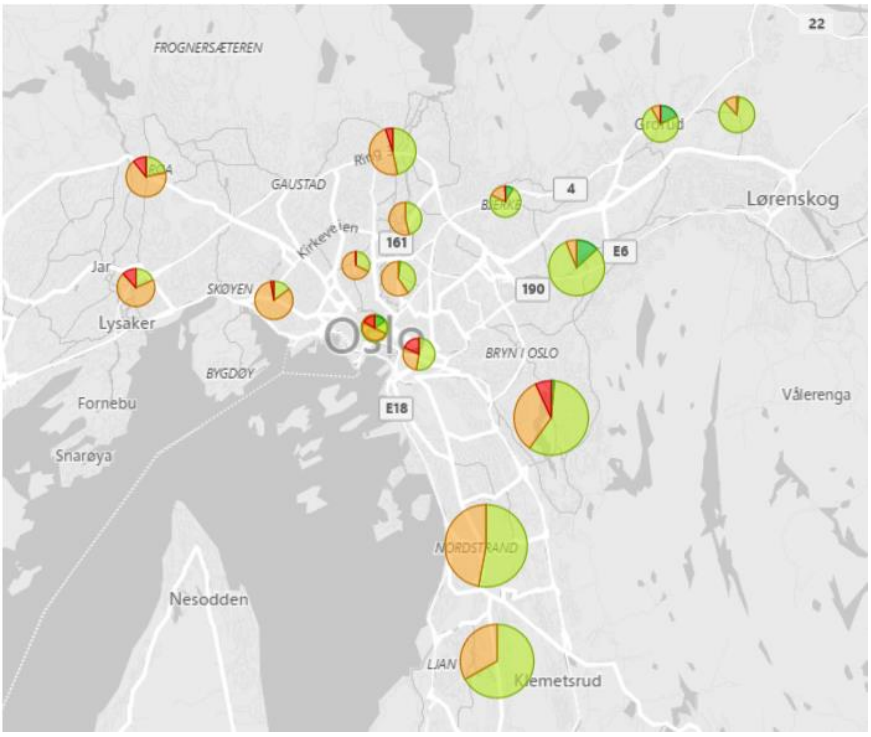

Fig. 10: Park area in the different grades in different geographical districts (pie size = total m²)

Figure 11 shows the same information distributed across management divisions.

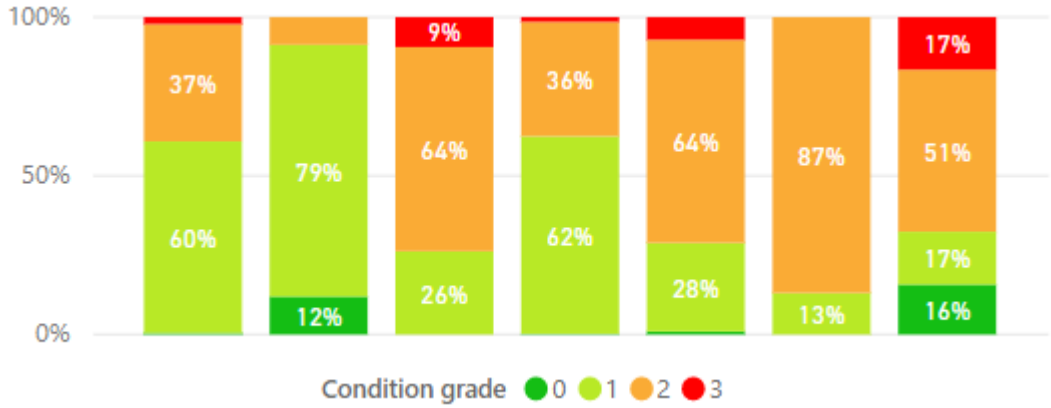

Fig. 11: Park area in the different grades in the different management divisions

3.3 Results part 3 – Maintenance capital needs

Elements and components with condition grade 3 are considered immediate needs and is recommended repaired/restored within a 5-year period. Elements with condition grade 2 is recommended restored within a 5-10 year period. Note that elements with condition grade 2 is not necessarily a maintenance backlog, but may be due to natural causes such as the component nearing its intended lifetime and is planned to be replaced. An ambition of no elements with condition grade 2 is therefore unrealistic. Elements in condition grade 0 and 1 are assumed maintained by normal upkeep and is not included in further calculations. Values are in NOK (2018) and are early estimates in the budgeting process.

Figure 12 presents the maintenance capital needs of the different maintenance divisions in BYM.

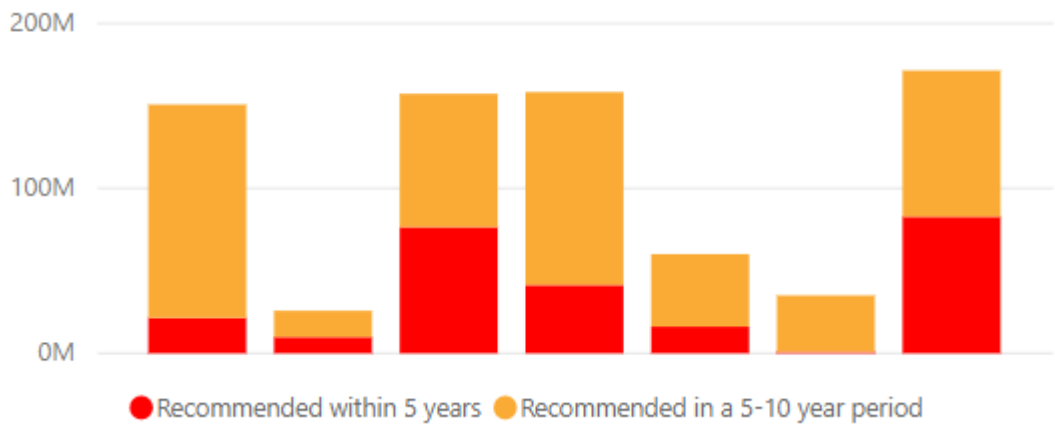

Fig. 12: Maintenance capital needs of different management divisions

3.4 Reliability and validity of results

Experience from using the methodology for huge amount of building, and same buildings several times, document that the methodology is replicable regardless which person doing the measures. It also shows, through case study, that the methodology is generic and can be used for other purposes than buildings.

The degree of uncertainty in these calculations make the values suitable for strategic use as orders of magnitude, but not as direct inputs in the budget process. Concrete actions needs to be defined, structured and cost estimated, preferably with the mapped conditions as basis. Because of the amounts of parks (close to 800) the uncertainty of cost calculations for the entire portfolio is somewhat mediated by the law of large numbers. In figure 13, uncertainty is shown in % as a function of amount of objects. For less than 20 objects, the uncertainty is 35-15 % but above 40 parks, it drops down closer to 10 %.

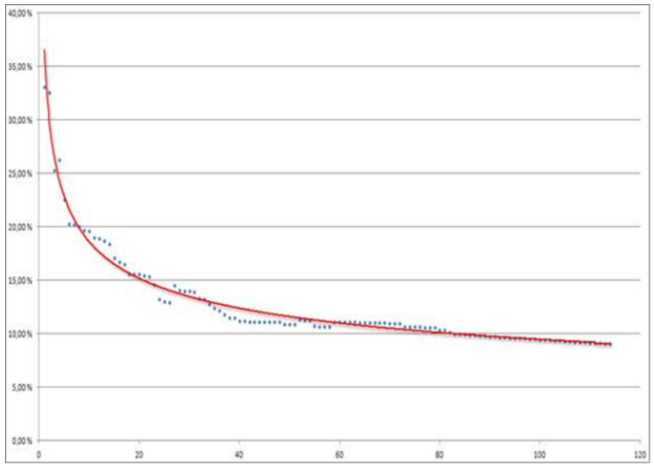

Fig. 13: Uncertainty of cost mapping portfolio (Multiconsult)

4. Discussion

A main objective has been to provide tools that can strengthen the strategic FM practice and bridge the gap between needs for users of urban areas by developing urban FM services. So far the results from practice has shown that the active approach to backlog and the way results are communicated to decision makers as shown is effective, and is being used actively in strategic planning. The tools may also be effective for FM-personnel in their daily work, as an aid in the dialog with users, but this requires a shift in practice towards an active strategic role, which is not so common today.

As the methodology is generic and based on measurable quantitative data, it can be used for any kind of issues. Aggregation of data is possible to obtain a communicative level for decision makers.

Based on increased interest for Urban FM, priority for further development should be a module assessing social aspects. To do that it is a need to define classification of social groups and – elements.

5. Conclusions

A new Urban FM role is seen as a position of knowledge, authority and trust in the urban community. To play this role it is important to have access to huge amount of data covering total aspects of services within urban context.

The assessment method described in this paper cover a need that is becoming increasingly more important as the focus of FM shifts towards strategic FM and added value for users of urban areas. The multiMap method and methodology has proved to be an excellent tool for mapping technical condition as a base for estimation of maintenance backlog in portfolios and as a first scan of single buildings and urban areas ie all space between buildings (parks, roads etc). Presenting results in 3D BIM and Google Earth has proved to be communicative.

Further development should focus on social aspects due to changing needs during people's life (Life Cycle Social Needs). Children, grown-ups and elderly people (social "types") has different needs (social "elements") that shall be satisfied in urban context. Sustainable FM is more than energy efficiency, upgrading of maintenance backlog of the building itself, it is combination with quality of interaction between economy; environment and the social aspects so obtain well-being in buildings and campuses. The role of Urban FM is an expansion of services for all stakeholders in urban areas. This has to be understood and accepted as an important actor by all stakeholders.

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Science meets Practice II:

New Ways in Building Automation

Facility Services: Impact of new technologies

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Abstract

Studies estimate that in general 47 % of all jobs will be automated due to digitalisation. The Facility Service (FS) industry is the third largest sector in the EU. FS will be more affected as it consists of more routine tasks. The research questions are: Which technologies are relevant for FS and when are they feasible? Based on literature review authors evaluated relevant technologies/use cases. Expert interviews were carried out to validate the results. A survey was conducted to define technical and economic feasibility. The results present the relevant technologies and their feasibility in FS.

Keywords: Facility Management, Facility Services, Applications, Evaluations of new technologies.

