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A facilities manager's typology of performance gaps in new buildings

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Abstract

Purpose: The gap between the expected and actual performance of newly built facilities has been widely described in the literature as 'the performance gap'. Mostly, the performance gap appears to be synonymous with the energy performance gap. Little attention has been given to other performance aspects that facilities managers recognise as deficient in newly built or renovated buildings like for instance difficulties in operation and maintenance. This study contributes with a typology of performance gaps, with the aim to offer a more nuanced understanding of the term, where the interests of facilities management are in focus.

Method: The empirical data consists of four in-depth interviews, two focus group interviews and three workshops. Except for one workshop, the data collection took place in Denmark.

Findings: The study identifies 12 types of performance gaps of which 'higher energy consumption' is one. The gaps are interdependent and initiatives to reduce one type of

gap can potentially lead to an increase in another. Furthermore, the study finds that the fatal (the most critical) gap is context-specific.

Implications: The findings of this study imply a need to change the way we previously have discussed the early involvement of the facilities management in design. The study shows that more involvement of FM is not necessarily better.

Originality: This paper is the first attempt to cover performance gaps of buildings from a holistic viewpoint and from the perspective of FM.

Introduction

Many resources go into the construction of new buildings. For instance in Denmark, the cost of new buildings in 2017 exceeded 110 billion DKK (14.5 billion Euros), and the number is increasing (Danmarks Statistik, 2018). However, when a new building is handed over to facilities management (FM), which is the organisational function responsible for the operational stage of the building, performance is not always as high as expected. This poses a problem, as the cost of operating the building by far exceeds the cost of constructing it (Hughes et al., 2004). Environmentally, the situation is similar: the operational stage is more resource-consuming than the construction stage (Maslesa et al., 2018).

With regard to energy consumption, several studies find a gap between the expected and actual performance of new buildings (Bordass, 2004; Gram-Hanssen & Georg, 2018; Mallory-Hill & Gorgolewski, 2018; Sunikka-Blank & Galvin, 2012). Other aspects, which FM has to deal with, are also observed to be deficient in some new

buildings, for example lack of functionality, poor indoor climate, difficulties in operation and maintenance, and poor cleaning solutions. In 2017, the costs of building repair and maintenance in Denmark were nearly 80 billion DKK (more than 10 billion Euros) (Danmarks Statistik, 2018). Although work has been undertaken on different types of performances with potential gaps in new buildings, the vast majority of research on performance gaps of new buildings exclusively investigates the energy performance gap. No prior research is found on gathering the performance gaps, including - but not limited to - the energy performance gap, of special interest of the facilities managers. Research gathering different types of performance gaps is needed to understand the interrelation between types of performance gaps, and furthermore to stress that the energy performance gap is not always the most urgent gap for facilities managers to bridge. Based on literature, expert interviews, focus group interviews and workshops, this study presents a typology of performance gaps from the perspective of FM.

Literature review

The Energy Performance Gap

An online search in the scientific literature for ‘performance gap’ or ‘building performance gap’ revealed a large pool of research on unforeseen energy consumption in newly built facilities. The ‘energy performance gap’, or simply the ‘performance gap’, is consistently defined as the discrepancy between expected and actual energy consumption (Coleman & Robinson, 2018; Frei et al., 2017; Gram-Hanssen & Georg, 2018; Menezes et al., 2012; Sunikka-Blank & Galvin, 2012; De Wilde, 2014). The ‘reliability gap’ is another term occasionally used to describe the discrepancy between expected and actual energy consumption (Mills, 2011; Ornetzeder et al., 2016; Valle & Junghans, 2014), although the definition is the same.

Researchers have suggested that, despite awareness in academia of other performance parameters of a building with potential gaps, the energy performance gap is the most measurable and consequently the most debated (Lowe et al., 2018). Other researchers have found that measuring the performance gap is not that simple. Complicating factors include uncertainties in the design process, a lack of measure points in the completed building and the influence on performance of external circumstances such as outdoor temperature (De Wilde, 2014).

Whether measurable or not, the term ‘performance gap’ is almost always applied in the literature to mean a gap in energy performance. By contrast, the term ‘building performance’ is not exclusively about energy performance. In the following, literature contributing to a broader understanding of performance gaps is presented, regardless of the term ‘performance gap’ is mentioned or not.

Other types of performance gaps

Some prior studies have called for a definition of performance gaps that concerns more than energy performance. A comprehensive study of more than 240 references (Frei et al., 2017) found that the term is largely used to refer to the energy performance gap. Consequently, it is suggested that the term should be widened to also include indoor environment quality and operational expenses.

FM researchers have also turned their attention to unexpectedly high levels of operational expenses; they include Boge et al. (2018), who mention ‘unnecessarily high operation and maintenance cost, increased replacement rate and negative impact on core business’. Borgstein et al. (2018) support the suggestion of expanding the definition of performance gap to include not only energy, but also indoor environmental quality and occupant satisfaction. Borgstein et al. (2018) describe not meeting a performance parameter as a ‘performance failure’, rather than a performance gap.

