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Approaches and tools toward integrated design of buildings and their environmental control systems

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Zusammenfassung

Das Ziel dieser Dissertation ist einerseits die Erforschung des aktuellen Status der Zusammenarbeit zwischen Architekten und Gebäudetechnikern und andererseits die Eruierung, ob eine besser strukturierte Planung und Konfiguration von Gebäudetechniksystemen durch spezifische und neue digitale Gebäudetechniktools erreicht werden können.

Um dies herauszufinden, wurden intensive Interviews mit Architekten und Gebäudetechnikern geführt. Sie teilten ihr Wissen und ihre Sichtweisen betreffend Gebäudetechniksysteme und sprachen über ihre Funktion in der Planung von zeitgemäßen Gebäuden. Außerdem gaben sie Einblicke in die Zusammenarbeit zwischen Architekten und Gebäudetechnikern und ihre positiven und negativen Erfahrungen.

Zusätzlich wurden Studenten interviewt, um auch an ihren Erfahrungen mit Professionisten sowie der Planung von Gebäudetechniksystemen teilhaben zu können und um in ihre Sichtweisen Einblicke zu gewinnen.

Diese Dissertation beinhaltet weiters die Details eines Schemas, welches ermöglicht, das Gebäudeautomationssystem und dessen Steuerungslogik hierarchisch darzustellen (Heizung, Kühlung, Belichtung und Belüftung). Dieses hat das Potenzial, die Professionisten bei der Planung der Gebäudetechniksysteme zu unterstützen und die Kommunikation zwischen Architekten und Gebäudetechniker zu verbessern.

Basierend auf vielen Pilotprojekten wurde das Schema kontinuierlich weiterentwickelt. Um seine Anwendbarkeit und Benutzerfreundlichkeit zu testen, wurde eine Studie durchgeführt. Als Teil eines Universitätsseminares testeten Studenten dieses Schema an realen Räumen und gaben Feedback dazu. Die Ergebnisse dieser Studie gaben Einblicke in Stärken und Schwächen des Schemas und gaben weiters wichtige Hinweise für die Weiterentwicklung.

Im Zuge der Interviews kommentierten auch die Professionisten die Anwendbarkeit und Brauchbarkeit des Schemas. Darauf aufbauend, wurde das Schema weiterentwickelt, verbessert und vereinfacht. Dadurch hat es

einen Status erreicht, in diesem es in der Planungsphase für Gebäudetechniksysteme eingesetzt werden kann.

Laufende Forschung soll dazu beitragen, dass das Schema automatisch, anhand eines Computerprogrammes oder Tools, generiert werden kann. Mit solch einem Programm oder Tool könnten Fehler in der Anwendung reduziert oder sogar vermieden und der Anwender auf entstehende Konflikte in der Steuerung hingewiesen werden. Die optimale Anordnung der technischen Geräte und Sensoren könnten in Folge mit solch einem Tool oder Programm automatisch dargestellt werden. Dieses Tool oder Programm könnte außerdem für ein ganzes Gebäude angewendet und um zusätzliche Funktionen erweitert werden. Damit könnte die Gebäudetechnik schon in frühen Planungsphasen berücksichtigt werden und sich die Kommunikation zwischen den Professionisten verbessern.

Summary

The aim of this dissertation can be described as follows: first, to find out the state of professional collaboration between architects and engineers and, second, whether a more structured and evidence-based approach can be achieved to the design and configuration of building's environmental control systems by means of specific and new computationally supported engineering tools.

Given this background, in-depth interviews with experienced professionals in both the architecture and engineering fields were conducted. They shared their understanding and views on building systems and their roles in the overall planning of modern buildings. Moreover, they gave insights into the collaboration process between architects and building service engineers as well as their positive and negative experiences. In addition, interviews were conducted with students to get insights into their experiences with professionals and planning building systems, too, and their takes on the subject in general.

Furthermore, this thesis includes the details of the schema for control logic distribution of building systems (heating, cooling, lighting, and ventilation), which could potentially support the building systems design process and enhance the communication between architects and engineers. Based on many pilot projects, the schema was constantly further developed. An experiment was conducted in order to test the schema generation methods' applicability and user friendliness. As part of a university course, students then tested the building systems control logic distribution schema on real architectural spaces. Participants also gave feedback regarding the potential and limitations of the method. The evaluation of the results shed light on the strengths, problems and needs for further development in the schema generation process. Furthermore, the interviewed professionals also shared their views on the feasibility and usefulness of the proposed schema. Based on this, the schema was, once again, developed further, improved, simplified and finally reached a status suitable for introduction into the practical design process of building's technical systems.

