Modelling Information Flow of Occupant Feedback in Office Buildings

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Abstract

Occupant comfort plays an important role in office buildings in terms of environmental, social, and economic aspects. Facility managers need to evaluate occupant feedback to moderate the negative consequences on office users and ultimately on the corporations that occupy office spaces. However, in the current facility management systems, occupant feedback is not effectively collected and evaluated; thus, facility managers cannot utilize this information in making critical decisions when operating, maintaining and retrofitting office facilities.

This paper presents the initial results of an ongoing research study, which focuses on integrating occupant feedback with Building Information Model (BIM) for assisting decision-makers in the facility management phase. The first step of this research study was to identify the information items that are required to represent occupant feedback for effective use in the facility management phase. To identify the required information items, interviews were performed with office users at ten office buildings and use cases were developed. To validate the use cases, interviews were performed with twelve facility managers. The aim of this paper is to present a sample of the use cases developed and describe the occupant feedback information flow observed in the office buildings. The results show that the occupant feedback data include detailed information related to: (1) location where the problem is observed, which is represented by building, and/or floor, and/or room, and/or façade, and/or table/zone/region depending on the case; (2) location of the user, that is represented by building, floor, room, table/zone/region, (3) source of the problem that is represented by type of building element and related building element, (4) source location, which specifies the location of a problem source that is different than the location where the problem is observed, and (5) time.

Keywords – Occupant Comfort; Facility Management; FM; Building Information Modeling; BIM; Use Case.

1 Introduction

Effective utilization of occupant complaints and feedback is crucial for successful operation, maintenance and retrofitting in offices. Many studies reveal the effects of occupant comfort on energy efficiency [1]; [2]; [3]; [4], employee health and well-being [5]; [6]; [7]; [8]; [9] and employee productivity [10]; [11]; [12]; [13]; [14]; [15]. Currently, to regulate indoor environment during design, operation and retrofitting in office buildings, occupant comfort standards (e.g., ASHRAE 55, EN ISO 7730) are used [16]. However, due to the variations in individuals' sensation levels, there is a poor relation between comfort conditions defined in the standards and the comfort conditions perceived by the occupants [17]. Occupant comfort and satisfaction increases when the occupant evaluations on performance parameters, such as thermal, visual, acoustic comfort, are considered by facility managers [18]; [19]. To measure functional comfort and identify possible workspace features which slows down or demotivates employees, collection of feedback from occupants is critical [20].

Collection of occupant feedback is currently performed by post occupancy evaluation (POE) tools, which are a type of building performance evaluation system. POE is defined as the "examination of the effectiveness for human users of occupied designed environment" [21]; [22]. The current POE tools, however, are lacking extensive inquiry about occupant satisfaction parameters [23]; [24], location based (spatial) occupant feedback [25] and easily understandable visualized data analysis and representation formats for facilities management (FM) [26]; [27].

Building Information Modeling (BIM) constitutes an effective platform to represent and analyze occupant feedback in facilities management. Although the need for BIM in facility management (FM) has been acknowledged by researchers and practitioners [28]; [29]; [30]; [31]; [32] BIM is still not being effectively utilized in this phase, including retrofitting activities [33]; [34]; [35]. FM is still dominated by corrective maintenance

and there is under-utilization of preventive, predictive, and condition-based maintenance in facility management despite the use of advanced FM programs [36].

The study explained in this paper proposes to integrate BIM and occupant feedback to assist facility managers in making critical decisions in FM, including retrofitting activities, as well as preventive, predictive, and condition-based maintenance in office buildings. The first step of this ongoing study was to identify the information items that are required to represent occupant feedback for effective use in the FM phase. To identify the required information items, interviews were performed with office users at ten offices and use cases were developed based on those interviews. The aim of this paper is to present a sample of the use cases developed and to give an overview of the information items required to represent occupant feedback in the office buildings.

2   Literature Review

As part of the literature review occupant comfort, post occupancy evaluation (POE) and its relation to FM, existing POE tools, and FM & BIM & POE integration topics are investigated.