The need to widen the definition of performance gap in facility evaluation is supported by authors investigating post-occupancy evaluation (POE) and building performance evaluation (BPE). As Tim Sharpe (2019) notes, user satisfaction is important: ‘Buildings are, after all, inhabited by people’. Performance parameters such as comfort and health and wellbeing are suggested additions to the evaluation of buildings.

Oseland (2018) also places more emphasis on users or occupants and employs both quantitative and qualitative methods to evaluate building performance. BPE takes into account, not only energy, but also other aspects of building sustainability such as water consumption and indoor environment quality (IEQ) (Vischer, 2018). The book *Building Performance Evaluation* (Preiser et al., 2018) is a thorough elaboration of the concept that includes a variety of performance parameters.

A recent BPE study of nine Canadian ‘green’ buildings that evaluated their predicted and actual performance (Mallory-Hill & Gorgolewski, 2018) measured, in addition to energy use, occupancy rate, water use and IEQ, the argument being that these factors influence one another. For example, a higher occupancy rate influences water consumption. In two buildings, the actual occupancy rate was double the predictions made during the design stage. Moreover, the study questioned, whether the (energy) performance gap can be used to define, when a building is a ‘failure’, as different actors perceive it differently.

Loftness et al. (2018) have put forward the concept of total building performance, which is measured by six critical parameters, namely 1: spatial quality, 2: thermal quality, 3: air quality, 4: acoustic quality, 5: visual quality and 6: building integrity. Again, it is stressed that these parameters must be evaluated simultaneously, as they influence one another.

The need to focus on occupant satisfaction and usability is supported by a team of Norwegian researchers, who developed 'USEtool'. The tool follows five steps of evaluating usability of facilities and relies strongly on the involvement of the occupants, including walk-throughs and workshops (Hansen et al., 2011). The Leesman Index also deals with the usability of facilities, but focusing solely on the effectiveness of offices based on employee surveys (Leesman, 2018). Both the Norwegian USEtool and the Leesman Index consider exclusively users' perceived performance and experience and do not include performance parameters such as energy consumption or maintenance costs.

A literature review on evaluation tools for hospital facilities illustrates the fragmented research that hitherto has been conducted in the form of the 'Evaluation Focus Flower' (Fronczek-Munter, 2013). The flower is arranged according to the three qualities of architecture defined by Vitruvius, classic Roman author on architecture, translated as Beauty/Form, Durability/Technology and Utility/Usability. When organised in the 'flower', it is obvious that different evaluation concepts may overlap, but none covers all three qualities.

Lindkvist (2018) describes the difficulties facilities managers experience in the early operational stage of newly built facilities, by investigating the hand-over process from construction to operation. The project phase and the operational phase were found to overlap, with the result that contractors were continuously fixing problems during operation. Another study found that 'it took several years of refinement and tuning' to minimise the (energy) performance gap in the case of two buildings (Mallory-Hill & Gorgolewski, 2018). In those years of problem fixing and fine-tuning, there was a temporary loss of building performance.

The stage at which performance gaps are 'rooted'

As an obvious starting point for finding ways to bridge the energy performance gap, researchers have investigated at which stage of a building's life a gap is 'rooted'. Frei et al. (2017) mapped the causes found in the literature, pinning them down to three major lifecycle stages: a) design and planning: b) construction and commissioning: c) operation. Some researchers believe that decisions and actions during the design stage has the most impact on the future performance of a facility (Boge et al., 2018). Others find that the impact is greatest at the operational stage, arguing that the influence of occupant behaviour and the building's operation on the building's performance is often overlooked (Borgstein et al., 2018; Hong et al., 2017; Liang et al., 2019; Lowe et al., 2018). Other researchers conclude that causes for performance gaps may be found in each of the lifecycle stages, or in a combination of all (Van Dronkelaar et al., 2016; Way & Bordass, 2005).

Method

The study applied a qualitative research approach, where data was collected in three parts as shown on figure 1. Each part was completed, analysed and evaluated, before planning and conducting the following part. Furthermore, the study utilized an abductive approach, where themes that arose from the data were tested and further developed empirically and by consulting the literature (Alvesson & Sköldberg, 2009).

Figure 1 gives an overview of the empirical data included in the study in the order in which they were collected, namely parts 1, 2 and 3. The first part consisted of in-depth interviews with experts and was chosen with the aim of investigating practitioner's experience with the energy performance gap. Eight types of performance gaps were extracted from this data. A second row of data collection was planned and conducted to obtain further insights on practitioner's view on performance gaps. This part

was based on findings from the first part of the data collection, namely the eight types. Two group interviews were conducted and analysed, leading to further development of the typology. To validate the findings, a third row of data collection was planned and conducted. With the aim of both disseminating the findings and getting the findings validated, three workshops were held. The individual data collection parts are described in the following.

