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Expanding Boundaries:
Systems Thinking for the Built Environment

SURVEY TOOL FOR THE BUILT ENVIRONMENT

H. Leindecker[1]*, D. Mittermaier[2]

[1] FH OÖ Studienbetriebs GmbH, Stelzhamerstraße 23, 4600 Wels, Austria
[2] FH OÖ F&E GmbH, Franz-Fritsch-Straße 11 / TOP 3, 4600 Wels, Austria
*Corresponding author; e-mail: herbert.leindecker@fh-wels.at

Abstract
The growing market share of building automation systems bears huge potentials in terms of energy savings and creates the opportunity to support its users in everyday life. Due to the direct impact on the building's residents, workforce, etc. the achievements and effectivity are highly dependent on the system user's satisfaction. The quantification of the rate of satisfaction has to be determined in cooperation with the affected parties, which can prove difficult without the suitable measures. In order to achieve this task, the online survey tool MOFNUG, developed by four Austrian Universities of Applied Sciences, provides novel approaches in terms of measuring the satisfaction of users regarding thermal comfort, indoor air quality, controllability of technology and various other building and user-related fields. Ideally, the questionnaire's evaluation should be complemented by measurement methods to establish relations between the proponent's subjective impressions and the variables of the area of interest.

Keywords:
Survey tool; User satisfaction; Building automation

1 INTRODUCTION

To fulfil the requirements of a sustainable and optimized building ("High Performance Building"), it is necessary to take into account user satisfaction, the highest and most difficult objective to be achieved in the planning and operation of buildings [1]. This principle also applies to the progressive automation of building systems aiming to enhance user convenience and comfort.

In this context the question arises, if these automated processes are accepted by the users as an increase in terms of comfort and if they appreciate the reduced amount of user intervention and which tasks shall stay manually operated.

As a consequence of the difficulties to quantify the vast range of factors influencing user satisfaction, a FFG-research project called MOFNUG („MOdularer Fragenkatalog für die NUtzerInnenzufriedenheit in Gebäuden") was introduced. The MOFNUG-project is a collaboration of four Austrian Universities of Applied Sciences with different perspectives in the spectrum of marketing, psychology, energy engineering or facility management. Right from the beginning in 2013 the main focus in the ongoing cooperation was on the development of an online survey platform, serving as an adequate "measurement tool" for user satisfaction.

This tool and its modules are designed to react flexibly to various conditions, such as different types of buildings or user-structures. A basic module ("cluster") therefore deals with the building and subsequently also with the building automation. Other additional modules are in progress or in the planning phase.

The online surveys should ideally be accompanied by research methods and measurements (e.g. indoor air-measurements) based on the "Toolbox" work-in-progress.

2 DATA AND METHODS

After detailed basis research on the topic thermal comfort, which has been verified by our own practical measurements, simulations and surveys, the MOFNUG-tool was optimized [1], the literature research has been extended and

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additional modules, processed by the research partners, have been integrated, such as the acoustic comfort and the visual comfort.

These modules form an important basis regarding the aspects of building automation, e.g. in order to achieve a high visual comfort it is necessary to create balanced lighting conditions with minimal disruption and to individually adapt the lighting according to the user's requirements.

2.1 Basics of building automation

Building automation should offer an opportunity to improve energy efficiency in new buildings, renovation or expansion of existing constructions and to obtain higher comfort levels for the building's users in parallel. Additionally, automated building services provide the foundation for enhanced security systems and are able to unite multimedia applications in a central control unit.

Besides, the substantial normative basis for thermal comfort (ÖNORM EN ISO 7730) and the general user satisfaction (ÖNORM EN 15252), the ÖNORM EN 15232 "Energy performance of buildings – Impact of building automation and building management" is identified as fundamental in the matter of building automation.

This standard assigns buildings unambiguous to energy efficiency classes. The classes range from "A" to "D", where "A" describes highly efficient, "B" advanced, "C" standard and "D" inefficient building automation systems, e.g. a building with the classification "D" lacks networked building automation functions, electronic room automation and energy monitoring. Fig. 1 indicates the discussed classes [2].

However, the problems of building automation are additional acquisition costs and the often limited possibilities regarding a building's expansion or renovation. Consequently, amortisation calculations result in extended long periods of time. Thus, economic considerations like savings due to increased energy efficiency, rarely are the sole argument for automation. Therefore, it is crucial to fulfil several functions simultaneously and to increase the satisfaction of users with the building and its systems in any case.