2.1.   Occupant Comfort

There are three basic pillars of the effects of occupant comfort in office buildings. These are social, economic and environmental dimensions. The social dimension includes the well-being and health of employees. It is proved that the well-being and health of employees are directly related with the work environment comfort conditions [37]. One of the main disruptions among the employees is caused by indoor air quality. Adequate ventilation, pollutants and moisture level in the air are the key factors affecting the employee health in an office environment. Also, lighting, high level of noise and vibrations directly affects the employee's psychology. As a result, disturbing environmental conditions slows down the work rate of employees and increases the amount of mistakes due to distraction. It is observed that the absenteeism rate due to health issues is lower in offices which satisfy occupant needs; therefore, the employee productivity in such offices is comparably higher [38]; [39]; [40]. Design-related comfort aspects such as indoor air quality, noise control, thermal comfort, privacy, lighting comfort, spatial comfort and noise comfort designate the level of employee performance. It should be highlighted that physical environment of the office affects 15-20% of productivity of personnel; therefore, productivity constitutes the economical aspect of comfort condition by eventually affecting the company financial-wise [41]; [42]; [37]. The environmental effects of occupant comfort level are also investigated in the literature. It has been identified that the occupant comfort dissatisfaction leads to inefficient use of building systems and causes an increase in building's energy consumption [18]. If the environment is designed to meet the requirements of the occupants and if the occupants understand how the building operates and how the controls systems are used, then it is possible for the occupants to contribute to lower building energy use [18]; [19]; [43]; [44].

The occupant comfort condition standards are used to regulate the indoor environment during operation and renovation periods of office buildings; however. There is a poor relation between comfort conditions defined in the standards and the comfort conditions perceived by the occupants since the sensation level of every individual is different [17]. Especially the evaluations of occupant feedback on performance parameters such as thermal, visual, acoustic comfort, indoor air quality, space usage and occupant control increases the occupant satisfaction [18]; [19]. Collection of feedback from users is vital to measure functional comfort and to identify possible workspace features which slows down or demotivates employees [20].

2.2.   Post Occupancy Evaluation (POE)

During the occupancy phase of the buildings, the building performance evaluations (BPE) are conducted via post occupancy evaluation (POE) tools. Post-occupancy evaluation (POE) is the process of obtaining feedback on a building's performance after it has been built and occupied. In the literature, POE tools are named as Occupant Satisfaction Measurement Tools, Indoor Environmental Surveys or Building Performance Evaluation Surveys. By collecting factors, such as energy consumption, building use, maintenance costs or user satisfaction, POE allows various and continuous improvement possibilities in buildings. Moreover, because of the advances in technology, POE transformed into a knowledge tool than a diagnostic tool in time. Generally POE tools consist of three core parts: questionnaires, bills and metrics, physical measurements (optional) [45]. The results of the questionnaire surveys enable the determination of indirect parameters and characteristics, such as individual characteristics of the occupants and their personality. The physical measurement enable the determination of direct parameters, such as air temperature, relative humidity, air velocity, globe temperature, CO_2 concentration, illuminance levels etc. Also, bills and metrics include documents related to energy consumption of the building and blueprints of the building.

2.3.   Importance of POE in FM

British Institute of Facilities Management has defined

FM as "the integration of processes within an organization to maintain and develop the agreed services, which support and improve the effectiveness of its primary activities" [46]. Facility planning (space management); health, safety, security; maintenance management; and work environment comfort conditions are the main aspects of FM, in which cleaning services, support services, property services, catering services, security services, etc. are provided.

In the current FM applications, IT systems are effectively used in many service areas, such as maintenance and space management. However; work environment comfort conditions are only detected via sensors and POE is not integrated with this data. FM receives the occupant feedback not as a continuous information source, but only as the source of some work orders, which are supposed to be closed after fulfilling required maintenance. In fact, occupant feedback plays an important role for the management of work environment comfort conditions by the facility managers, and there is a need for advanced approaches for effective collection of occupant feedback data.