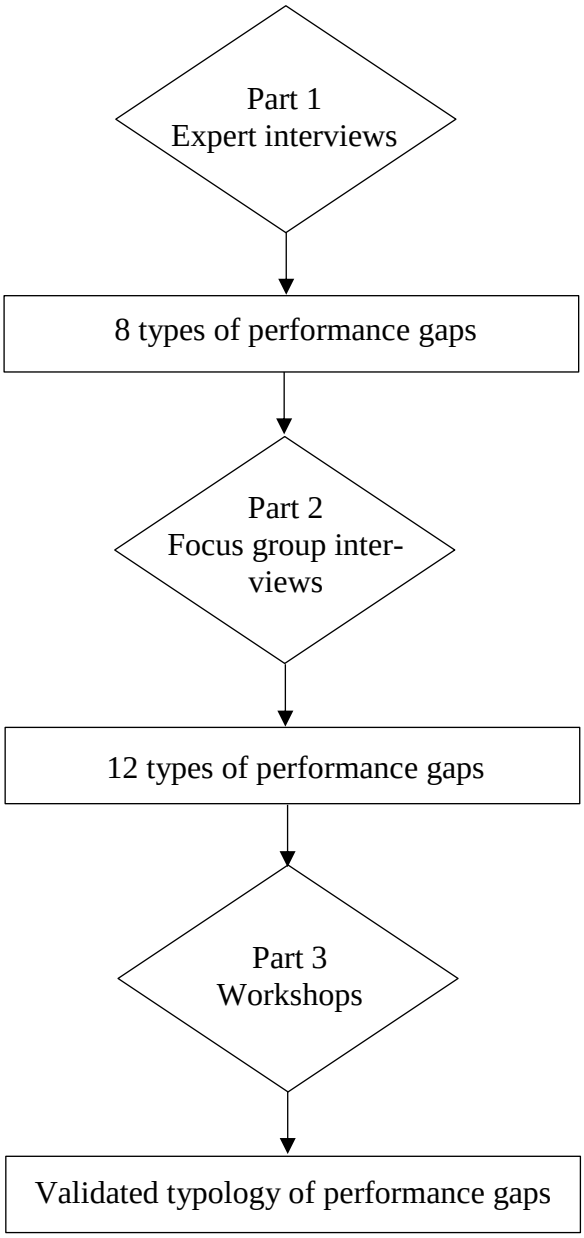

Figure 1 Data collection part one, two, and three.

Data collection part 1: Expert interviews.

Four semi-structured interviews with experts on building projects were conducted as the first part of data collection. Table 1 shows the distribution of interviewees and duration of the interviews. Purposive sampling technique was applied and interviewees considered being especially informative (Saunders et al., 2016) in respect to performance gaps in new buildings, were selected. Interviewees were experienced in large building projects, two from the building client side and two from the design side, to give maximum variation within the relatively small sample. The limited number of interviews in this first part was considered sufficient as it served as a base for the following steps rather than as results in itself.

The interviews had an exploratory nature (Saunders et al., 2016), in which the interviewer used a protocol as a checklist, but questions were posed in the order most likely to make the conversation flow naturally. The protocol included questions about the design process in general and in particular about the energy performance gap.

Table 1 Distribution of interviewees and duration of interviews

Role	No	Interviewees/Participants	Relevance to the study	Duration
Building designers	1	Building client consultant, self-employed.	Experienced project manager of large and complex building projects. Known for focusing on integration of operational knowledge in design.	64 min.
	2	Architect, owner of architectural firm.	Experienced in all stages of building projects, primarily large non-residential projects. Known for focusing on sustainability.	49 min.
Building owners (clients)	3	Director of a technique and environment division in a real estate and property investment company.	Experienced top manager for both building project divisions and operation divisions. Known for his involvement in the Danish 'Building Green' organisation.	53 min.

	4	Former project manager in a new building division for a large private company; now a self-employed building client consultant.	Experienced project manager for large complex building projects in an organisation with an internal operational division. 'Builds to occupy'.	50 min

The interviews were analysed by open coding (Strauss & Corbin, 1998) by using Atlas.ti® software. As such, the transcribed interviews were closely examined to detect every piece of text related to performance and performance gaps, in the broadest possible understanding. Then, codes with similar characteristics were conceptualised, resulting in eight concepts (Strauss & Corbin, 1998), hereafter named 'types' of performance gaps. The eight types formed a preliminary typology of performance gaps.

Data collection part 2: Focus group interviews

The second part consisted of two focus group interviews with the aim of further development of the preliminary typology. Focus group interviews were chosen to produce insights that would be less accessible without the discussion among interviewees (Kevern & Webb, 2001). An important finding from the first part of the data collection, expert interviews, was that the interviewed practitioners did not share the same focus on the energy performance gap as the literature. Consequently, the research team found it important that practitioners continuously informed the study. In both focus group interviews, the interviewees were part of a pre-existing group (Kevern & Webb, 2001) and none had been interviewed in the first part of data collection. The first group was four stakeholders of an ongoing research project about operational friendly building design, and had met several times before. The second group were three colleagues in a FM consultancy department of a large private consultancy company. Table 2 shows the participants, all from Denmark, duration and time of the focus group interviews. Participants

were chosen for their knowledge on and experience with FM and trouble shooting in completed building projects. Like interviewees in part one, interviewees in the focus group interviews were chosen as they were expected to be especially informative to the study (Saunders et al., 2016).