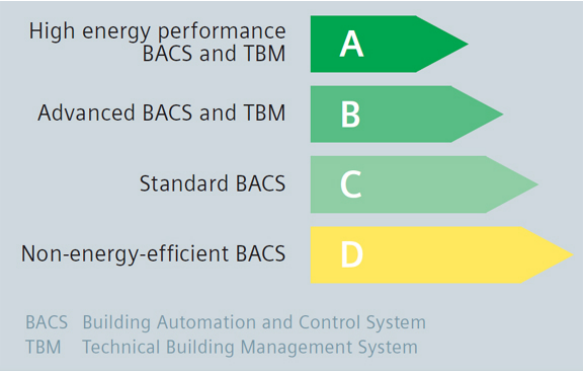

Fig. 1: BACS energy performance classes - BS EN 15232 [3].

2.2 Fundamental functions

This chapter contains a listing with an excerpt of the most important functions achieved with a building automation system. In order to specifically enhance user satisfaction, manufacturers developed integrated comfort functions in their products:

- Automatic or scheduled functions such as automatic wake up lights, timed door locks, automatic shutdown of consumers
- Window functions and control of awnings or blinds
- Heating set point reduction

Additionally, building automation systems allow the integration of security applications, figures of opportunities constantly rising:

- Intrusion detection
- Consumption / switching status monitoring
- Smoke / fire alarm
- Monitoring of power circuit, water pipes, overheating

The potential for increasing energy efficiency is an essential part of building automation, as suggested in EN 15232 (referring to chapter 2.1). Energy conservation is probably one of the most crucial points regarding the system's promotion, since these functions can directly reduce costs:

- (Intelligent) smart metering
- Heating and air conditioning control
- Energy management and consulting

Furthermore, multimedia features can be added among the previously mentioned opportunities. However, these functions require displays, panels or compatible operating systems to communicate with the automation system:

- Audio Integration
- Visualization of images and videos
- Internet integration

In addition, there are document management capabilities enabling centralized data storage, the personalized and situation dependent output of data and various other functions. Remote access to a centralized system without programming

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skills is established by content management systems [4].

2.3 Energy savings

Becker and Knoll conducted a comprehensive literature research and an experimental study at the Hochschule Biberach. The results of the literature research are shown in Fig. 2, relying on 117 sources. The numbers in the brackets describe the underlying amount of sources per category. Note the part-wise relatively large bandwidths due to differently defined functionalities and combined measures [5].

The lighting (E), energy management (I), ventilation (G) and general functions (A) hold the biggest potentials for energy savings. Other trades like sun shading (B), heating (C), the optimisation of controls (D), energy efficient devices (F) and cooling (H) bear lower potential to conserve energy.

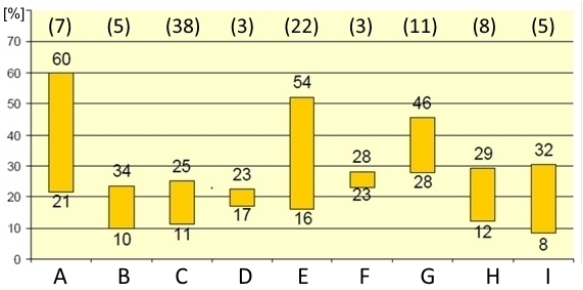

Fig. 2: The theoretical potentials for savings of Building automation [5].

Partly considerable savings are one reason for the automation of energy-intensive trades and they allow justification for potentially higher installation, acquisition or cleaning costs of a building.

Under the direction of Christian Struck a preliminary study with literature reviews and surveys has been executed in order to gain knowledge regarding the energy-saving potential by building automation [6].

The calculated energy saving potential evidenced that beside the applied technologies, there is a heavy dependence on the type of building. The savings potential is indicated by 49% in shopping centres, 39% in office buildings, 27% in residential buildings and 18% in hospitals. The values were determined by calculations with the TRNSYS building simulation software.

The theoretical saving potential is also heavily influenced by users. They have to be able to deal with the installed systems and its manual control units and be prepared for their influence.

2.4 Customer acceptance

Professor Michael Krödel from the University of Rosenheim concentrates his work on building automation and technology. As part of this activity, studies dealing with the topic of consumer acceptance were supervised by him.

His studies discuss on the one hand, which automatism or manual intervention is required and on the other hand, which one is unnecessary or useless.

The analysis of the replies to a survey among potential building automation users younger than 30 years derived from his paper shows rather surprising results: the remote access function has a low acceptance rate, although the participants belong to the smartphone generation. The focus was on energy efficiency established by individual room management as well as some security and comfort functions. The highest acceptance among the research group was accomplished by a centralised "shut off everything" button and networked smoke detectors, followed by room temperature control, automated blinds and malfunction detection [7].

2.5 Needs and desires

Besides the technical feasibility of the automated trades the desires and needs of users, suppliers and manufacturers also have to be taken into account.