2.4. Existing POE Tools

There are many POE tools developed over the years focusing on different building types. Various methods and techniques were developed to extract user requirements regarding safety, health, comfort, functionality and efficiency, and aesthetic quality of buildings, and to identify defects in the system [47]. POEs are powerful tools for demonstrating whether or not building programs are delivering best value and for identifying areas for improvement. Currently, architects, built environment professionals, industry bodies and even clients prefer building evaluations through POE since they can see the benefits of evidence-based decision making in achieving their organizational goals. However the current POE tools are lacking some crucial features such as (1) extensive inquiry about occupant satisfaction parameters, (2) spatial occupant feedback, and (3) visualized representation of easily understandable data analysis results.

1. In POE measurement graphs, there is no extensive inquiry about occupant satisfaction parameters which are the indicative of occupant satisfaction. In the research studies, it is found that the satisfaction level of the occupants is measured using several parameters, but the dissatisfaction of the occupant or the reason of the complaint is not interrogated [23]; [24]. Lack of details constitutes a problem in case of a need for detection of specific problems.
2. The evaluation tools are not collecting spatial occupant feedback. The spatial information can enrich the feedback data and point out the building element related to the complaint. This information cannot be delivered to decision makers; therefore, a historical occupant feedback platform does not exist. It is known that linking the performance data to occupant location increases the system efficiency [25]. In a previous study, Hua et al. (2014; 2015) linked the occupant feedback to building spaces (i.e., rooms). However, this approach is not sufficient for open office environments and homogenous evaluations cannot be performed since usually open offices are large areas. Also, it is not possible to give feedback about the common areas other than offices.
3. There is lack of data analysis and representation of analysis results in the systems. In the current systems, the data obtained from evaluation system is not reflected in the facility management application [26]. The greatest obstacle is that the data is not processed and analyzed in a way that the decision makers need and not presented in an easily accessible, refined and visualized way [27]; [26].

2.5. FM & BIM & POE Integration

BIM is a process which uses 3D, parametric and object-based models to create, store and use coordinated and compatible data throughout the life cycle of a facility [48]. The system goes beyond a visual modeling by means of 3D numerical modeling feature. It is a multifunctional management and information exchange tool which can contain all the information for manufacturing. Also, the information embedded in BIM models can be used for the operation of the facility [49]. Thanks to the developed exchange formats such as IFC Standards, data exchange between BIM tools is possible [50]. BIM integrated FM systems utilize effective decision making during operation and retrofit phases and consequently increases the building performance and occupant satisfaction [51]. The usage of BIM in FM bridges the information gap between the authorities in design and construction phase and the owner. It helps to reduce the costs since the data is ready to use and easy to reach in the model. Also, the models can be integrated into building automation systems which helps the FM to manage the buildings more effectively. Lastly, by enabling faster analysis and correction of problems, it helps to improve building performance and therefore the occupant comfort. In recent years, it has been emphasized that a BIM-integrated FM system is needed for delivering facility performance data more effectively to decision-makers in FM or retrofitting processes [25]; [52]; [53]; [54]; [55]; [56]. The application of such a system is not reported in any of the studies, even though the required approaches are proposed frequently.

3 Method

To identify the information items that are required to represent occupant feedback, the current information flow between employees and facility managers are investigated for reporting of complaints and feedback. A set of interviews were performed and use case scenarios were developed based on these interviews. Ten office employees, who work in ten offices in different companies, participated in the interviews. All office buildings chosen for the study have automation systems for HVAC control and operated by professional FM firms, but are diverse in terms of size, type of offices (cellular/open-plan), type of activities, facades, finishing materials, energy efficiency levels and none of them have BIM models. All the office users were asked four open-ended questions;

1. What kind of complaints did you report before?
2. Whom did you report your complaint?
3. Which communication method(s) did you use to report your complaint?
4. Which information did you provide to the authorities about your complaint?

According to the information obtained during the interviews, thirteen use case scenarios that represent occupant feedback/complaint information flow were developed. For each use case scenario, a use case diagram using Unified Modeling Language (UML) was created.