1. Introduction and research questions

Facility Management (FM) is a key function in managing the demand and fulfillment of services and infrastructure necessary for the core business. Facility Management influences the ability to act proactively and meet all requirements of the core business. On the other side, it is to optimise the costs and performance of assets and services (Österreichisches Norminstitut 2007). Digitalisation impact Facility Management in two main areas:

Due to changes of the core business (new ways of working) the demand for infrastructure and services changes.

Digitalisation also has a big impact on the Facility Service (FS) provision: the application of new technologies, for example, Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML) allow control over the complexity of FM processes and services in a more effective way.

The paper concentrates on the second area.

The outsourced FS industry is the third-biggest industry regarding of employment in the EU (Stopajnik & Redlein 2017). This makes the FS industry very important. Furthermore, it must be noted that services around buildings and infrastructure cannot be off-shored. FM-activities have a high significance for process optimisation (Chotipanich 2004). Therefore, the application of new technologies, like IoT, AI and ML becomes an important factor (Selinger et al 2013). The starting point of a large-scale implementation, of so called smart technologies, is that such technologies must provide some level of performance for specific applications before they will begin to diffuse (Čas et al 2017).

Many studies are analysing the impact of digitalisation on work processes. These studies assume that routine-tasks will be most affected and conclude that there will be drastic changes and shifts in required skills (Nagl et al 2017, Stopajnik & Redlein 2017a, Frey & Osborne 2018). The study of Frey and Osborne (2018) showed on how susceptible different jobs were to computerisation in the US. They estimated that 47% of all jobs would probably be substituted by computers. On basis of technological progress in machine learning, mobile robotics, they determined the probability of computerisation for over 700 occupations. Furthermore, the study of Stopajnik & Redlein (2017) shows the impact of digitalisation on the Facility Service Industry. They

estimated that typical FS activities (Österreichisches Norminstitut 2007a) are at very high risk, e.g. Installation. Maintenance, repair work has a 50 % probability to be automatised, janitors and cleaners have a probability of 66 %, and first-line supervisors of housekeeping and janitorial workers show a probability of 94 %. (Stopajnik & Redlein 2017, Peneder et al 2016) to be automatised.

	EU	**US**
Total number of employees in Total business economy	135.601.377	90.337.386
Total number of employees in Facility Services	14.438.876	9.008.432
Proportion of employees in Facility Services	10.65%	9.97%

Tab. 1. Comparison between the numbers of employees for business economy in general and for the FS sector in the United States and the European Union, from 2014 (Stopajnik & Redlein 2017)

Existing research postulates that technological developments like IoT, AI, ML can help to fulfil FM requirements better and reduce costs in the same time. The existing studies give only a macro-economic view on the changes within FS. (Stopajnik & Redlein 2017, 2017a, Frey & Osborne 2018) But an estimation of relevant technologies and use cases/scenarios are needed to depict how these technologies will change the industry. The research objectives of this paper are to provide an evaluation of the relevant technologies, their application possibilities (case studies) and their technical and economic feasibility. The research questions are:

1. What technologies are relevant for optimisation of the Facility Service provision?
2. What is their technical and economic feasibility?

2. Methodology

The study is based on the Mixed Method Research Approach that combines quantitative and qualitative research methods. This means, the Mixed Method Approach combines quantitative surveys with qualitative data collection methods, e.g. personal interviews, expert groups, workshops with professionals and content analysis. The goals of qualitative research are induction, discovery, exploration, theory/hypothesis generation. The major goals of quantitative research are deduction, confirmation, theory/hypothesis testing, explanation, prediction using standardised data collection and statistical analysis. Quantitative and qualitative method have

lack of strengths (Johnson & Christensen 2007). The goal is to draw from the strengths and minimize the weaknesses of both research methods (quantitative and qualitative) in single research studies and across studies. Taking a mixed position allows researchers to mix and match design components that offer the best chance of answering their specific (research) questions (Johnson et al 2007).

The used methodology consists of three steps.

1 Extended literature review was used to define the relevant technologies and generate use cases and scenarios. Scenarios created described future development for feasible using of new technologies for Facility Services.
2 A questionnaire was developed to define the technical and economic feasibility of the scenarios/technologies due to a survey. The quantitative study had the goal to validate the results of the qualitative steps done before.
3 Expert interviews were carried out to validate these scenarios. The survey was carried out in spring of 2017. 50 German-speaking facility managers from the healthcare industry were interviewed. The result was a list of smart building technologies and the estimation of their feasibility.

2.1. Literature review

A broad literature review was carried out to analyze and evaluate existing publications for potential use cases and forecasts of the changes due to digitalization in the sector focused. The first thread of thought ensured that the authors of the study would maintain a neutral perspective by finding as many studies as possible which dealt with operationalization of new technologies independently of theoretical traditions. The second thematic thread focused on the instructional perspective, since the authors were interested in business premises and properties of digital environments that might support facility services.

The two remaining threads restricted our search to technologies and applications in that context. The authors considered the fast pace of short product cycles and new technologies are being developed (Multi-Annual Roadmap 2018). It was expected that publications of technology companies and journals will be more important sources than those of books. Hence, the authors screened reports of following areas: Business project descriptions, press articles, promotion reports, evaluation reports (scientific & consulter), project descriptions from councils and communities. The authors searched empirical studies published in peer-reviewed journals with a publication date from January 2000 to February 2018. Digital Reports like IEEE Xplore digital library, Harvard Business Review or Researchgate were powerful resource for discovery

of scientific and technical content published by institutes of technical engineers and its publishing partners. This procedure resulted in n = 350 records. The journal that was the most frequently represented was IEEE. The next step was to conduct short project description screen. To broaden the scope also cases from different industries were included in the analysis. This was done to enable Relocating: changes of the location and production methodology (Servatius 1985). In most articles, figures about the economic effects/benefits are based on the study of a single technology or one specific industry case. Different kind of usability in the use cases were gathered in the category of "services/domain", 93 in sum. The data presented is not specifying in detail how the impact could look like. Existing data cannot be used for a general proof for the feasibility of use cases in the area of FS (Čas et al 2017). Therefore, relevant technologies and use cases founded in the literature were gathered.

The use cases were clustered according to:

- current service field, in which it is applied (Österreichisches Norminstitut 2007a)
- technologies used and
- technical and economic feasibility.

2.2. Use case validation

The results were presented to experts to validate the findings but also to develop new scenarios. The results gained, were the basis for a draft of use cases how new technologies can change the operation of buildings/infrastructure and service provision.

2.3. Survey

Based on the scenarios a questionnaire was developed and more than 50 facility managers of the health care sector were asked to evaluate the technical and economic feasibility of the use cases/scenarios and the applied technologies. In a highly regulated industry like healthcare, compliance is especially important. Guidelines set high standards in a cost-effective manner. (International Organization for Standardization 2001)

The data was entered in MS Excel and analysed. The basis of the used statistics was parameter distribution, i.e. mean, median and max of total answers. To understand the tendency of data and the underlying distribution of the data. Measures of central tendency, also known as measures of location, are typically among the first statistics computed for the continuous variables in a new data set. The main purpose of computing measures of central tendency is to give you an

idea of what is a typical or common value for a given variable (Boslaugh et al 2008). The results are validated by questioning the outliers, retracements and changes in trends.

3. Results

Ten innovative technologies were identified from literature review (Chotipanich 2004, Selinger et al 2013, Nagl et al 2017)

- Sensors/Internet of Things
- Drones
- Augmented reality
- Virtual reality
- BIM
- Mobile apps
- RFID
- Robotic (cleaning/transport/security)
- Automation
- BIG Data

3.1. Feasibility of IoT

The first scenario elaborated was the IoT (Internet of Things), which enables objects to connect and to exchange data. For example, smart sensors are being used today in walls and floors to monitor temperature, structural integrity, and to control light systems. IoT includes “embedded intelligence” in individual items that can detect changes in their physical state. Sensors give things a “voice”: by capturing data, sensors enable things to become context-aware, providing more experiential information to help people and machines make relevant and valuable decisions (Selinger et al 2013, International Organization for Standardization 2001).

The methodology described above now applied to derive the technical and economic feasibility (years till feasibility) of IoT in FS.

The left column of Fig. 1 and 2 shows the results of the use case definition based on literature analysis and expert interviews. The applications of the technologies derived from step one and two were included in the survey. Afterwards the experts were asked to evaluate the technical and economic feasibility. Fig. 1 shows the answers for the technical feasibility, Fig. 2 shows the answers for the economic feasibility. The range of answers is described by using median (which are 0 years), mean and max of the answers (years till feasibility). The statistical data allows realistic feasibility estimation.

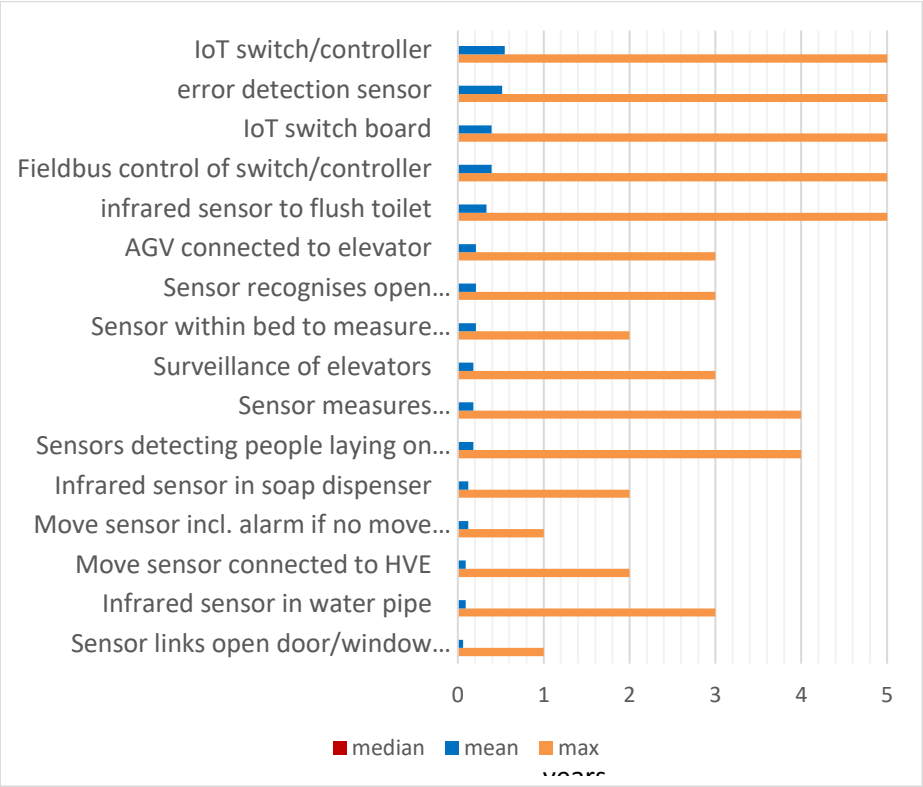

Fig. 1. Technical feasibility of Sensors/IoT in the FS sector (years till feasibility)

The experts estimated this technology as already technical feasible. IoT devices are able to produce the energy they need by themselves and those applications can be easily connected to the WIFI of the buildings, enables the use of IoT in addition. (Xu et al 2014) Hand dryers with sensors and move sensors are already in use and therefore technical feasible. Sensors, which recognises to open the door/window by sending message and infrared sensor to flush toilet show a short time till they are technical feasible. IoT switch/controller and IoT switch boards have a mean technical feasibility of around half a year. The answers show that IoT and IoT sensors have a short time till they are technically feasible.