The extension of independent living is one of the most promising aspects for users and manufacturers as well if the foundation beneath the system is sophisticated and barrier-free. Furthermore, the data exchange with nursing homes and health surveillance is of high relevance among users and can be associated with the previous aspect.

Beside these functions regarding health and age assisted living, suppliers and manufacturers have to fulfil the user's desire for individualisation, interactivity and multi-device-consumption [8].

Nevertheless, it has to be bared in mind that these applications have to be energy efficient and reasonably priced in order to achieve sustainability and generate a high market share.

Not only the technology itself but also its usefulness decides whether new systems are accepted or not. Security and safety, comfort and economic considerations significantly influence the user's decisions. Providers of products and services have to handle these requirements [8]:

(i) Increase in safety and security terms:

- Safety functions for people and environment
- Denial of unauthorised data access and manipulation
- Secure operation of the provided infrastructure, fault-tolerant systems, plausibility checks, integrated hazard prevention, technical safety
- Protection of privacy (e.g. video surveillance)
- Reliable and plausible confirmation of remote operation
- Fast and guaranteed error diagnostics and troubleshooting (online service)
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(ii) Comfort enhancement:

- Preserve independence of lifestyle (e.g. handicaps, age-related constrained motivity)
- Information and communication technologies should work discretely in the background (important for specific target groups)
- Controllability of the technology, possibility of intervention at any time
- High integration rate (useful and comprehensible connection of services)
- Logical memorability of the service (e.g. intelligent heating)
- Multifunctionality of physical user interfaces (e.g. universal remote)
- Ease of use (“universal design”)

(iii) Inexpensive application:

- Low initial costs, high flexibility and upgradeability
- Acceptable price in proportion to the difficult to quantify benefit convenience functions
- Expendability in dependence of user requirements and financial framework conditions (“hot plug & play”)

3 RESULTS

This chapter focuses on the current status of the online questionnaire in the MOFNUG-project. The expansion regarding building automation took place primarily in the cluster 15 "Controllability of technology".

3.1 Module of questionnaire “Controllability of technology”

The questions of this cluster are mostly consisting of the question type "7-Point Custom Label Likert Scale". This type has seven possible answers, wherein the first and the last (seventh) point are occupied by the conflicting answers (labels are set). The respondent can choose between the clear-cut answers or his perceived reduction, whereby the strength of discomfort can be illustrated. Here are some examples from the questionnaire:

The following trades of the building are controlled automatically (Selection: heating, cooling, ventilation, lighting, shading):

- Is it possible to control the blinds in larger rooms in groups to quickly achieve the desired shading conditions and to save time?
- Is it possible to control the lighting in larger rooms in groups to quickly achieve the desired lighting conditions and to save time?
- Which operating options do you have to change the indoor climate?
- How difficult is it for you to operate the various functions for temperature, shading, window and lighting control?

The questions were reviewed and supplemented by Zainer [9]. It should also be made a statement whether the indoor environment is maintained during the day and whether the users are generally satisfied with the automation.

- Is it ensured that in summer your selected indoor climate is maintained during your entire stay or do you need to adapt your inputs?
- Are the systems of the building emitting distracting noises?
- Which Building technology is automated to an unnecessary level, should therefore be better user controlled than automatically?

In an extended part of the question modules it is all about whether or not the users unknowingly contribute to conserve energy, which is established by Building automation in conjunction with energy metering.

- Do you save energy intentionally (e.g. by switching off redundant light sources, short/complete changes of air instead of permanently opened windows, etc.)?
- Are you aware of your personal energy consumption?
- Are there motion sensors in use at your workplace to switch of power when absent?
- Does your office have a central switch to power off all devices at the end of your working hours?

The questions provide explanations that can be accessed by the respondent wherever decisive. The aim of the questionnaire creator should be to select only as many questions as necessary for significant results [9].

3.2 Conducted surveys

Two major surveys took place in pursuance to test the MOFNUG-tool and to acquire information provided by experts as well as layman.

The “Gebäudeintegrierte Photovoltaik” (“Building integrated photovoltaics”) survey targeted to gain new insights from BIPV business insiders and the “Gebäudeautomation an der FH Wels – Wie zufrieden sind Sie?” (“Building automation at the University of Applied Sciences Wels – Are you satisfied?”) survey investigated the satisfaction of the employees regarding the automation systems in their activity area.

The conclusion of these surveys will be presented at the SBE conference 2016.

4 DISCUSSION

For the creation of a survey it is crucial to have knowledge regarding the building, its automation systems and occupants. It should be differentiated whether the respondents are layman or experts in the assessed technical issues and subsequently to create varying surveys.