In both focus group interviews, the preliminary typology was presented, after which participants discussed it, suggested changes, or pointed out the need for clarifications of the typology based on their practical experience. The typology was not changed from the first to the second focus group interview. However, suggestions on changes from the first focus group interview were passed on to the second focus group orally by the researcher conducting the focus group interview. Based on the focus group interviews, the typology was further developed.

Table 2 Focus group interviews

	No	Interviewees/Participants	Relevance to the study	Duration
Focus groups	1	2 associate professors at the Copenhagen School of Marine Engineers 2 FM consultants	Experienced with FM from teaching FM courses. Experienced with FM consultancy.	60 min.
	2	2 FM consultants 1 Commissioning expert	Experienced with FM in general and specialized in trouble shooting in newly completed buildings.	60 min.

Data collection part 3: Workshops

Part three of the data collection was conducted to validate the typology. As mentioned, a finding from the first part of the study was that practitioners and the literature do not share the same focus on the energy performance gap. For this final part of data

collection, both practitioners and researchers were consulted for validation of the typology. Workshops as a research method was chosen to both validate the typology and give participants new insights on their own interests and in that way, the purpose was two-fold. The latter purpose resulted in easy access to participants, who willingly investigated their time in the workshop and participated actively. The facilitator was aware of the two-fold purpose, balancing the need for research outcome and the need for participant's outcome. The workshops were self-contained and participants were not asked to do preparations to the workshop (Oerngreen & Levinsen, 2017).

Workshop participants were chosen for their knowledge on building projects and FM, from either practice or research. As it was the case in the focus group interviews, participants of the three workshops were part of pre-existing groups. Table 3 shows the participants, duration and time of the workshops. There was an overlap of participants in focus group interview 2, and workshop 1. None of the participants had been interviewed in the first data collection part. Participants of workshop one, with two participants, and three, with five participants, were all from Denmark. Workshop two was held at an university in Norway with three international researchers as participants. The research team of this study knew that all three groups were in one way or another engaged in the topic of new buildings not performing as expected after hand-over. As such, they were chosen to be especially informative about the topic (Saunders et al., 2016).

A researcher from the research team facilitated all workshops. Like the focus group interviews, the researcher first gave a presentation of the study and the developed typology and asked participants for comments and questions. Additionally, the workshop participants were asked to do two exercises about the typology together as a group. The researcher introduced the exercises, one at a time, gave instructions during the exercises and answered questions, but did not participate in the exercise. Audio recording,

photos and notes documented the workshops. Summaries were made afterwards.

Table 3 Workshops

	No	Interviewees/Participants	Relevance to the study	Duration
Work-shops	1	2 FM consultants (same as Focus group 2)	Experienced with FM in general and specialized in trouble shooting in newly completed buildings.	60 min.
	2	3 FM researchers at Norwegian University of Science and Technology (NTNU)	Hold knowledge on FM, design and construction projects.	90 min.
	3	5 FM staff members at Campus Service, DTU	Experienced with project management of building projects (3). Experienced with trouble shooting in completed buildings (2).	90 min.

Working with the 12 types of performance gaps during the two exercises fulfilled the two-fold purpose. First, it made the participants familiar with the types. Second, as the participants discussed how to answers the exercise, they gave examples on how they had experienced the individual types.

The first exercise was about the ‘rooting’ stage of the individual gaps, that is, when decisions or actions were made causing the later presence of a gap. The three stages of planning/design, construction and operation (see Literature review) were applied. Twelve labels (Post-its®), each with a number from one to twelve representing the performance gaps, were handed out to the participants. They were asked to discuss, when in the lifecycle each performance gap was most likely to be ‘rooted’. Finally, they were asked to place the labels on the table top under the headings for the three stages, as they saw relevant.

In the second exercise, participants were asked to place the same labels, each representing a type of gap, in accordance to which parameter of quality, time or money,

they found most fundamental in avoidance of a gap. The third and largest group did not do the second exercise due to time limitations.

The purpose of the exercises was to get rich discussions about the gaps among participants to validate the typology, rather than it was the purpose to get their answers to the exercises. Consequently, outcome of the exercises were not included in the findings.

Findings

Expert interviews

In the expert interviews, the respondents were asked, if they had experienced a performance gap. As this was the initial stage of the study, the interviewer posed the question only in relation to energy. None of the four interviewees gave a clear answer to this question. Two (one designer, one building client) confirmed that there often is a gap, but the size is difficult to measure. One interviewee answered that it was beyond his expertise, and one answered the following: '*Actually, I am afraid that we really do not know… when a new building with a predicted energy consumption of x kilowatt hours is handed over… then there is no one who verifies, if that actually remains the case five years on*' (building client).