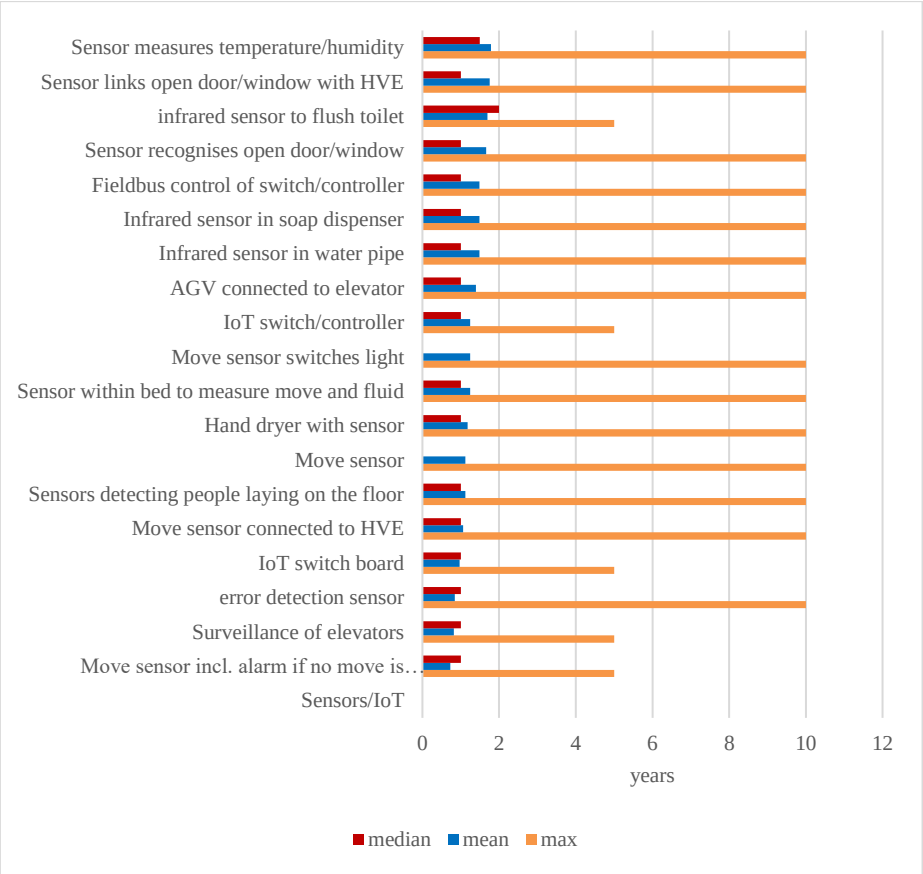

Fig. 2. Economic feasibility of Sensors/IoT in the FS sector (years till feasibility)

Fig. 2 shows the economic feasibility of sensors. Move sensors and surveillance sensor for elevators are already economic feasible. Whereas IoT devices measuring temperature/humidity, open doors and windows are still too expensive. (Kone 2018)

In general, IoT devices have the shortest technical and economic feasibility.

3.2. Feasibility of Mobile Apps

Mobile Apps were also evaluated to be highly realistic use cases for Facility Service (FS) provision.

Fig. 3 shows the technical feasibility of Mobile Apps. Order confirmation, failure message sending via apps, path finding and controlling room climate have a mean of 0,3-0,5 years.

Fig. 4. shows economic feasibility of Mobile Apps. Using apps to control room climate show a mean time to economic feasibility of 1,3 years and a median of 2 years. Order confirmation has a mean of 1,1 years, path finding and send failure messages show an even shorter time to economic feasibility. Statistical data analysis shows discrepancies between some estimations.

Many experts consider this technology to be applied soon, some believe it will take longer until this technology is technical feasible. This can be seen in the big differences between median values (which are 0 years),mean and max values.

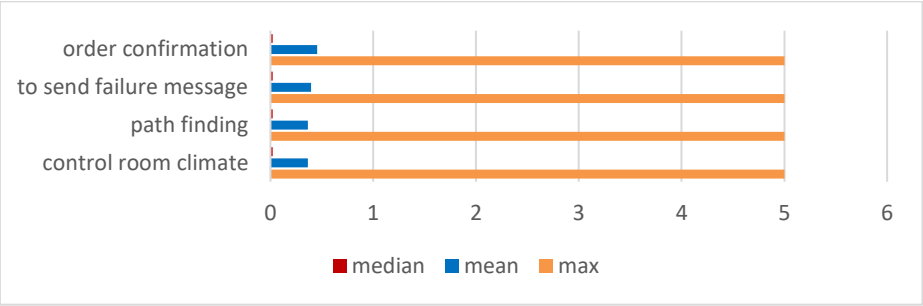

Fig. 3. Technical feasibility of Mobile Apps in the FS sector (years till feasibility)

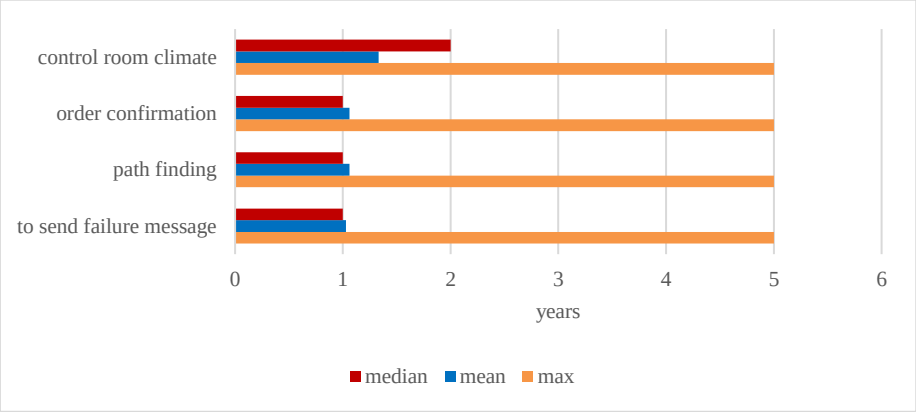

Fig. 4. Economic feasibility of Mobile Apps in the FS sector (years till feasibility)

In general, Mobile Apps are estimated to be technical in 0,5 years and economic feasible in about a year in FS operation. The reason for relatively high feasibility is that Mobile apps optimize the service of procurement. (Deloitte 2018) The economic feasibility is in all cases longer than one year, which is twice longer than the technical.

3.3. Feasibility of Drones and Robotic

Drones and service robots have been mostly restricted to providing benefits in repetitive applications. Robots working with consistent precision and repeatability. The future demands other capabilities – particularly in the fields of professional and consumer service robotics. If robots are to move into other fields they must become more flexible and provide benefits in a larger variety of situations. (Čas et al 2017, Multi-Annual Roadmap 2018)

Different use cases in FS provision like providing building maps, general or sewage inspections were found in literature research and named by experts. Fig. 5 shows the results for technical feasibility of using drone applications. Drone applications will be technical feasible in a range of 1-2 years and economic feasible in a range of 3-5 years. Providing building maps, general inspections and sewage inspections had a mean below 2 years. This technology provides affordable 3D maps of existing buildings and may lead to a change in the profession of architects and civil engineers, as these are the two professions providing as-build drawings. As these drawings are also the basis for CAFM tools, their usage possibilities may change also.

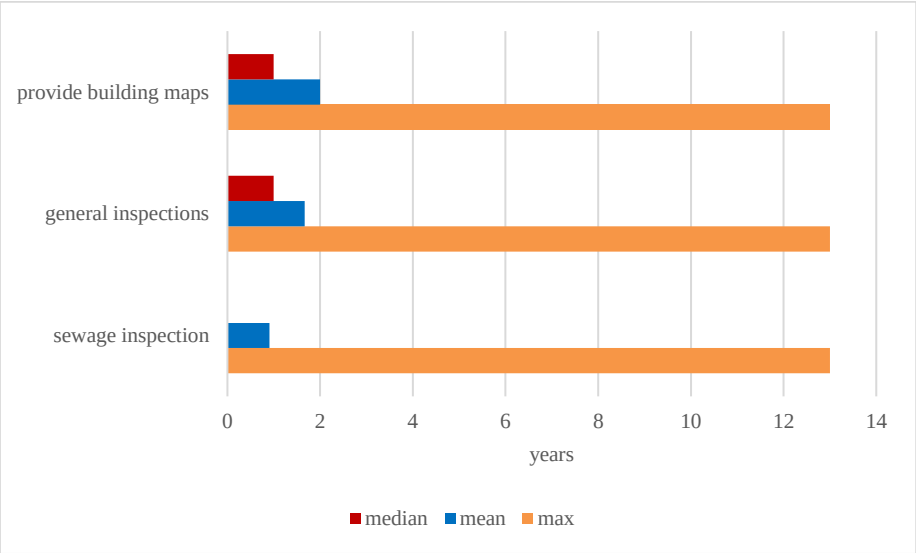

Fig. 5. Technical feasibility of Drones in the FS sector (years till feasibility)

The economic feasibility of Drones is shown in Fig. 6. The provision of building maps will be economic feasible with a mean of 3,5 years, general inspections with a mean of 2,5 years and sewage inspections with a mean of 2 year. Especially in the areas of inspection, Drones can optimise the service provision. Instead of human climbers doing the inspection of the roofs and outside of buildings Drones can deliver precise information about the conditions without endangering humans. AI tools can analyse the detailed pictures to diagnose first changes in the surface leading to major damages later. But the economic feasibility will take more than 2 years in average.