To validate the use cases that were developed, use case scenarios and UML diagrams were presented to twelve facility managers. Their feedback was received via interviews and reflected in the use cases. The methodology is also shown in Figure 1.
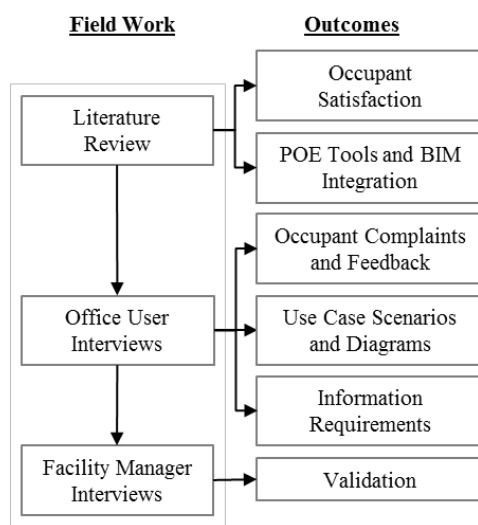

Figure 1. Methodology flowchart

4 Results

Out of thirteen use cases that were developed via interviews with office occupants and facility managers, three of them are provided as a sample in this paper. Information requirements that were identified from the use case as an outcome were presented along with each use case scenario.

Use Case Scenario 1 : Indoor Air Quality – Odor

Actors: Employee, facility manager, technical staff
Triggers: The employee realizes that there is an unpleasant odor in the office coming from the cafeteria.
Scenario: The employee realizes that there is a bad smell in the office coming from the cafeteria. He calls the facility manager and complains about it. The facility manager directs a technical staff team to the entrance floor to make an inspection about the complaint. After the inspection, the technical staff offers the construction of an automated door between the Blue Zone (offices) and the corridor that opens to the cafeteria. The facility manager accepts the offer and as a solution the door is constructed.
Outcomes: Building, Floor, Zone, and Source Location (different room for problem source, ex: cafeteria)
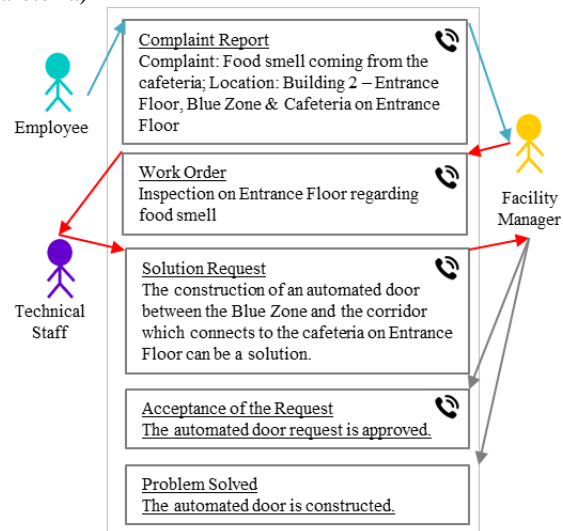

Figure 2. UML diagram of use case scenario 1

Use Case Scenario 2: Visual Comfort – Reflection

Actors: Employee, facility manager, administrative affairs manager
Triggers: The sunlight is reflecting on the computer of the employee and the employee cannot see his screen
Scenario: The sunlight is reflecting on the computer of the employee and the employee cannot see his screen.

He reports this problem to the facility manager. The facility manager comes to the office of the employee and inspects the problem on site. After identifying that the problem is observed between 11:00 and 15:00, the facility manager decides that there is a need for a window shade. The facility manager calls the administrative affairs manager, reports the problem and requests a window shade for office X. The administrative affairs manager accepts the request of window shade procurement. The facility manager purchases the window shade. By using the window shade, the employee prevented reflection on his screen between 11:00 and 15:00 while working at his computer.

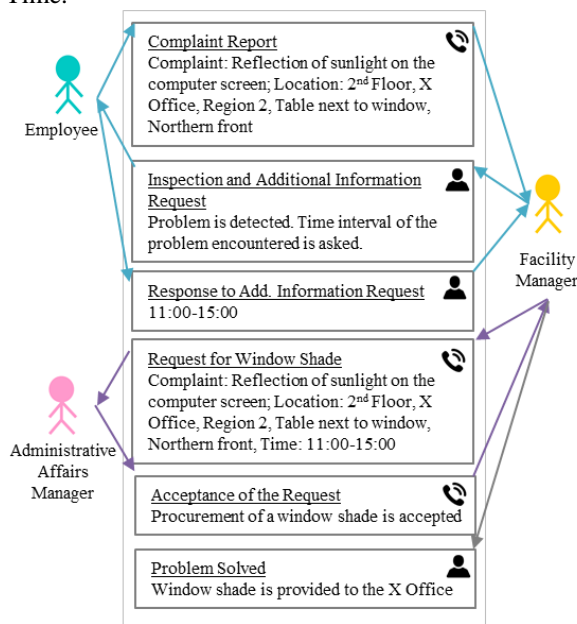Outcomes: Floor, Room, Region, Table, Facade, Time.