Having answered whether they had observed a performance gap or not, the interviewees on their own initiative, commented on the interviewer's focus on energy performance. One interviewee (architect, partner in an architectural firm) said: *'When we talk about "operation", we often mean energy consumption. That is what it traditionally is ... but the real "operation" is about you and me! It is about the employees being well and thriving ... They are the real operation cost.'* Comments such as this inspired the re-

searchers to investigate other performance aspects potentially not fulfilled in new buildings mentioned during the interviews. Further review of literature was done, this time including literature investigating other performance parameters failing in new buildings than energy performance. The following eight types of gaps were detected by analysing the transcriptions.

- Higher energy consumption
- Higher operational costs
- Higher maintenance costs
- Operation start-up loss
- Disappointing ”user experience”
- Unsatisfactory indoor climate
- Mismatch with business case
- Double operation or no operation

Focus group interviews

The participants of the two focus group interviews shared the opinion of the interviewed experts that gaps of building performance concerns more parameters than energy. From the focus group interviews, it was found that: A) Lack of flexibility is another performance parameter found ‘gapping’ in new built buildings. B) User experience is too broad a term to cover experience of both FM staff and core business staff. C) Not meeting legal requirements has been experienced by the interviewees to be a problem in new buildings. D) Expenses changed from Capex to Opex is another challenging issue, when new buildings are handed over to FM. The issues A, B, and C were brought up by interviewees in the first focus group interview. Interviewees of the second group agreed upon A, B, and C and furthermore suggested issue D.

A typology of 12 performance gaps was developed, see figure 2, based on both expert interviews, review of literature and focus group interviews.

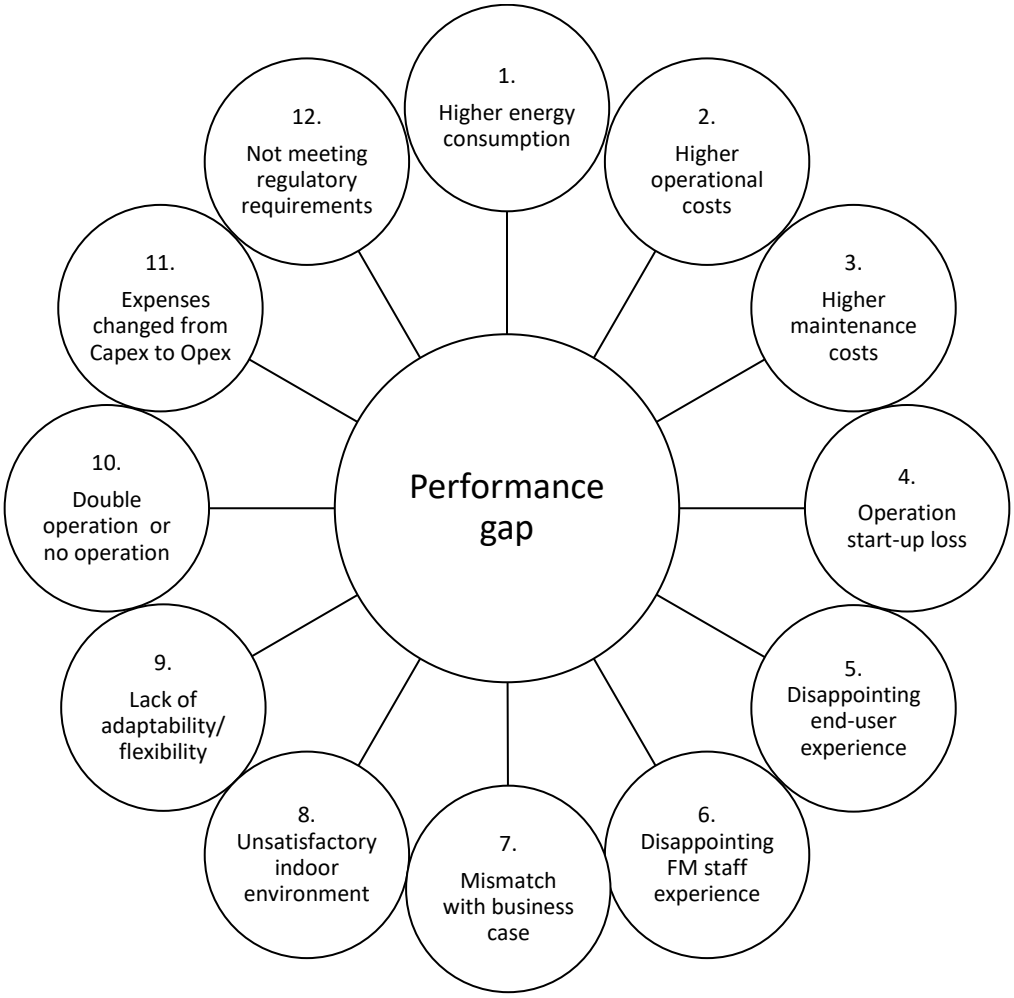

Figure 2 Typology of performance gaps in newly built buildings – from a FM perspective.