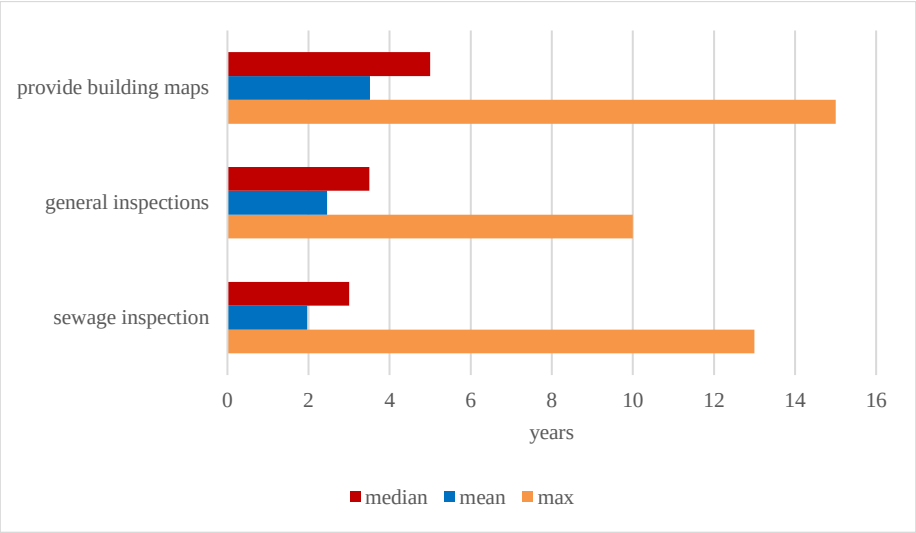

Fig. 6. Economic Feasibility of Drones in the FS Sector (years till feasibility)

3.4. Feasibility of technologies in general

Table 2 sums up findings from literature review, expert interviews and evaluation for all technologies analysed. Table 2 gives in the first column an outline about the relevant technologies in the area of FS operation (results step one and two). The second and third columns provide the mean timeframe of the technical and economic feasibility. Feasibility is measured in years till feasibility, which represents the results of the survey. Some applications of technologies are more likely to become technical and economic feasible than others.

To sum up, use cases of IoT will be feasible in shortest mean timeframe. Considerably evidence exists in the literature (Multi-Annual Roadmap 2018, Xu et al 2014). It will need 0-0,55 years to become technical feasible and 0,73-1,79 years to become economic efficient. Application of Mobile Apps is the second highly reasonable technology. It will take between 0,36-0,45 years till use cases of this technology become technical feasible, and 1,03-1,33 years that they become economic feasible. Robotics comes next, with a mean timeframe of 0,45-2,03 years to become technical feasible, and 1,33-3,91 years to become economic feasible. These examples could directly be used to optimise FS processes. Building Information Models (BIM) become technical feasible in a short time (0,33-1,09 years), but it would need a mean timeframe of 1,94-2,24 years that this technology becomes economic feasible.

The study shows that the most important technologies are Sensors/IoT, Mobile Apps, RFID and Robotics. Whereas, technologies like BIM, Augmented and Virtual reality require more time until they will begin to diffuse in the area of FS operation.

Tab. 2. Technical and economic feasibility of new technologies

Technologies	**Technical feasible** (mean timeframe till feasibility)	**Economic feasible** (mean timeframe till feasibility)
Sensors/IoT	0 – 0.55	0.73-1.79
BIM	0.33 – 1.09	1.94 – 2,24
Mobile Apps	0,36 – 0,45	1,03 – 1,33
Robotics	0,45 - 2,03	1,33 – 3,91
RFID	0,52 – 0,75	1,27 – 1,85
Digitalization / Automation	0.58 – 1.73	1.82 – 2.27
BIG Data	0.70 – 0.79	1.61 – 2.06
Virtual reality	0.91 – 1.00	1.82 – 2.42
Drones	0.91 – 2.00	1.97 – 3.52
Augmented reality	1.18 – 1.58	1.67 – 2.3

4. Conclusion and outlook

The literature review, the expert interviews and the survey accomplished show that digitalisation has a big impact on the Facility Service (FS) provision. Results show that most relevant technologies like IoT, Mobile Apps and Drones are already widely spread and technical and economic feasible. Connected Sensors can already be implemented in business processes, Mobile Apps will follow soon. Robotics is the next technology to follow. Other technologies like virtual and augmented reality will take longer till they can bring economic benefits. The results for RFID and BIM were unexpected as the literature presents them as technological feasible. The experts estimate a long time till these technologies are economic feasible. It also must be considered that some technologies are based on each other's. For example, augmented and virtual reality need a CAD or BIM model of the building that they can be applied. Therefore, producers of equipment provide alternative use cases like cloud maintenance guidelines that are provided through augmented reality technology. These use cases need a shorter period to be economic feasible.

Some applications of new technologies allow control over the complexity of FM processes and services in a more effective way. They disruptively change the way services will be provided in the future. They enable on demand service provision instead of scheduled or preventive task execution based on historic data.

In addition, dangerous tasks can be transferred to Robots or Drones. This study demonstrates a high potential for practical implementation of IoT, Mobile Apps and Robotics.

The research done also shows, that the effects of digital transformation on FS processes are not yet fully understood and will need further research. Most of the surveyed companies still use a lot of standard technology to cover FM processes and functions. Other technologies like AI, ML develop so rapidly that their usage possibilities cannot be evaluated properly. This postulates the need for further research and the application of technologies in practical use cases to prove especially economic feasibility. Based on this research and further studies the demand for training for the service employees also need to be estimated to enable them for the usage of the new technologies.

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Digitalization & Facility Management: Energy Flexibility of Existing Buildings

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Abstract

Future energy systems will require buildings to be able to manage their energy demand and generation in dynamic ways. The technical realization of such energy flexibility in buildings in response to local climate conditions, occupant needs and grid requirements is currently quantified in research and development projects, many of which take place in newly erected buildings as flagships for the related digitalization and seamless automation of technical building services. However, building stock and facility management portfolios tend to consist of existing buildings with differing, highly diverse performance qualities that may pose a problem for generic solutions. The objective of this paper is to highlight potential options, and to sketch an engineering perspective of making existing buildings energy-flexible. For this purpose, on-going work in various control research projects is selected to present issues in (1) the development of a suitable controller, (2) home and building automation design, and (3) building commissioning and diagnostics for future building controls. Non-technical requirements for quality of performance in these cases are summarized. In conclusion, and based on the reviewed projects, a potential strategy for building management is the avoidance of risks and costs associated with the introduction of energy flexibility by using published standards and open protocols for automation, and by documenting their as-operated status in a digital format in all buildings.

Keywords: Energy flexibility, Smart building, Home automation, Building automation

1. Introduction

The integration of renewable energies into existing electrical distribution grids is causing instability in the grid, which cannot be controlled by the existing infrastructure at all times and in all cases. Flexible management of supply and demand of energy at the side of the grid participants aims to optimize grid operation by controlling grid utilization rates within preferred ranges. For decisions on specific strategies for energy flexible operation of individual buildings or building types, large scale models are required, which are based on actual grid data and actual urban environments as built and as operated. For the purpose of this paper, observations and insights from selected projects are used to assess the efforts for making existing buildings energy flexible, and to conclude on how facility resp. building management could provide assistance.

The structure of the paper is as follows: Section 2 is on the potential buildings can offer for grid stabilization: While solutions are in high demand to reach climate goals internationally, they have to be accurately modeled and validated, and project examples are cited that could successfully arrive at strategic constellations of building elements for use in national building stocks. Section 3 is on engineering efforts for energy flexible buildings that are being followed up. Here, current research work related to development of a control mechanism and parameters, their integration and their maintenance is exemplified. These activities take part in different control worlds, namely grid-level control, home and building automation, and building controls, but they share non-technical requirements for quality of performance, discussed in Section 4. Based on these priorities and validated through the projects, recommendations for assistance by building management are formulated.

The so developed recommendations are based on valid and generalizable qualitative indicators, however, their predictive strength, i.e. the potential impact on time and costs of engineering by following up on the recommendations will be addressed in future work.

2. The potential of energy flexibility in existing buildings

Decisions on load management strategies cannot be based on single buildings, but they require clusters of buildings, such as city quarters, which are typically mixed building stocks. The primary question is whether buildings can contribute the load potential grid operators are looking for. Second, what is a good strategy to reliably deliver this performance? The answers vary with country, grids and building stocks present. There is large interest on the EU level to foster development in buildings that enable grid optimization. In Section 2, information about progress on a methodology for characterization of energy-flexibility is presented. Modeling

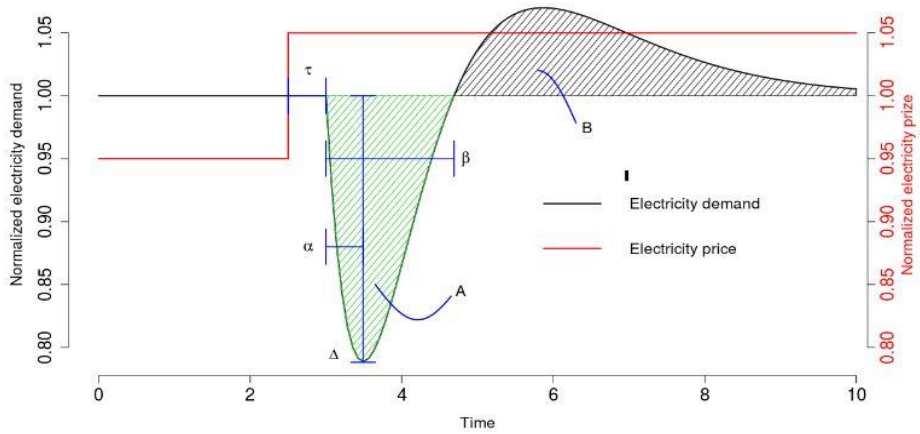
examples address the potential of heat pumps in smart grids, and of building typologies on a national level suitable for optimizing grid operation.