Figure 3. UML diagram of use case scenario 2

Use Case Scenario 3: Indoor Air Quality – Odor

Actors: Employee, facility manager, technical staff

Triggers: The employee thinks there is a bad smell coming from the air-conditioning (AC)

Scenario: The employee reports his complaint via a phone call about the unpleasant odor coming from air-conditioning to the facility. The facility manager directs a technical staff to do an inspection. The technical staff changes the filter in the air-conditioning unit and reports back to facility manager. The facility manager notifies the employee about the maintenance work.

Outcomes: Floor, Room, Building Element Type, Related Building Element (Building Element Location)
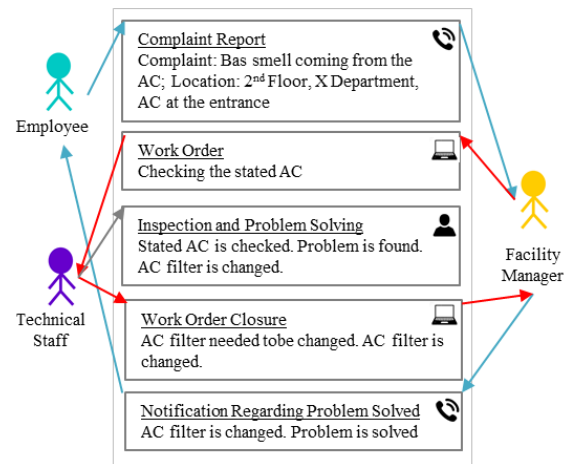

Figure 4. UML diagram of use case scenario 3

The use cases demonstrate that information requirements are different for each case. From use case scenario-1, *building*, *floor*, *zone*, and *source location* outcomes are obtained. Building, floor and zone represent the different granularity of location information of problem. The source location specifies the location of a problem source that is different than the location of the occupant. In the case of the unpleasant food smell in the office area, cafeteria represents the source location whereas the office represents the room/zone/region where the office user works.

From use case scenario-2 *floor, room, region, table, facade,* and *time* information requirements are gathered. Floor, room, region and table represent the location of the user. Since the complaint is related with a certain building frontage, the façade where the problem is observed is needed as well. Lastly, time stamp is important since the complaint is time dependent.

The information outcomes of the use case scenario-3 are *floor, room, building element type,* and *related building element (building element location).* Floor and room gives information regarding user location. Since the complaint is related to a certain building element, the type and exact location of it are needed as well.

Table 1. Information requirement outcomes of use case scenarios

Use Cases	Building	Floor	Room	Table	Region	Zone	Facade	Building Element Type	Related Building Element	Source Location	Time
1	x	x				x				x	
2		x	x	x	x		x				x
3		x	x					x	x		

Information requirements gathered from the use case scenarios are summarized and listed below:

- Location where the problem is observed (represented by building, and/or floor, and/or room, and/or façade, and/or table/zone/region depending on the case)
- Location of the user (represented by building, floor, room, table/zone/region)
- Source of the problem
  - Type of Building Element
  - Related Building Element
- Source Location
- Time

5   Conclusion

This paper presents the initial results of an ongoing research study, which focuses on integrating occupant feedback with Building Information Model (BIM) for assisting decision-makers in the facility management phase. The first step of this research study was to identify the information items that are required to represent occupant feedback for effective use in the facility management phase. The aim of this paper is to present a sample of the use cases developed to identify the required information items and describe the occupant feedback information flow observed in the office buildings.

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The next step of this study is to determine how the required information items are represented in IFC and if necessary, how IFC should be extended to represent those information items. Future work includes developing a prototype that collects occupant feedback from the user, stores in BIM and presents to the decision-makers for effective facility management.

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