Workshops

The third part of the data collection, workshops, validated the 12 types further. The participants provided supplementary examples of the 12 gaps, but none that led to changes in the typology. A brief description and examples gathered in all three data collection parts are given in the following.

Gap 1 is ‘higher energy consumption’ and the one the literature investigates by the terms ‘building performance gap’ or ‘reliability gap’. Energy goes into heating, cooling, ventilation and lighting of buildings. Furthermore, energy goes into the processes taking place in buildings, for example related to IT and producing goods.

Gap 2 is ‘higher operational costs’. Operation is here understood as cleaning, waste handling, supplies, caretaking, monitoring and daily supervision. The gap appears when costs for these services are higher than estimated or expected. Both the interviewed experts and workshop participants mentioned examples of this. One interviewee referred to a large commercial project in central Copenhagen. In the operation stage, they had experienced an unexpected cost of cleaning the surroundings every morning due to the lively nightlife of the neighbourhood. In the same project, window cleaning were more expensive than expected, as it had to be done by a rope climbing (rappelling) team.

Gap 3 is ‘higher maintenance costs’. This gap occurs, if building parts or installations need more frequent maintenance than expected, if spare parts are more expensive than expected, or if the part in need of maintenance is difficult to access or the spare part is difficult to get. A workshop participant, referring to a recent project he was involved in, gave the following example: *“… That is, for example, when you make 380 fire shutters that are impossible to service, and you then need to spend two months each year doing it”*.

Gap 4 is ‘operation start-up loss’, which primarily is loss of energy due to difficulties in the early operation stage, often caused by lack of or insufficient commissioning of installations. An example is when lowering the room temperature outside working hours is not possible yet due to lack of programming of the building management system.

Gap 5 is ‘disappointing end-user experience’ and occurs, when a certain user experience concerning functionality, aesthetics, or convenience is not met. An example is, when the design of an expensive hotel or restaurant does not meet expectations of a certain aesthetic level. Another example is, when the layout of a working space, for example an office floor, causes inconvenient workflows, or offers too few meeting rooms.

Gap 6 is ‘disappointing FM staff experience’. This is similar to gap 5 and concerns both aesthetics, functionality and convenience. However, particularly the focus group participants argued that FM staff experience difficulties that are different from other user groups. Examples given by the focus group participants include too small or poorly located cleaning rooms.

Gap 7 is ‘mismatch with business case’. This occurs, when the building does not meet the conditions, which were anticipated in the business case. Examples are less parking space for cars than initially anticipated, less hotel rooms than anticipated, or less office space to sublet than anticipated. The gap can appear stepwise during the design stage, but it can also unexpectedly appear in the operation stage.

Gap 8 is ’unsatisfactory indoor environment’. This covers unexpected challenges relating to the thermal indoor climate, acoustic environment and air quality. A workshop participant described challenges with noise from the ventilation in 80 percentages of the rooms in a newly built large multi-functional building.

Gap 9 is ‘lack of adaptability/flexibility’. This gap occurs, when a building is difficult to adapt to changing needs during the facility’s lifetime. A focus group interviewee gave an example of a recent case she had been involved in, where the number of staff in a large organisation was dramatically reduced. Comprehensive conversion of the building and in particularly the technical installations was needed to make it possible to sublet the now redundant office space.

Gap 10 is ‘double operation’, which occurs when two facilities are needed instead of one during occupation or relocation. Alternatively, when the facility is handed over (delayed or not), but the facility is not suitable for ‘business’ yet. An example given by a focus group interviewee concerned moving the large consultancy firm in which she was employed to a new built headquarter. To ease the relocation process, 200 employees were moved at a time, followed by another 200 a week later and so forth. Stretching the move caused double operation, as services such as cleaning and catering were needed in both the new and the old headquarters at the same time.

Gap 11 is ‘expenses changed from Capex to Opex’. This gap occurs, if the operation budget needs to cover expenses (Opex – operational expenditures) in relation to the new building, which were expected to be included in the building project and its budget (Capex – capital expenditures). This can be caused by the need for cost cutting due to budget overrun for the building project or it can be a matter of unclear communication about what is covered by the budget of the building project. Examples of the latter are expenses to blinds, furniture, way-finding signs, and keys.

Gap 12 is ‘not meeting regulatory requirements’. This occurs, when a building does not meet requirements from authorities. An example is, when the building does not pass acceptance check by the fire authority, before the planned opening day, or the authority in charge of working environments withholds its approval of the workplace.