2.1. Energy flexibility of buildings

In most developed countries, the energy use in buildings accounts for 30-40 % of the total energy consumption (WBCSD 2009), and it is used for space heating, heating of domestic hot water, cooling, ventilation, pumps, control and lighting of rooms, as well as for appliances used by occupants. A large part of the energy demand of buildings may be shifted in time (Le Dréau and Heiselberg 2016), (Reynders et al. 2013), (Patteeuw et al. 2015), and may thus significantly contribute to increase the flexibility of the demand in the energy systems. In particular, the thermal part of the energy demand, e.g. space heating/cooling, ventilation (ventilation is both a thermal and electrical load), domestic hot water, as well as hot water for washing machines, dishwashers, and heat for tumble dryers can be shifted. Energy flexibility of a building can, therefore, be defined as the ability of a building to manage its demand, but also its generation (e.g. from photovoltaics) according to the local climate conditions, user needs and grid requirements. Energy flexibility of buildings will thus allow for demand side management/load control and thereby demand response based on the requirements of the surrounding grids.

That energy flexibility of buildings is an important asset for the future energy systems has also been recognized by the EU commission, as it is proposed to include a smart readiness indicator (SRI) in the upcoming revision of the EPBD (EU 2016a). The purpose of the SRI in EPBD is to *"inform the consumers about the ability of buildings to operate more efficiently, monitor and control energy use and interact with the users and the grid"* (EU 2016b). Furthermore, it is stated that *"A smartness indicator will reflect the … (iii) readiness of the building to participate in demand response, charge electric vehicles and host energy storage systems"* (EU 2016b). However, as the EU Commission demands a very cheap procedure for the determination of the SRI of a building, it can be feared that the SRI will be of little use. In order for a SRI to be useful for both the building side and the energy network side, there is a need for an approach that takes into account the dynamic behaviour of buildings, rather than a static counting and rating of control devices. It is further important to minimize the CO_2 emission in the overall energy networks, rather than to optimize the energy efficiency of single energy components in a building. Such approach is being developed by IEA EBC Annex 67 Energy flexible buildings (annex67.org), and is described in Junker et al. (2018).

The methodology is a physical data and simulation based approach for quantification of services in use. The general objective is to standardize the external penalty signal to enable comparability of energy flexibility among different buildings (Fig. 1).



Where: τ is the time from the signal is submitted to an action starts
α is the period from start of the response to the max response
Δ is the max response
β is the duration of the response
A is the shifted amount of energy
B is the rebound effect for returning the situation back to "reference"

Fig. 1: Potential of energy flexibility as a function of a building's or system's response to a step change in the external penalty signal (Jensen et al. 2017).

2.2. Demand response of homes and the potential of thermal mass in Belgium

At the building level, many sources exist to offer flexibility to district energy systems. Labeeuw et al. (2014) identified an active demand reduction (ADR) potential of 4 % of the total residential electricity demand using white-good appliances (i.e. dishwashers, tumble-dryers, washing machines). These results are obtained through a large-scale demonstration project monitoring electricity consumption data in 1693 Belgian households between 2006 and 2009, as well as from 500 field surveys. They conclude that, although these white goods can have a significant impact on the electricity consumption with a share equaling the primary reserve capacity, the active demand response of wet appliances does not meet the requirements for response time needed for these power services.

With the electronification of thermal systems in the residential sector, e.g. through the introduction of heat pumps, these systems may as well provide a significant contribution for the demand flexibility needed to optimize electricity networks. At the same time, the interest in 4th generation district heating systems is increasing in heating dominated climates, since these systems promise to provide a sustainable and flexible way of incorporating low-carbon and renewable heat sources such as waste heat from industrial processes, solar, and geothermal energy (Lund et al. 2014).

Patteeuw et al. (2015) evaluated the impact of large scale heat pump integration in the Belgian residential sector analyzing scenarios with and without active demand response (ADR). In the scenario without demand response, heat pumps are controlled to minimize the energy consumption on an individual building level resulting in significant peak demands on cold winter mornings, when all heat pumps operate at the same time. Also, such a control is agnostic for the availability of RES (renewable energy sources) products, hence, it does not contribute to increase RES uptake in the market. Active demand response using the thermal mass of the dwellings as well as the domestic hot water storage tank to decouple the electricity demand from the thermal demand allows to significantly reduce the extra peak capacity required when installing the evaluated 250.000 heat pumps (Fig. 2, below). In the case of buildings equipped with floor heating, almost the entire need for additional peak power plants was avoided, in the case of radiator heated buildings (which represent faster thermal dynamics) on average 30% reduction in peak power was found. At the same time ADR resulted in on average 15 % CO_2 reduction due to increased uptake of renewables.

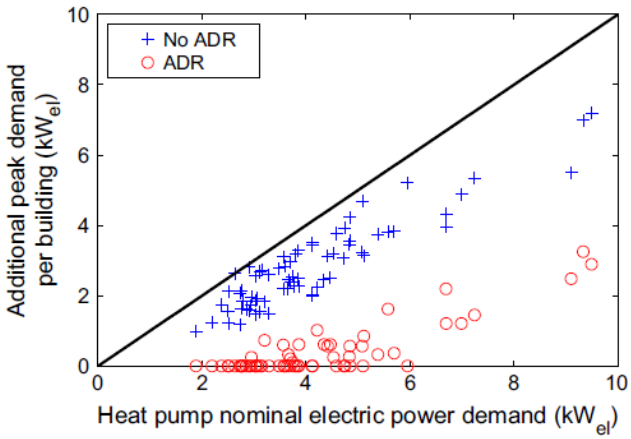


Fig. 2: Performance of ADR in peak-shaving. The electric power that each building is contributing to the demand at peak time is shown with respect to the nominal electric power demand of the heat pump (Patteeuw et al. 2015).

2.3. Simulation of the Austrian building stock

In Austria, heating load management potentials for four representative Austrian building typologies (A, B, C, D – see Fig. 3, below) have been studied using the TABULA dataset (2016). Based on the different insulation levels due to the year of construction, there is a countable influence on the shiftable domestic heating loads when using heavy-weight constructions, optimizing passive solar gains and activating additional thermal storage combined.

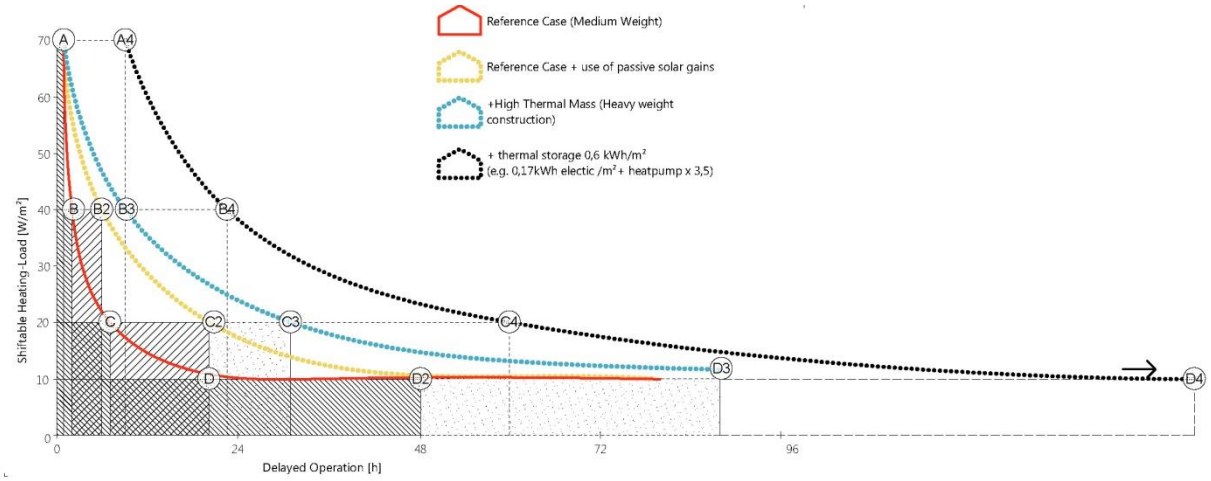


Fig. 3: Load duration curves of four different Austrian typology-buildings showing the potential of shiftable domestic heating load over time by delayed operation (Weiss et al. 2018)

Load shift periods were evaluated for a cold week of January with the following assumptions:

- an indoor operating temperature range of 19..22°C
- the heating system with simple radiators as heat dissipation system is switched off at 22°C and cools down until the temperature reaches the lower limit of its setpoint

The cooling curve thus describes the ratio between the heating load in each type of building of a cold week in January per square meter of treated floor area [W/m²] and time [h] during which the operative temperature is ranging within the predefined 19°C..22°C.

The **blue curve** indicates the potential of these buildings with an increase of the specifically effective heat storage capacity of the primary construction per square meter treated floor area, from approx. 60 Wh/m²K for the reference buildings (medium brick construction) to 110 Wh/m²K (heavy reinforced concrete construction). The **black curve** shows the increase in flexibility when approximately 0.6 kWh/m²a of thermal energy can be stored.

Basically, the curve can be used for any day / season of the year (assuming the heating power at the time is known) to roughly describe the ratio of heating load to time within the set comfort limit, including thermal mass and additional storage. The curves can be used to estimate the impact of different building technologies on the shiftable heating load of different building types (see Weiss et al. 2018).

3. Technologies for realization of energy flexibility in research studies

In this section, research efforts in engineering of energy flexible buildings are introduced. They represent activities for development of a suitable controller, the integration of controller functionality in buildings, and commissioning and maintenance of the integrated controls.