Additional research would advance the schema further towards automated generation by a tool or computer program. This, in turn, could reduce the likelihood of schemes being generated in a wrong fashion or turning out too complex. What's more, conflicts between control devices could be pointed out to the professionals more easily and the optimal positions of devices and sensors could be automatically arranged. Moreover, this tool or program could be extended to include additional functions. It could hence make it easier to take the building technology into account from the very beginning and, as a result, the communication between the architects and the building engineers could also improve.

Acknowledgments

Writing a dissertation is a long process with many ups and downs and I would like to express my highest and utmost appreciation to all those who provided me the possibility to complete this report. Special gratitude goes to my supervisor Prof. Dr. Ardeshir Mahdavi, who has been a mentor, inspiration and friend throughout this journey with his extensive knowledge and his kind nature. He always stood by my side with help and advice, for which I am eternally thankful.

I would like to thank the participating students for their efforts towards and applying the proposed schema generation method, and another thank you goes to the professionals who took a lot of time to answer my interview questions, without which this thesis would not have been possible.

My largest support and motivation during my time as a PhD student came from my family and friends. I especially want to thank my friend Senka Balic and my grandparents Hedwig and Walter Malner for their mental support all the time. During the dissertation time, my son Marwin was born. He always provided variety in everyday life in addition to work and dissertation and gave me new inspiration and motivation.

A special thank you goes to my deceased parents Brigitte and Wolfram Rader, who taught me to pursue my goals and never to give up.

Contents

Chapter 1. Introduction

1.1. Motivation

Buildings are expected to provide a modern envelope and adequate indoor environments. The building technology plays an increasingly important role. To that end, multiple requirements must be met, including proper design of building fabric and envelope, adequate selection and sizing of the building service systems, and effective building controls and operation. Ineffective control of building technology causes problems to the occupants and unnecessarily high energy consumption.

The increasing mechanization and automatization of buildings causes new tasks and challenges for the involved architects, service engineers and construction workers. This requires a good knowledge of the different professionals in the planning and construction process of intelligent buildings. To achieve optimal planning result, a good cooperation between architects and building service engineers from the beginning is essential.

The integration of building services in the planning process at as early a stage as possible is of great importance to achieve an optimal result (Monsberger and Fruhwirth 2018). It appears that this fact is often neglected, and collaboration between different professionals is poor in many cases. Very few architecture offices make use of existing computer tools facilitating collaboration and enabling simultaneous processing on a project (such as BIM), and small companies in particular not ever use them (Rader and Mahdavi 2016a, 2016b).

Decisions regarding the environmental control systems' types and devices, the number and extent of control zones, as well as the type, number and

positions of sensors are not sufficiently explicated and often seem to be made on an ad hoc basis. The optimal operation of buildings' environmental control systems may be hampered by the insufficient coordination of processes in one domain (e.g. thermal control system) with other domains (e.g. visual control system). The currently prevailing practices to design buildings' environmental control systems and the associated control processes may be argued to display a number of shortcomings. To address this challenge, in-depth communication and collaboration between architects and building service engineers in the design process is important (Rader and Mahdavi 2016a, 2016b).

The education of architects in Austria focuses especially on the aesthetic aspects in buildings and building-technology topics are taught only to a limited extent. However, the visual design of buildings is not enough to plan well thought out and contemporary architecture. By a lack of training opportunities in the construction industry, there is a considerable knowledge deficit in the field of building technology and building automation.

Despite the advantages of the modern (automated) building technology (e.g. improved comfort, reduced energy consumption, more security), one often gets the impression in conversations with architects that the building technology is seen as an area that leads to nuisance in the planning and holds them back. In addition, building service engineers often complain about their late involvement in the planning process and the lack of understanding of their work. Overarching thoughts and actions, beyond one's own trade, are often neglected. There is a focus on building fast and cheap.

An actual Austrian study confirm that building technology in general, the late decisions regarding building technology and the lack of cross-trade coordination are seen by professionals as a common cause of disturbances in the project process. Moreover, the late integration of building engineers

in the planning phase causes disturbances[1] (Monsberger and Fruhwirth 2018).