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This basic information lays the foundation for the creation of a questionnaire. With the credentials to access the website you have the opportunity to set it up, deliver it digital or analogue and finally evaluate the replies of the proponents.

The MOFNUG-tool provides the possibilities to create and adapt surveys in a flexible and accessible way and is able to generate evaluations of the responses automatically. The question data base is permanently expanding resulting in a large scope of application. The screenshot in Fig. 3 is exemplary for the design and structure of the MOFNUG-platform.

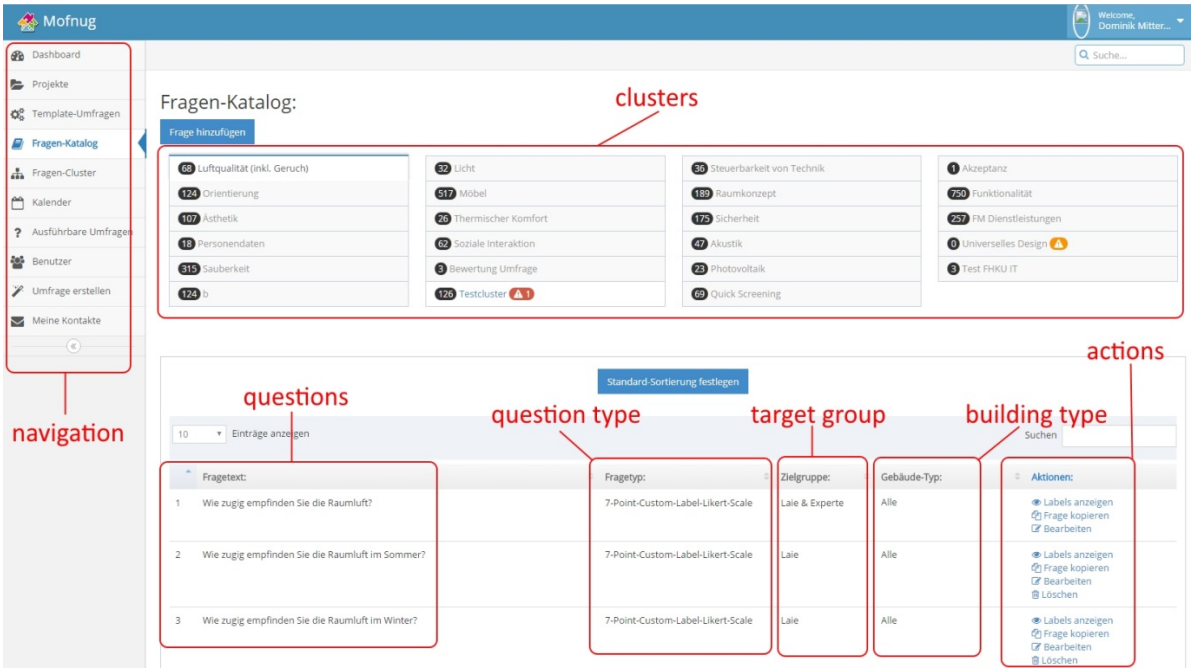

Fig. 3: Showcase for the MOFNUG-tool with explanations (red) [10].

5 CONCLUSION

As the subject of this study includes several equally important areas of construction technology, an extensive basic research was necessary, although there is still a lack of substantial studies. The technical possibilities in the building automation sector implied that they are properly implemented, can be a major contribution to the improvement of the energy performance of buildings.

EU norms and governmental regulations provide a healthy basis for the decision and therefore the investment in a building automation system, especially for non-residential buildings. Companies are encouraged in the form of subsidies or tax reductions to increase investments, finally resulting in lower life cycle costs and benefits for the environment.

The difficulties of building automation are based on the interference of systems due to the various comfort and energy saving functions and their mutual interaction. The integral planning approach suggests that building automation has to be discussed among experts and the later users in the earliest possible design stage (depending on building type).

Furthermore, the important aspect of automation beyond necessity has to be taken into account. A technical system is only satisfactory if it is working properly. Too many features and automated trades often result in a reduction of user satisfaction. Users attach great importance to the fact that windows and doors can be handled manually and the possibility to adapt sun shades and alter the temperature independently.

The research project MOFNUG offers the opportunity to the involved parties to modularly tailor questionnaires on the subject's requirements. The integration of measuring instruments allows a comparison of the knowledge obtained by the surveys with precise measurement data. Thus, an optimized quality of buildings can be realised more easily. The aim is that future buildings have the least possible environmental impact and are able to adapt to external conditions quickly, without interfering with the building's users and simultaneously save energy. With careful planning and execution this is already possible today.

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