3.1. A dynamic CO_2-based control of a swimming pool heating system

This example is a part of the Danish CITIES Project (www.smart-cities-centre.org) and the EU H2020 SmartNet project (www.smartnet-project.org). The purpose of this project is to demonstrate the flexibility of summer houses with a swimming pool. Swimming pools are flexible in the sense that due to their thermal inertia, it takes a rather long time for them to heat and cool. In CITIES, the objective has been to minimize emissions while still respecting comfort requirements. In the SmartNet project, the same setup is used for price-based control, and the prices are selected such that the total system can provide various grid services as described in (Madsen et al. 2015).

In the setup, the controller for heating the pools can be formulated in a way which minimizes the total CO_2 emission. Alternatively, the same setup can be used to do price-based control. This also gives the opportunity to solve some ancillary service problems in e.g. low voltage grids (DSO grids as described in (De Zotti et al. 2018)).

In the future electric energy system, one of the main challenges will be to keep the voltage level in weak DSO (low voltage grids) areas close to the reference. This challenge is even more pronounced in areas with a lot of summerhouses, since the use of the houses is less predictable, and because the electricity grid here is often rather weak. However, summerhouses with swimming pools constitute large energy storages, which can be used for solving some of the issues related to the electricity grid.

In the following, we will focus on a setup of model predictive control of the heating of the swimming pools, which aims at minimizing the CO_2 emission. The houses considered here are using a heat pump.

The share of renewable-based electricity in Denmark varies significantly and rapidly, as seen in Fig. 4 for a week around December 1st, 2016.

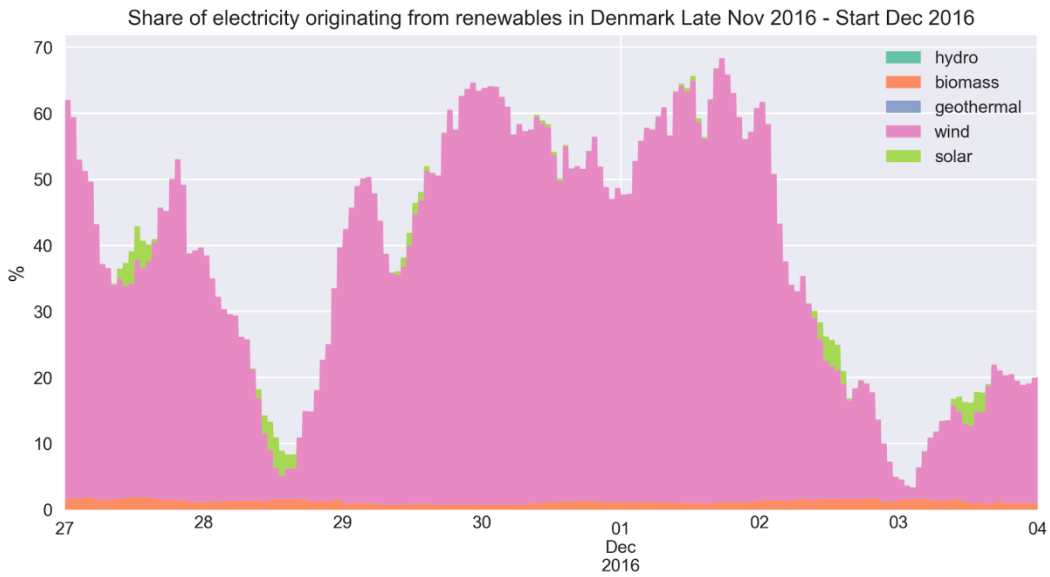


Fig. 4: Share of electricity originating from renewables during a one-week period around December 1st, 2016. Data is computed based on historical data from http://www.electricitymap.org. This translates into a very volatile carbon intensity (i.e. the overall emissions required to produce 1 kWh of electricity).

It therefore makes sense to optimize with respect to total emissions, by incentivizing flexible devices to consume when the carbon intensity is low.

In the setup, the actuator is a controllable thermostat listening to a signal from a local controller (called SN-10). The SN-10 unit controls the actuator in order to keep the controlled pool temperature (outgoing water temperature) close to a setpoint. That setpoint can be lowered or increased temporarily in order to save energy or to preheat, depending on the expected CO_2 intensity of electricity consumed.

- **Forecasting and Control**

In the initial settings, the models used are of the ARX type (see Madsen 2008), whereas regime switching models will be considered at a later stage. The need for the regime based models arrives due to the fact that the dynamics of the house and the pool will depend on the use of the summerhouse and maybe also on the number of people and/or the activity levels. The algorithms for forecasting and control are implemented at the DMS and cloud computing facility operated by ENFOR. Forecasts of the expected CO_2 emission related to the power mix are provided by the the company Tomorrow.

- **Data Management System and Cloud Computing**

The Data Management System is hosted by ENFOR (www.enfor.dk), so all the data is hosted here, and the interaction with the system takes place via this setup. The Cloud Computing facility at ENFOR also hosts the controllers.

The ENFOR services, illustrated in the figure below, consist roughly of the following parts:

1. Web-service: Supports requests for data upload from FlexGrid, ie. the house data, and requests the latest house state from Novasol.
2. Tomorrow client: Fetches CO_2 forecasts made by Tomorrow
3. FlexGrid client: Uploads water temperature setpoints and pump status to FlexGrid
4. Novasol client: Fetches availability schedules from Novasol web-service
5. Weather forecasts: Provides local weather forecasts
6. Algorithms: Forecasts and control based on house data and the weather forecasts
7. Data storage and management: Includes a graphical user interface

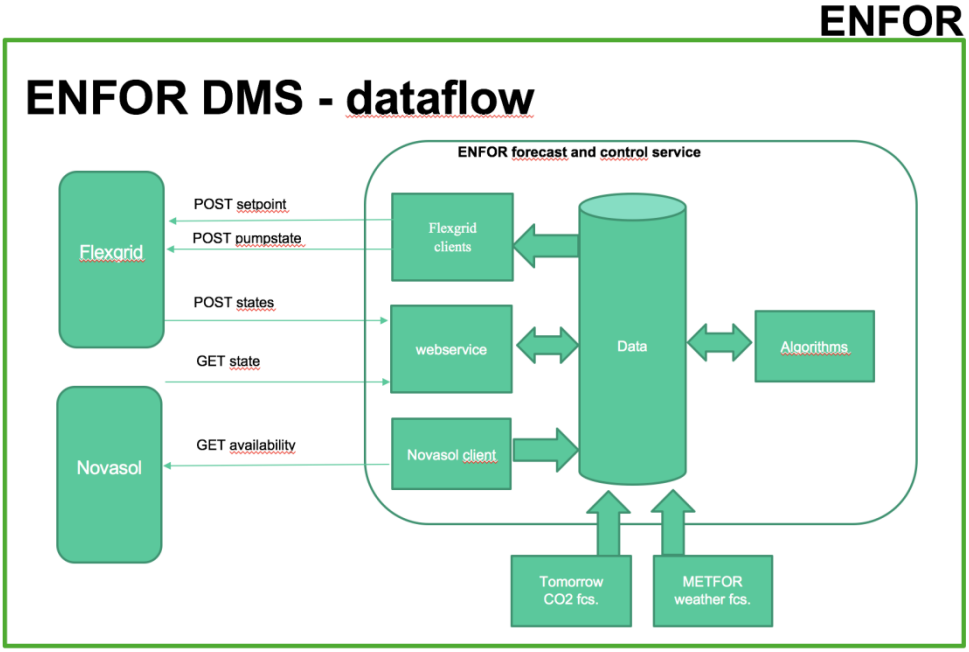


Fig. 5: Data management architecture.

The users of the cloud based controllers can switch between being 1) Energy Efficient (the energy consumption is minimized), 2) Cost Efficient (the total cost is minimized), and 3) Emission Efficient (the total CO_2 emission is minimize) - see Junker et al. (2018).

- **Some results**

In the following, two houses are considered. The first house D7811 is using CO_2-based control, and consequently the total CO_2 emission of the related power production is minimized. Fig. 6 shows a screen plot from the controller of the ENFOR smart house portal. The blue lines are the lower and upper limits of the pool temperature. The red vertical line show the actual time, and we can see that the controller decides to overheat the pool within the next hours, since the CO_2 emission is expected to be low for these hours, while we expect a much higher CO_2 emission for the following hours.

Fig. 6: A house (D7811) using CO_2-based control. This minimizes the total CO_2 emission related to heating up the swimming pool.

The second house (P32788) is using price-based control, and here, Fig. 7 shows the measurement of the ENFOR smart house portal. We have shown a period with negative power prices as indicated around the period marked with a green dashed ellipsoid. It is clearly seen that, as a result of the negative power prices, the controller is heating up the pool to the maximum water temperature. Due to the large inertia of the pool, the preheating under the period with negative prices implies that the summer house does not need to use power for heating for a rather long time.

Fig. 7: A house (D32788) using price-based control. This minimizes the total costs related to heating up the swimming pool. This screen plot contains a period with negative power prices (green ellipsoid).

3.2. Complexity and integration of information models for building-to-grid services

In building-to-grid processes, buildings act as end nodes in the smart grid. Since their physical integration requires investment costs and novel technology concepts, it is important to quantify *how* buildings can play a critical role in the grid nationally.

A potential improvement for demand side management through building-based load forecasts was investigated in a study on building information systems, where building energy performance was characterized with a novel method involving a complex thermo-dynamic building model (Metzger et al.). A controlled flexibility study with a cluster of 500 apartments in Vienna, Austria, showed that, with the improved model compared to a linear model used for smart grid simulations at the time, 33% more events suitable for load shifting could have been offered to the grid within the specified indoor temperature control limits (Table 1, below).

Tab. 1: Distribution of load shifting decisions. The linear model compared to the improved model overpredicted comfort violations (329 of 1000 analyzed events) (Metzger et al.)

Decision	Outcome	Occurrence
Shed load	Comfort Violated	329
	Comfort ok	61
Do not shed load	Comfort would have been ok	137
	Either not possible or comfort would have been violated	473

While a complex energy model brings about higher quality for planning of forecasts, it also potentially means an increase in monitoring effort on site. Hence, in theory, an efficient implementation that builds on existing infrastructure and information in already installed devices and systems, such as smart meters and building and home automation systems would be ideal. This ideal is challenged in the real world by the uncertainty of installed infrastructure in individual buildings and homes of modeled clusters and requirements for unobtrusiveness of the in-situ measurements in operating buildings. In a case study in a new campus building of the University of Innsbruck, these challenges acted as barriers for optimized field measurements, despite the fact that most of the required sensors were already installed and integrated in regular building operations (Pfluger et al. 2017, pp. 45-51).