Although many people know the term “smart home” (see Figure 1 and Figure 2) from the media, only few of them understand what it is about. As a consequence, the integration of an automated building technology is not a priority. Due to a lack of architects’ and building service engineers’ knowledge and experience in this field, progressive building is often but an afterthought. Still, buildings, which require unnecessary costs for building services are often planned and built and end up being defective in later use. Cost and construction time overruns are the order of the day. Most new residential buildings in Austria are built entirely without automated building technology or it is limited to automated blinds and radiators. Sensors are still a rarity and technical devices are often not interconnected. As the Austrian real estate magazine OIZ states, sun protection systems in offices and upscale housing are controlled automatically almost exclusively, however, this does not apply to subsidized housing. Users there can only choose between shutters and venetian blinds (OIZ 2019). The speaker of the federal association for sunprotection technology states: ‘It would be advisable to have automated sun protection everywhere, since offices should not overheat on weekends either, and neither should apartments when people are on vacation’[2] (Gerstmann 2019, p. 40).

[1] The Austrian study “Die Gebäudetechnik im österreichischen Bauprozess” focuses on the questions whether the field of building technology is particularly sensitive to conflicts and disruptions in complex construction projects compared to other trades, and whether professionals have a common understanding of this issue.

[2] Translated from original German by the author. Original text: “Sonnenschutz soll zweckmäßigerweise automatisiert sein, weil Büros auch am Wochenende oder eine Wohnung auch im Urlaub nicht überhitzen sollen.“

Actual literature on control theory does not focus exactly on this subject matter. Research work in this domain (Mahdavi 1997, 2001a, 2001b, 2004, 2005, 2012, Mertz and Mahdavi 2003, Mahdavi and Schuß 2013, Rader and Mahdavi 2014, 2016a, 2016b, Rader and Mahdavi and Pont 2015, Mahdavi and Schuß and Rader 2015, Mahdavi and Rader 2014, 2016) has concentrated on developing a schema for control logic distribution of building systems (heating, cooling, lighting and ventilation), which has gone through a series of evolutionary steps. This schema could both support the building systems design process and enhance the communication between architects and engineers.

Given this background, the thesis should give insights in the actual state of professional collaboration between architects and building service engineers. Moreover, this research should facilitate the understanding of the current state and possibilities for improvement of the collaborative and integrated design of buildings' technical systems as well as the related potential of the aforementioned building systems control logic distribution schema.

Figure 1: "Smart Home": Control panel in a residential building.[3]

[3] Source: www.shutterstock.com

Figure 2: "Smart Home": Control via phone.[4]

[4] Source: www.shutterstock.com

1.2. Research statement

The present research effort addresses two challenges. First: to explore the state of professional collaboration between architects and engineers. Second: to analyze if specific and new computationally supported engineering tools and schemes can support a more structured and evidence-based approach to the design and configuration of buildings' environmental control systems.

The first effort involves extensive interviews with experts and students. These interviews with experienced professionals in both the fields of architecture and engineering (from different offices and with different professional experiences) and students, give general insights about their education and experiences in professional life.

The survey aims at evaluating and juxtaposing the answers received from the perspectives of different agents of a construction project (architects and building service engineers). As a result, both congruent and contrary points of view and assessments of the issues at hand will result, which in turn provide us with insights into the status quo of construction projects. Moreover, challenges and problems can be identified, a potential need to act can be derived and attempts at a solution developed.

The aim of the second challenge is to develop tools and schemes which are intended to add clarity and transparency to the building systems design process and could both support this design process and enhance the communication between architects and engineers.

In order to address the aforementioned challenges, extensive research of professional literature was carried out initially, and professionals were interviewed to help us determine what counts as a modern and user-friendly building and what possibilities for integrated and automated building systems technology there are.

A questionnaire was designed in order to find out more about the approach and communication as well as cooperation between the professionals.

The interviewed architects and building service engineers were chosen from a range of professionals from differently sized offices and varying degrees of professional experience from Carinthia and Styria. The survey applies to the current situation in Austria, which is why only Austrian experts were chosen.

Two test interviews were performed with one architect and one building service engineer, after which the questionnaires were revised once again.

The interviewees were first contacted by email and given an introduction and an overview of the subject matter. About a week later they were called and dates for interviews set up.

A total of 29 architects and building service engineers agreed to do an interview. The others were not interested, didn't have time or couldn't be contacted despite several attempts.

The interviews took place over a time period of three years. They were performed orally and recorded using an audio device. Thereafter, they were transcribed and evaluated.