The fatal gap

The types are organised from 1-12 in figure 2 in the order in which they appeared from the initial analysis of the four expert interviews and focus group interviews, not according to importance or cost or any other factor. Already during the first part of the data collection, the expert interviews, it was clear, that the importance of the gaps depends on the specific project. In a new office building, the fatal gap

is more likely to be ‘disappointing user experience’ (gap 5) or ‘unsatisfactory indoor climate’ (gap 8), rather than ‘higher energy consumption’ (gap 1). The following is an example that one of the interviewed experts gave from a hotel project (building client consultant):

‘*When you design mirrors from floor to ceiling in a hotel room… housekeeping has to bring in a stool [to stand on] when they are cleaning ... That takes one additional minute per room… Add 800 rooms, at an hourly rate of 150 DKK, and you find that it costs around one million DKK every year in operation.*’

From the quote, it is impossible to judge, whether mirrors from floor to ceiling are the right or the wrong design solution. If ‘disappointing user experience’ (gap 5) would be fatal, then it might be the right design, but if ‘higher operational cost’ (gap 2) would be fatal, then it is a wrong decision. Consequently, the typology cannot be organised according to importance, as this is context-specific. The perception of which performance gap is fatal also depends on the responsibility and interest of the facilities manager. For instance, some have responsibility for the overall business case and both for Capex and Opex, while others only have responsibility for Opex. Therefore, the perception of the importance of ‘mismatch with business case’ (gap 7) and ‘expenses changed from Capex to Opex’ (gap 11) will probably be very different and contradicting.

Gaps are interlinked

When the fatal gap (there can be more than one) is identified in a project, it is tempting to focus solely on bridging this particular gap. However, this is not necessarily advisable, as the gaps are interlinked. They potentially affect one another in at least three ways. First, if one gap closes, another may open. Second, there may be a snowball effect, where one gap is causing another gap. Third, the gaps

may affect one another when bridging one gap automatically leads to - if not bridging then at least - narrowing another gap.

One of the experts provided an example illustrating, how closing one gap can open up another. He described a large building project, where oil-treated wooden floors were chosen. This design solution causes ‘higher maintenance costs’ (gap 3), as floors need to be re-treated with certain intervals. However, in the example given, it served the purpose of meeting a certain end-user experience. Since ‘disappointing end-user experience’ (gap 5) was considered fatal in this specific project, wooden floors was considered appropriate, despite an increase in maintenance costs. Another example provided by one of the interviewed experts, concerned end-users that are not given the possibility to open doors or windows manually. This design solution was chosen to avoid ‘unsatisfactory indoor climate’ (gap 8), potentially also ‘higher energy consumptions’ (gap 1). However, it may cause ‘disappointing end-user experience’ (gap 5), or even ‘higher maintenance costs’ (gap 3), if windows or doors are damaged, because they are forced to stay open with wedges.

Participants of the third workshop gave an example illustrating, how gaps can affect one another as a snowball. They had recently moved in to their new built office building. After they had occupied the building, it was found that the acoustic indoor climate did not meet the regulatory requirements. Different actions to reduce noise were taken, including closing a large lunch area on the ground floor with an open connection to the office space on the floors above. Assumingly, providing the employees a common lunch area was part of the business case – and later a part of the building brief. Thus, ‘not meeting regulatory requirements’ (gap 12) caused a ‘mismatch with the business case’ (gap 7) as the common lunch area was removed.

Design of daylight in buildings was mentioned by one of the interviewed experts as an example of how bridging one gap automatically leads to - if not bridging then at least - narrowing another gap. She argued that the right design of daylight can prevent the gap 'unsatisfactory indoor climate' (gap 8) together with 'higher energy consumption' (gap 1). Furthermore, proper daylight design can bridge the gap of 'unsatisfactory end-user experience' (gap 5).

Workshop two was held with researchers, the others with practitioners. No significant difference between these two types of participants were found. This is unexpected, as the literature review showed that the focus of research and practise is not identical. The typology was discussed without suggestions for changes in all three workshops. Furthermore, the discussions and finally the lay out of the labels in the workshop exercises were to a large extend similar in all workshops.

Discussion

Performance is more than energy

In the literature, the performance gap is often synonymous with the energy performance gap. In the light of this study, this narrow definition of the term is problematic. Furthermore, the literature deals mostly with the gaps individually, or in best cases a few at a time. It is understandable, that in-depth research must investigate one issue at a time, to achieve a thorough understanding of each of the gaps. When it comes to practise, an individual treatment of the gaps must be avoided or supplemented with a holistic assessment.

Other performance gaps than energy

The reviewed literature covered several of the performance gaps included in the typol-

ogy. The most commonly mentioned concerns gap 8 ‘unsatisfactory indoor environment’, and there is a distinct research discipline focusing on indoor climate. Gap 2 and 3 concerning ‘higher operational cost’ and ‘higher maintenance cost’ is mentioned in FM-related literature for instance by Boge et al. (2018), but has not been researched much. Gap 4 ‘operation start-up loss’ is mentioned by Lindkvist (2018) but has not been researched much, either. Gap 5 concerning ‘disappointing end-user experience’ is researched widely in the literature on building performance evaluation and POE. Gap 6 concerning ‘disappointing FM staff experience’ is much less researched but covered by some FM-related research like Jensen (2012) and Rasmussen et al. (2019). Gap 7 concerning ‘mismatch with business case’ is hardly covered as such by research, but there might in the context of construction management be some research relating to this gap. Gap 9 concerning ‘lack of adaptability/flexibility’ has not either been researched much as such, but there is a field of research on adaptability/flexibility of buildings often of a normative character. Gap 10 concerning ‘double operation or no operation’ is as far as the authors know not covered at all in earlier research. Gap 11 concerning ‘expenses changed from Capex to Opex’ is not mentioned in the reviewed literature, but it might be covered in limited degree in some construction management research. The last gap 12 concerning ‘not meeting regulatory requirements’ was not found specifically in the reviewed literature, but it is probably part of some research on energy performance gap as well in other specialist literature for instance in relation to indoor climate and fire protection. Nevertheless, this paper is the first attempt to cover performance gaps of buildings from a holistic viewpoint and from the perspective of FM.