Following up on these results, the Automation Systems Group of TU Wien, Austria, is currently developing a virtual solution with laboratory simulated performance and optimization of control networks, which holds the capability for comparison of different scenarios. Fig. 8 shows an overview of the system architecture for validation of the optimized information model from the study on building-based load forecasts, which assumed utility-driven demand response (Metzger et al.). The building measurement layout for the forecasts in this study could be minimized to one indoor temperature sensor per apartment and computation of apartment heat load, the latter of which could be acquired from data of the apartment's smart meter, for instance. Additional quality of service information of the tested layout has to be accounted for in any optimization step, pictured here as a stand-alone implementation on a local field computer. The method for optimization requires a generic model for evaluation of different infrastructure typologies with sufficient modularity for further optimization steps.

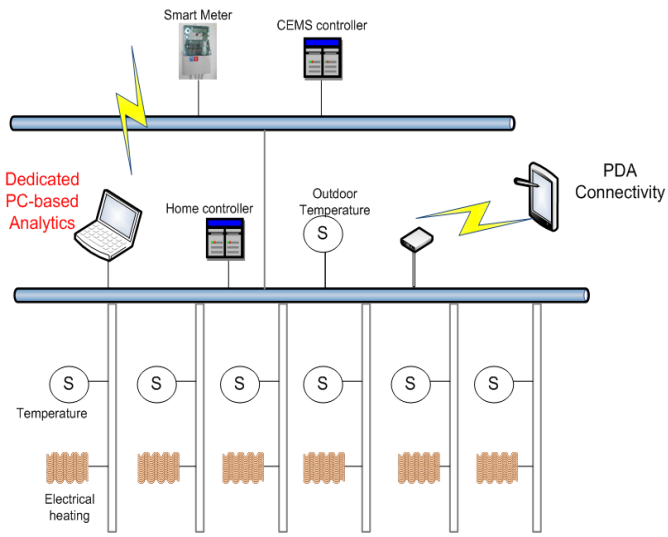


Fig. 8: Overview of systems architecture for field validation as part of an integrated home automation system. Each apartment building has 6 separate apartments.

Furthermore, a concept for evaluation of information privacy and security of the planned field layouts is part of the proposed solution, partially based on experiences from the development of a cybersecurity module for the user role in indirect control of energy flexibility:

To address the desire and to support the end-users' claim of more self-control and energy efficiency, the Automation Systems Group is part of the project "Adaptable Platform for Active Services Exchange" (AnyPLACE, www.anyplace2020.org/). The project addresses a modular, secure and flexible energy management system deployed in local field computer ("smart hub"). The developed platform comprises a bidirectional service exchange gateway with management and control functionalities enabling the interaction between end-users, market representatives, electricity networks operators and ICT providers (Fig. 9). Among other features, it allows end-users to manage their energy expenditure and take advantage of dynamic price tariffs to minimize their energy costs.

To protect users from malicious attacks and data abuse, security and privacy aspects needed to be included in the design and implementation of the platform from the very beginning. To this end, an analysis of EU-wide regulations regarding security and privacy was conducted. From there, requirements for the development of the platform were derived. As core component of the AnyPLACE solution, a cybersecurity module was developed responsible for storing the key material used to protect the platform. With this module, data and communication can be signed/verified and de/encrypted. This way, the core principles of information security (confidentiality, integrity and authenticity) can be provided. To secure the platform and its application, the secure development lifecycle (SDL) was followed comprising of five consecutive phases: (1) definition of security requirements, (2) design & implementation, (3)

security testing & verification, (4) release, and (5) security response. In addition to laboratory testing and validation of the developed platform, a field trial was started at the end of 2017 in the area of Dörentrup, Kreis Lippe (Germany).

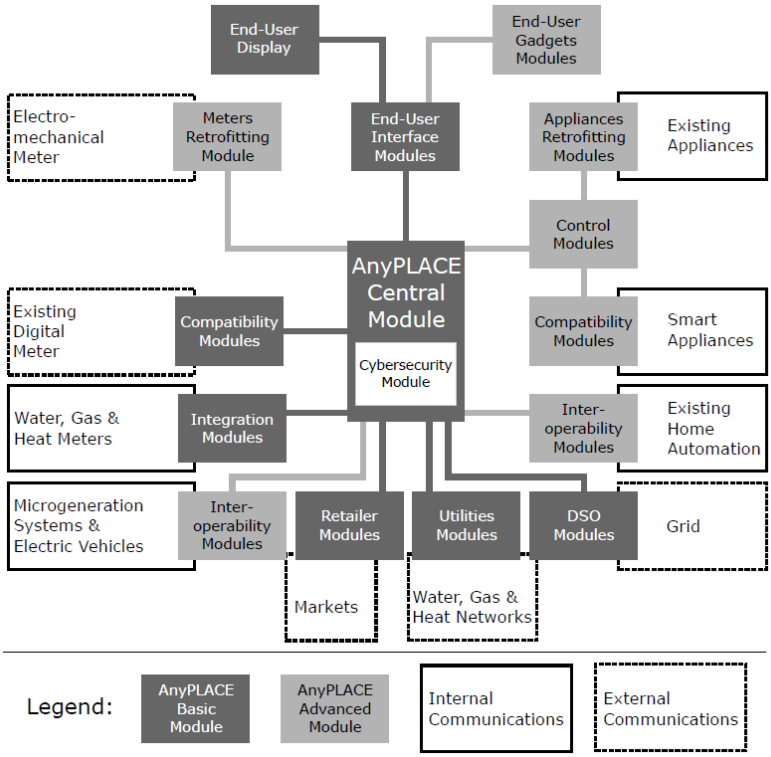


Fig. 9: AnyPLACE architecture (Henneke et al. 2016)

3.3. An automated and continuous performance testing framework for office buildings

As part of the international research project COORDICY (COORDICY 2018), an online building energy performance monitoring and evaluation tool (ObepME) was developed aiming to better monitor, characterize and evaluate building energy performance, and ensure a proper operation (Jradi et al. 2018). The tool includes a set of building performance tests serving as a basis for fault detection and diagnostics throughout the building operational and management phases and forming a backbone for an automatic and continuous building commissioning and evaluation. In addition to performance testing and monitoring, the tool is intended to be used for investigation and evaluation of various energy systems operational patterns and modes, including control strategies and DR events.

An overview of the processes of the tool is shown in Fig. 10. An overall building 3D architectural model is developed. Then, building specifications and characteristics along with the 3D model are used to develop a holistic dynamic energy model in EnergyPlus, capable of simulating building performance. Data collected from the building including weather conditions, occupancy profiles, systems operational parameters and set points, and energy

consumption reported by different meters are used to calibrate the developed holistic energy model. Using the calibrated model, simulations are carried out automatically and continuously on a daily basis to predict the building performance. Simulations are compared to actual data collected from building meters. When a performance gap is detected, an overall fault detection and diagnosis process is implemented to identify any underperformance issues and system faults.

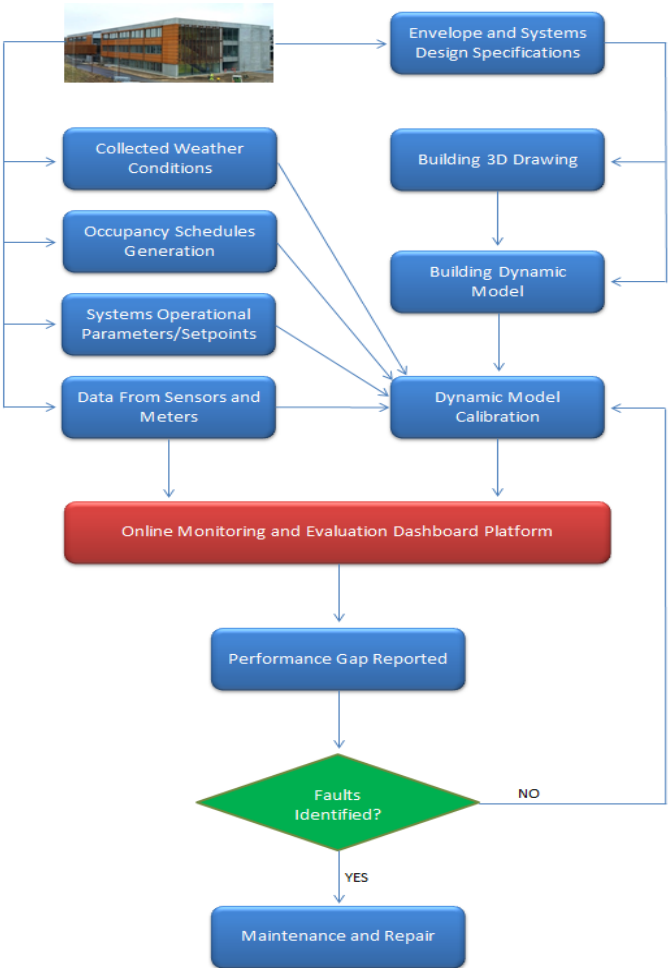


Fig. 10: ObepME Tool Framework (Jradi et.al 2018)

The EnergyPlus building model is implemented into the ObepME tool using Functional Mock-Up Interface (FMI) (FMI, 2010). FMI serves as an open co-simulation protocol allowing models developed in various modeling and simulation environments to communicate with each other, or to connect with third-party software. The dynamic building model is exported to a self-contained file, Functional Mock-Up Unit (FMU) that can be run by any FMI compatible framework (EnergyPlusToFMU, 2018). Selected input and output variables are exposed in the interface, and are mapped to the corresponding data streams from the data collection platform.

With the aid of the FMI, ObepME is completely model-agnostic needing only an FMU and mappings for the selected variables to data streams. The online energy simulation architecture is shown in Fig. 11, where data are accessed via sMAP and the simulation engine is embedded in a FMU, and run through FMI.