The above mentioned schema was further developed in parallel with the survey. Note that this tool is originally developed by Prof. Mahdavi from the Department of Building Physics and Building Ecology, TU Wien analysed (Mahdavi 1997, 2001a, 2004, 2005). The effort of this thesis is to test it on real spaces, explore its' usability and applicability and further-develop it.

To empirically explore the viability of the schema generation method, a test was conducted involving a number of architecture and engineering students. They were introduced to the schema and tested it on real spaces. This helped determine whether the application of the schema was user-friendly and intelligible. After the students had tested the schema, they filled in a questionnaire in order to receive feedback on the schema and the further development (Rader and Mahdavi 2014).

The professionals also provided specific feedback concerning the scope and potential of the developed tools and schemes for the automated

generation of building control schemas. Consequently, it could again be further developed. The interim results of the evaluations were presented in the following papers:

- Mahdavi A. & Rader B. 2014. *Testing a method for the generation of the systems control schemes for buildings.*
- Rader B. & Mahdavi A. 2014. *Usability assessment of a generative building control logic distribution scheme.*
- Rader B. & Mahdavi A. & Pont U. 2015. *Bridging the gap between systems controls and architectural design.*
- Mahdavi A. & Schuß M. & Rader B. 2015. *A Multi-Zonal Schema for Systematic Compartmentalisation of Building Systems Control Logic.*
- Rader B. & Mahdavi A. 2016a. *Bridging the gap between systems controls and architectural design.*
- Rader B. & Mahdavi A. 2016b. *Supporting integrated approaches to the design of buildings and their technical systems.*
- Mahdavi A. & Rader B. 2016. *Integrated buildings and systems design: approaches, tools and actors.*

The results of this study facilitate the understanding of the current state and possibilities for improvement of the collaborative and integrated design of buildings' technical systems as well as the related potential of the aforementioned building systems control logic distribution schema.

In future, the schema can be tested by professionals and developed further to become applicable not only to rooms but to entire buildings with complex spaces. Furthermore, the schema can be digitized and a digitally applicable tool can be developed for integration in different planning programs for architects and building service engineers.

1.3. Structure

The research presented in this thesis pursues the following objectives:

- **Chapter 2: Approach**

  The research questions and the procedure to answer these questions are presented. This chapter also describes the criteria according to which interview partners were selected and how the interviews were conducted, transcribed and evaluated. In addition, this chapter describes how the schema could be further developed and made more user-friendly.

- **Chapter 3: Professional collaboration between architects and engineers**

  To obtain general information and get insights about the educational background of architects and building service engineers as well as the interface areas of architectural and mechanical design and the experiences in professional life, extensive interviews with professionals in both architecture and engineering fields were conducted.

- **Chapter 4: Control schema generation method (introduction)**

  A schema for control logic distribution of building systems (heating, cooling, lighting and ventilation) is presented. The method of deriving this schema has gone through a series of evolutionary steps and could both support the building systems design process and enhance the communication between architects and building service engineers.

- **Chapter 5: Test and further development of the schema**

  A test with architecture and engineering students shows the viability of the schema generation method. The students tested the method on different spaces and generated schemas for the distribution of control logic. The results of the students' projects, the comments about the strengths and weaknesses of the method as well as professionals' feedback of the schema are presented in

this chapter. Another objective involves the further development and simplification of the schema to facilitate its comprehensibility and application.

- **Chapter 6: Conclusion**

  The conclusion provides an overview of the evaluation of the professionals' comments and the control schema generation method development process. The research questions are answered, results are summarized and ideas and suggestions for future research are presented.

Chapter 2. Approach

2.1. Research questions

Integrating increasingly complex building technologies for lighting, cooling, heating and ventilation in order to achieve the optimal indoor environmental conditions in modern buildings, poses a challenge for all building specialists. To avoid insufficient coordination processes, a close coordination of architectural design and building systems configuration is essential. This results in the following two research questions:

I. **What is the state of professional collaboration between architects and engineers?**

II. **Can specific and new computationally supported engineering tools and schemes support a more structured and evidence-based approach to the design and configuration of buildings' environmental control systems?**

The first research question determines how the cooperation of the professionals works, if and where there is potential for improvement and if there is a need to change the current practices in communication and collaboration between architects and building service engineers. For this purpose, detailed interviews with students and professionals were conducted.