Building clients and facilities managers have different perspectives

There is a need to examine building projects from the facilities manager’s perspective, because it differs from the perspective of the building client. In the perspective of the

building client, criteria as cost and time of the project are often crucial. In the perspective of the facilities manager, cost and time of the building project itself is less important. In a number of cases, the building client is a part of a FM organization. In such cases, theoretically, the aim and focus of the building client and the facilities manager is identical. However, in practise, the building client staff and the operational staff often are divided in two sub-organizations within the larger FM organization (Jensen, 2012, Rasmussen et al., 2019). The typology presented here can serve as a base for the collaboration between the two and illustrate the different perspectives of the two roles.

The performance gaps can be used to develop a common understanding and manage of expectations among stakeholders of what is most important in a new building projects and to identify critical success factors that can form a basis for communicating priorities to project management and designers in the early planning phase.

Implications for the facilities manager's role

The findings of this study imply the need to change the way we have previously discussed the early involvement of the facilities manager (Jensen, 2012; Rasmussen et al., 2019). The study shows that more involvement is not necessarily better. When facilities managers are involved in the design process, they must realise a) that the fatal gap is project specific, and b) how the gaps are interconnected, as involving them can otherwise be counterproductive. By trying to close one gap (the one that is closest to their niche in FM), they risk opening up another.

Nuancing the debate by developing the 12 gaps shows that a very different kind of knowledge on the part of the facilities manager is needed to bridge the different gaps. It may even be that his or her knowledge is not needed to close some of the gaps. With the typology, practitioners and researchers can start to discuss what kinds of skills and competences are needed to close the individual gaps, and, perhaps most important,

which actor(s) can help to balance the 12 gaps, to ensure that involving FM to close one type of gap does not open up other gaps.

Limitations and generalisation

This study was of a qualitative nature, which has been a strength to be able to develop and validate the typology of performance gaps. However, it also gives the limitation that we cannot say anything specifically about, which gaps are most and least important (fatal), besides general statements about the gaps being context-dependent.

Another limitation is that the data collection mostly took place in Denmark and mostly involved Danish experts. The only exception was workshop two, which took place in Norway and involved researchers from Ireland, UK and Norway. It can be noted that this workshop did not show any disagreement with the typology. This support our expectation that the typology applies to other countries besides Denmark. We also found support for this in one of the expert interviews (Architect, partner in an architectural firm):

"When we look back (...) at [complaint] cases with customers: They are because of problems with ventilation and the indoor climate, the FM oriented (...). These customers, they don't get the solution they want. (...). It's not just in Denmark, it's international, also with our international business partners."

Conclusion

The study shows that practitioners are greatly concerned about several potential gaps in performance other than energy gap. The presented typology includes 12 performance gaps from a FM perspective with the energy performance gap primarily being covered

by literature. The energy performance gap is off course still very important, but the study demonstrates that attention must be paid to other gaps, too, and in particular, that focusing solely on the energy performance gap poses the risk of causing other gaps. Building clients must take actions to ensure that the demand for low energy consumption in new buildings does not lead to the neglect of other types of gaps.

The consequences of the gaps are context-specific and vary from project to project. Thus, a hierarchical organisation of the types of gaps is not appropriate, as all gaps can be equally important until they are related to specific projects. The 12 types of gaps are highly interconnected. Actions to bridge one type of gap can help bridge other gaps, too. However, actions to bridge one gap also carry the risk of opening up other gaps. Solving each gap requires specialised knowledge and deep insight into the individual topics of the 12 gaps. Thus, a broader understanding of all of the twelve gaps is needed in each project.

Policymakers should ensure that ambitions to lower energy consumption in new buildings is not causing other types of performance gaps. At the present, there is an overwhelming focus on reducing energy consumption in many countries and huge funding has been allocated for instance by the EU to energy related research and development; particularly concerning new buildings. This study indicate that there is a need to put more political attention towards building operation and to building performances in other terms than just energy.

Further research

Based on the typology, further research and development on possible ways to bridge the gaps and mitigating actions to avoid them are recommended. The skills and competences needed to close the different gaps should also be investigated.

The performance gaps have consequences, which is the reason why they are worth investigating. They have consequences on either the core business, the life quality of those who occupy the building, and the environment of the planet. We suggest further research to investigate, how often the different gaps occurs, the consequences and the related cost of the gaps. Moreover, we hope researchers in the future will investigate the 'fatal gap' more, as it may be possible to generalize which gaps are fatal in certain types of buildings.

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