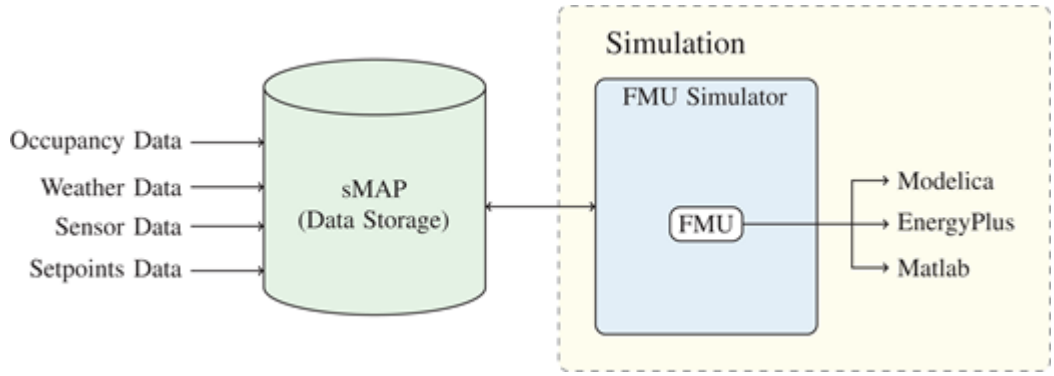


Fig. 11: Online Energy Simulation Architecture (Mattera et.al 2018)

The ObepME tool is configured and currently running in the OU44 building on an automatic and continuous manner. The building has a Schneider Electric building management system (BMS) capable of controlling and optimizing different energy systems operation on different building levels. All the sensors in the building are accessible through a KNX bus, transferring records to the BMS based on the configuration. Various data collected from meters around the building are fetched from the BMS into a centralized database platform using Simple Measurement and Actuation Profile (sMAP) protocol. The OU44 building instrumentation publishes sensor data through a publish-subscribe substrate. A set of processes each subscribe to a subset of these data streams and publish streams representing a key performance indicator (KPI) to the same substrate. Whenever a new value is received on either of the inputs, an output is generated. A dashboard application subscribes to these KPIs, and updates a visual representation each time a value is received.

Combining real-time measurements onsite with calibrated dynamic energy performance model simulations is key to improve the overall energy efficiency and the operation scheme of different energy supply systems. This is in addition to enhancing the building flexibility quotient through the testing and implementation of effective operation management and control strategies in the building. This was highlighted by Li (2014), and demonstrated in a case study of Sutarja Daj Hall at UC Berkeley, where the calibrated dynamic energy model along with real-time data were used to implement and test different energy efficient measures, in addition to demand response events and scenarios for heating, cooling, and lighting systems. Moreover,

the dynamic energy performance model could aid implementing an online model predictive control, as reported by Henze and Krarti (2005) and by May-Ostendorp et al (2011). In overall, one of the main features of flexible buildings is providing the opportunity for owners and occupants to implement functional and operational strategies targeting various energy supply systems without comprising indoor thermal comfort and energy consumption baselines. This would require a continuous performance monitoring and a platform to test such strategies. Thus, the proposed framework and the developed tool serves as a basis to test and implement operational methodologies, and control approaches including DR events aiming to optimize the energy performance of various energy supply systems.

4. Discussion

As shown above, engineering for energy flexible buildings takes part in specialized control technologies at the grid-level, in home and building automation, and in building controls. What unites them is that they share priorities for quality of performance in engineered services, which have to be complied with in design. These are discussed below.

For technical facility management, critical requirements for information and control systems related to energy flexibility have to be satisfied in existing buildings. To estimate the effort of adaptation of building operation to energy flexible operation, the principles of energy flexible operation, as well as the requirements for predictive and dynamic management of energy consumption have to be understood. Overall, it can be described as a dedicated service with the following tasks:

1) Energy forecasts have to be produced, and a schedule for e.g. next day operation prepared and communicated to the grid entity.
2) Related devices are distributed, and must be (made) capable of acting together in controlling the building systems under reduced power conditions, and for feeding back surplus energy into the grid.
3) Reduced power conditions may come from two different contracts:
    a. *Direct control* is a utility-initiated operation, where building operations respond to requests for immediate power reduction that originate in smart grid operation.
    b. *Indirect control* is an occupant-initiated operation, where building operations respond to requests for scheduled operation of devices to avoid economic penalties, such as energy price or carbon dioxide emissions.

Research steps in this regard are to find a representation of sufficient quality, implement this model in a distributed system, operate it in a decentralized way, and – different from legacy automation - maintain and optimize it to ensure its quality over the building life cycle.

Ideally, these new solutions are built on top of an existing infrastructure. Independent of the complexity of implementations, and as a point of view of the authors' research experience in

buildings, providing for the following technical, non-functional engineering requirements can lower cost and risk associated with the introduction of energy flexible operation:

- *Testability of buildings and systems*

In research projects, often, simplified controls layouts are used to be able to focus on the research question at hand, which often results in only minimal requirements for access to building systems during tests. Examples of the type and timing of **access to building systems** in energy flexibility studies are setpoint modulation, on/off control of a ventilation system, or testing a reduced scope of building operation (e.g. at construction before occupancy, or forecasting services only). In contrast, fully functional energy flexibility processes will be complex and highly networked in the future, and will affect operating buildings at all scales. While, during building adaptation to energy flexibility, unobtrusiveness will be critical to minimize costs and risk, it has to be taken into consideration, that most existing buildings may not be built and equipped for testing in the way RD&D (research, development and demonstration) buildings are, for instance. Therefore, test methods, which function under conditions of minimal access to building systems or with abilities to model building parts out of reach of sensors, will be advantageous. On the other hand, such services have their limitations when it comes to **training staff and occupants** to familiarize with the new operations and technologies, partly because most of their processes cannot be visualized for user information or feedback. For this purpose, simplified and first generation tests might provide customizable functionalities for user learning and exploring.

- *Quality of representation*

For improved **testability** in buildings, accurate **documentation** of the building "as-operated" is vital. In larger buildings, local control systems may be **interoperable** and already share information in a network that is also already visualized for user control. However, existing networks have to be based on **open or published standards and protocols** to be able to reuse the infrastructure. Any information and control systems, existing as well as future, will have to be **scalable** to be economic ("added value") in a smart city and smart grid environment, where an increasing number of devices and buildings will be networked in clusters of sizes that cannot be predicted at the beginning.

- *Quality of building models*

The role of using **dynamic energy performance models** as a basis for testing and implementing various operation management and control strategies in buildings was demonstrated and highlighted. This will lead to an overall energy efficiency improvement in addition to enhancing the building flexibility quotient. Moreover, to satisfy this role, such dynamic models need to be combined with real-time measurements on-site aiding the

calibration process and allowing validation of the impact of implemented strategies. However, to save time and resources in development of such dynamic building energy models, requirements for digital models need to be developed and implemented for allowing a smooth transfer from building information models (BIM) to building energy models (BEM). Such reequipment is currently implemented in Denmark, where all new public buildings need to be digitally managed and interchanged with a **reequipment of digital models** to be delivered in the handover phase (Svidt and Christiansson, 2008).

- *Quality of service over time*

It is clear to most that controlling building power and heat at the grid side are **mission-critical** operations that require robust and well understood methods. For energy flexibility in buildings, this mission-criticality now also applies to the control networks servicing the installed building hardware. Engineered systems have to be designed for **dependability**, so their runtime does not have to be interrupted to recover from an operations error. For dynamic processes, control networks have to be designed for **availability** to ensure the quality of service of the communication flow between existing and new components. When engineered control networks are also designed for **maintainability**, not only the integration of new components and functionality is quality-controlled, but they could also support remote maintenance in regular operations, if desired. A resilient grid performance is required for national security of energy systems. When buildings connect to the grid, their communications have to be **secure** at a similar level to avoid performance gaps that could be used for attacks on the grid. On a personal level, **information protection** and **privacy of information** will be critical for the acceptability of energy flexible services, as first experiences with the roll-out of smart meters have shown. Last but not least, **efficiency** in control networks and solutions will be critical, not only in terms of sampling efficiency, but particularly **energy efficiency** of services to ensure that the energy saved during the load management operations is not consumed by the information, communication and controls processes in existing buildings.

In summary, the realization of energy flexible building management involves testing controls and automation solutions as a function of building performance. In this context, information on building performance and access to it acted as constraints to the solutions developed for energy flexibility. Hence, building management could improve the testability of buildings and building systems by providing this information in a digital format, and by adopting a policy of exclusively implementing protocols for automation that are “open”.

5. Conclusions

For energy flexibility in residential, commercial and institutional buildings, the following can be concluded:

- A proposed methodology for computation of the potential energy flexibility performance of buildings is available, which includes the ability to compare buildings' performance in this regard independent from their individual differences.
- In contrast, implemented solutions for participation in demand response programs will be diverse and building-specific due to the individuality of buildings and operated building solutions. While the complexity of control processes involved in coupling the building sector to the grid becomes evident, formal evaluations of implemented solutions down to the last building meter are slowly evolving.
- Providing for improved testability of a building and its systems can lower costs and risk involved in adapting to energy flexibility. Exercising existing best-practice strategies, such as adoption of published standards and open protocols for automation, and accurate documentation of the as-operated status in a digital format in all buildings, would support several requirements for quality of service simultaneously.

Acknowledgments

This article was a collaboration activity within IEA EBC Annex 67 'Energy Flexible Buildings' (annex67.org). The overall management of Annex 67 is funded by the Danish Energy Agency [grant no. 64014-0573]. The authors acknowledge respective partial funding under the following projects: 'Energy Flexible Buildings' [FFG 853033] under the Austrian IEA cooperation program, Dissertation Project 'EFLEX-NZEB' [FFG 856025] with support of the Austrian Ministry of Transport, Innovation and Technology in 2.3, 'CITIES' (funded by Innovation Fund Denmark) and 'SmartNet' (funded by EU) in 3.1, 'BL4DSM' (funded by Austrian FFG) and 'AnyPLACE' under EU Horizon 2020 [grant agreement No. 646580] in 3.2, and 'COORDICY' funded by Innovation Fund Denmark [ID number: 4106-0 0 0 03B] in 3.3.

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