To answer the second research question, the schema for the distribution of control logic regarding systems control and automation in complex buildings was tested on different spaces in different buildings. The schema has been developed and improved in numerous steps to make it usable for

professionals in the future. Moreover, students and professionals evaluated its' applicability and user friendliness and gave feedback about the schemas' strengths and weaknesses.

2.2. Procedure

As mentioned in the previous chapter, the focus of the dissertation is on the exploration of the actual state of professional collaboration between architects and engineers on the one hand, and on the development of a computationally supported engineering tool and schema on the other hand. In order to gather information about the actual state of collaboration of architects and service engineers, a questionnaire with professionals was developed (questionnaire is included in the appendix).

Qualitative methods were predominantly applied to both the collection of data and the assessment of said data in this paper. Yet, this does not mean that quantifying steps were categorically excluded from the assessment process in the survey at hand. The first few interview questions for the experts are closed and quantitative in nature.

When choosing interview partners, we made sure that the companies where the interviewees are employeed were of different sizes. This criterion was, however, disregarded when it came to bulding service companies, since there is a somewhat limited number of such companies in the states being examined (Carinthia and Styria). The actual goal was 30 architecture offices and 30 building service engineering companies. Since most interviewees gave rather elaborate answers and the individual participants' corresponding responses became somewhat repetitive after only a few interviews, a total number of 19 architects and 10 building service engineers were interviewed in the end. The interim results were continuously published (see chapter 1.2.). All interviews are anonymous and equipped with a number for allocation purposes. The transcribed written version does not contain any of the names of people and companies or other indications that would allow for a clear assignment to people, companies or buildings.

The interview is designed to have a standardized interview containing general data (professional experience, size of the company, field of activity) in the first part of the questionnaire, which allows for easy comparison of

the replies. The second part then is a mix between a standardized and a qualitative interview with open-ended questions. This part gives the interviewees a chance to report on their experiences and develop their own relevances.

In order to ensure clarity, the questionnaire is structure into three parts of topically interconnected questions:

- General data
- Questions regarding education and training
- Questions regarding practical experience

Results from literary research and findings from previous research, personal experiences and talks with experts served as the basis on which the interview questions were designed.

In order to ensure the interviewees could finish the questionnaire, we made sure the interview would not last longer than 20 - 40 minutes. The interview was tested several times and questions were shortened to reach said goal. Furthermore, questions were tested for intelligiblity and improved to that effect.

A total of 37 architects and 34 building service engineers were asked whether they would be willing to give an interview. They were first contacted via e-mail (see appendix) to provide them with an introduction and overview of the topic. About one week later, they were contacted by phone to set a date for the interview.

A total of 19 architects and 10 building service engineers were willing to be interviewed. The others were not interested, did not have time or could not be reached despite several attempts, which makes for a response rate of 51% for architects and 31% for building service engineers.

The interviews were conducted between August 25th, 2014 and February 5th, 2017. All interviews were conducted orally except for one, which was in writing due to the long distance and at the interviewee's request.

The interviews were transcribed between February 24th, 2015 and December 3rd, 2017 in a series of steps, as follows: First, a tape of the complete interview was played. Second, the interview was played back again, question by question with pauses in between, and extensive transcriptions were produced. The responses and interposed questions were recorded in as much detail as possible, with a focus on grasping and recording the meaning of the individual sentences. Words that couldn't be recognized and statements deemed unimportant (i.e. not contributing to the research) as well as too excessive statements were dropped in the transcription. Nonverbal activity received very little treatment in the protocol, since this paper does not focus on non-verbal behaviour. Also, this would require a recording technology capable of capturing and assessing gestures and facial play more clearly. The assessment at hand, however, aims to cover and analyse the statements in their completeness. The following types of activities were still added to the protocol: pauses for thinking, laughing and sighing.

For purposes of comparability and clear presentation, the questions were arranged in tables following the transcription, one table for architects and one for building service engineers: The first line contains the questions, and the columns below contain the professionals' responses. This table display makes the comparison and juxtapposition of the different responses easier. Many interviewees gave very elaborate answers or replied to questions that were only posed later on. These responses were allocated to the corresponding questions in the tables. In the time period from April 18th, 2015 to August 30th, 2018, these tables for presenting findings were continuously produced.

To get further informations about the actual state of professional collaboration between architects and engineers, and in order to explore the subject matter from yet another perspective, another interview with students was conducted. Another custom-made questionnaire was developed for this purpose (see appendix). In contrast to most of the interviewed professionals, the students had very little practical experience

and are very receptive to new ideas, maybe even because of that very reason. It is because of this criterion that their experiences hitherto and points of view provide vital information for the further development of the schema.

This interview contains 19 major questions and was performed as part of a lecture at Vienna University of Technology.

The three parts are arranged by the following topics:

- Questions regarding education
- Questions regarding practical experience
- Questions regarding the schema

Unlike the interviews with the professionals, these interviews were conducted in writing. In order to receive the questionnaires back as complete as possible and ensure comparability, this questionnaire contains, for the most part, standardized questions with predefined possible answers. For questions regarding the schema, additional qualitative questions were posed, so students would have more freedom answering these.

Prior to conducting the interviews with the professionals and the experiments with the students, already existing findings and publications about this schema were analysed (Mahdavi 1997, 2001a, 2004, 2005, Mertz and Mahdavi 2003, Mahdavi and Schuß 2012, Pröglhöf-Piriwe 2008).

In an attempt to further develop the schema to such an extent that it could later be applied by professionals, the existing schema was tested in rooms as a first step, in the following manner: Different rooms were choosen and floor plans compiled. Existing technical devices were mapped on the plan, and the presence of additional fictional technical devices was assumed, and they were also mapped. Their zones of influence were charted in a simplified manner, after which the generation of the schema started. All of these steps were carried out manually on paper. The more complex rooms always resulted in conflicts within the schemes, which led to a further development of the schema.

A test was performed with the above mentioned students in order to find out how user-friendly this schema is and in how far an improvement is necessary. The experiment involved 29 architecture (84%) and engineering (16%) students. In an introductory session the schema generation method was introduced. The students chose different rooms of different sizes from different buildings, consequently, a large spectrum of rooms was covered and a maximum of results was reached. The experiment resulted in 22 completed assignments. In order to explore how intelligible the applicability of the schema is and where issues may occur, the students were allowed to ask questions during the work process, when things were unclear. They were also supposed to present an interim result, about two weeks after having been introduced into the subject matter initially. This result was checked for mistakes in the implementation of the generation process of the schema. Students were then informed of the mistakes, following which they reworked the schema once again and filled in a questionnaire additionally, which contained eight questions about the applicability of the schema for the respective chosen room.

They were asked to specify how much time was approximately necessary for applying the method to the rooms they had selected. They were also supposed to give examples of the main problems they had encountered in using the method and what problems they expected in using the method for larger rooms.

This approach, in addition, made it possible to receive information on obscurities and application issues and analyse these.

Based on the analysed results, the schema could be further developed and designed more user-friendly.

Chapter 3. Interviews with professionals

3.1. Overview

To obtain general insights about the interface areas of architectural and mechanical design, extensive interviews with experienced professionals in the fields of both architecture and engineering were conducted (from different offices and with different professional experiences). In total, nineteen architects and ten building service specialists were interviewed. The questions pertained to the educational background, experiences in the professional life, planning processes, collaboration between architects and building service engineers and the role of building systems.

They were also asked to give specific feedback concerning the scope and potential of the method for the automated generation of the building control schema (chapter 5.3.).

3.2. General information about the professionals

The first interview part deals with general questions about the professionals' background as well as the current work situation. It contains the following questions for architects:

1.1. How long have you been working in the construction industry?

1.2. How many employees are there in your company?

1.3. Are the design and building plans exclusively designed by architects?

These are questions in the first interview part for the building service engineers:

1.1. How long have you been working in the building technology industry?

1.2. How many employees are there in your company?

1.3. Is the building technology exclusively designed by building service engineers?

Results

The professionals have between one and over 20 years experience in their fields. While 80% of the building service engineers have more than 20 years of experience, it is less for most of the architects (see Figure 3). For the interview, the intention was not to select professionals with long professional experience almost exclusively, but most architects and service engineers become self-employed only after a long period of relevant professional experience.

Some companies are one-person businesses and others employ over 15 people. Most architecture offices (11 of 19) have up to five employees and six of ten building technology companies have up to six employees (see Figure 4). As the smaller architectural companies and building technology companies predominate in Austria, the interviews were conducted mainly with professionals from one-person businesses or small companies. Especially in small companies, the architects take on the complete task of drawing and only a few get support from interns or technical draftspeople.

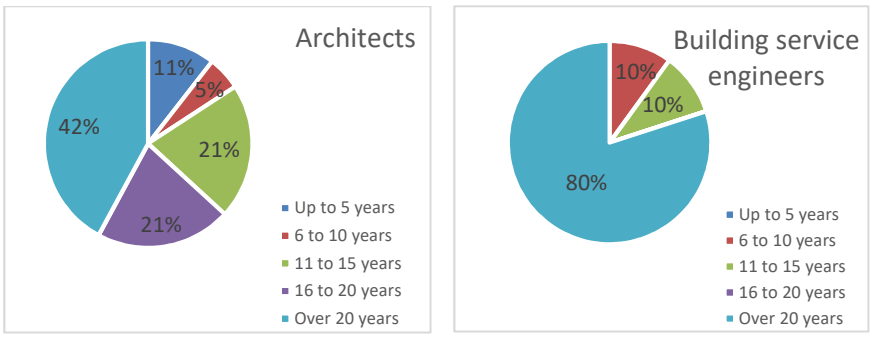

Figure 3: Professionals' experiences.

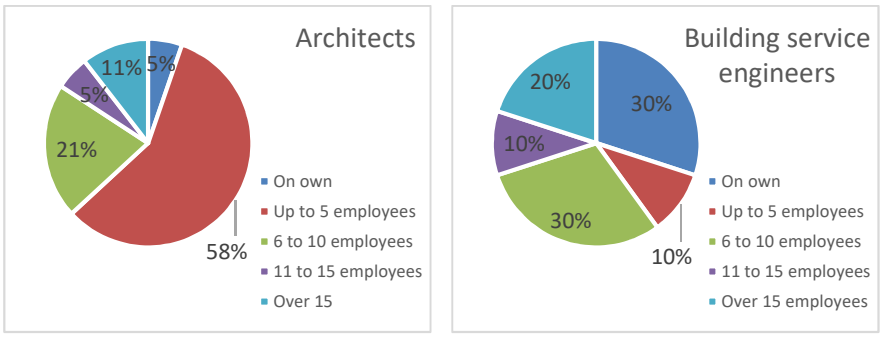

Figure 4: Number of employees.

The majority of the architects (14 from 19) stated that only architects design the building plans, in five companies the students, trainees and technical draftspeople take over this work. In eight companies, the building technology is exclusively designed by building service engineers, and in two cases, it is the task of the installateurs and electrical engineers (see Table 1).

Table 1: Overview of professionals' questionnaire results part 1 (general information about the professionals). [5]

		Architects	Building service engineers
How long have you been working in the construction industry?	up to 5 years	2	
	6 to 10 years	1	
	11 to 15 years	4	
	16 to 20 years	4	
	over 20 years	8	
How long have you been working in the building technology industry?	up to 5 years		0
	6 to 10 years		1
	11 to 15 years		1
	16 to 20 years		0
	over 20 years		8
How many employees are there in your company?	on own	1	3
	up to 5	11	1
	6 to 10	4	3
	11 to 15	1	1
	over 15	2	2
Are the design and building plans exclusively designed by architects?	Yes	14	
	No	5	
Is the building technology exclusively designed by building service engineers?	Yes		8
	No		2

[5] The table is translated from original German by the author.

3.3. Educational background of the professionals

To get some insight into the educational background of the professionals and to find out if and what they had learned about building technology in their education, in the second part of the interviews the architects were asked the following questions:

2.1. What is your highest educational qualification?

- o HTL (which?)
- o University (which?)
- o Other education (which?)

2.2. Did you learn anything about building systems in the course of your education?

2.2.1. If yes, what did you learn and how detailed?

2.2.2. Was this sufficient for professional life?

2.3. Did you attend further education or training concerning building technology?

2.4. Do you think architects should learn about building systems in the course of their education? (yes, no)

2.4.1. If yes, what and how exactly?

2.4.2. If no, why not?

In this part of the interview, the building service engineers answer the same questions as the architects, with the exception of the following question:

2.2. Did you learn anything about the professional responsibilities and working habits of architects in the course of your education?

Results

Nearly all architects (95%) attended a university, but only 30% of the building service engineers did the same (see Figure 5). While several universities in Austria offer an education for architects, the university training as a building service engineer is rare. The full-time programme of building technology is currently only offered at one University of Applied Sciences in Austria: In Pinkafeld (Burgenland) there are Bachelor's and Master's degree programmes for building service engineers and building managers. A further part-time degree course, which also deals with building services, is available at the Salzburg University of Applied Sciences: Bachelor's degree programme "smart buildings" and Master's degree programme "smart buildings in smart cities" (see Figure 6).

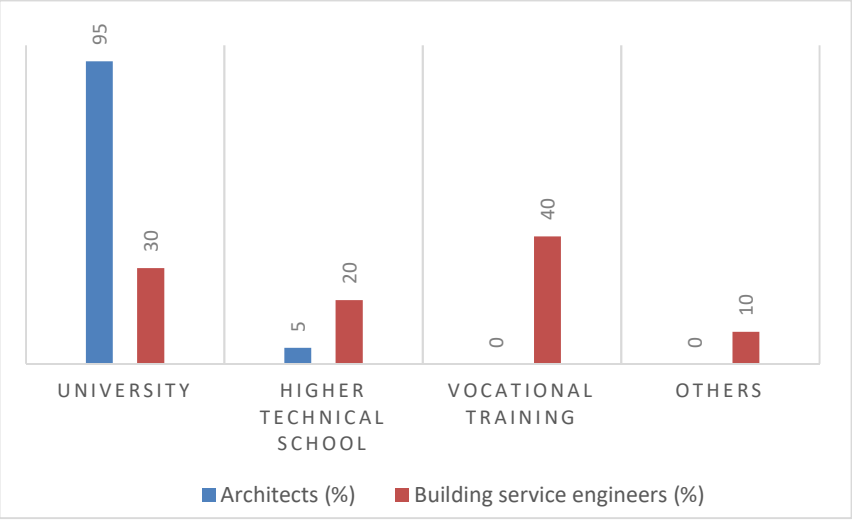

Figure 5: Highest educational qualification (architects: 19 answers; building service engineers: 10 answers).

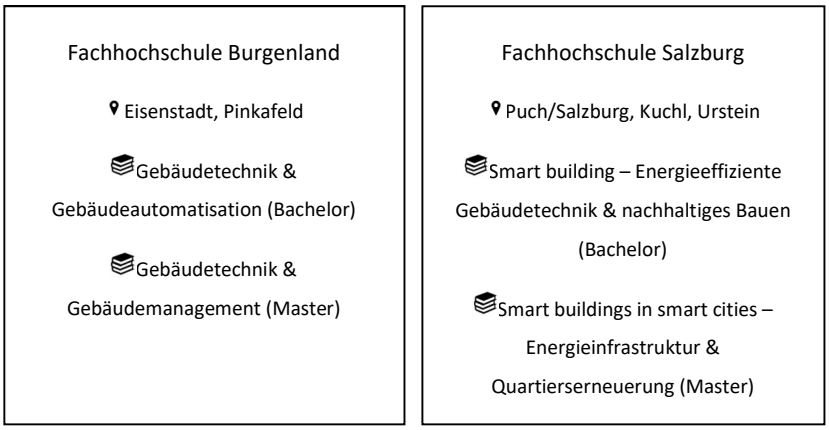

Figure 6: Universities of applied sciences In Austria which offer a building technology program.[6]

Most architects (89%) learned a little about building systems in the course of their education, but the majority stated that what they learned was insufficient for professional life. Only 20% of the building service engineers learned about the professional responsibilities and work habits of architects in the course of their education. Both groups agreed that it is important for the architects' planning and working process to learn about building systems (see Table 2).

The professionals were asked what should be learned about building systems in the course of their education. Architects think that the university graduates should have a basic understanding of building technology. Building service engineers stated that it would be useful if architects learned more about the dimensioning of the installation shafts and technical rooms. Many professionals addressed this problem.

Most of the architects stated that they have not received any further education or training concerning building systems (79%). This depends above all on the areas of responsibility of the architects.

[6] Source: www.studieren.at

Table 2: Overview of professionals' questionnaire results (educational background of the professionals 2.2.-2.4.). [7]

		Architects (%)	Building service engineers (%)
Did you learn anything about building systems in the course of your education? (19 answers)	Yes	89%	
	No	11%	
Did you learn anything about the professional responsibilities and working habits of architects in the course of your education? (10 answers)	Yes		20%
	No		80%
Have you taken any further education or training concerning building systems? (19 answers)	Yes	79%	
	No	21%	
Have you taken any further education or training? (10 answers)	Yes		100%
	No		0%
Do you think architects should learn about building systems in the course of their education? (yes, no) (19 answers; 10 answers)	Yes	100%	100%
	No	0%	0%

The importance of architects having a basic knowledge about building technology, is also shown by the study "Building services in the Austrian construction process" [8] (Monsberger and Fruhwirth 2018). One question of this report deals with the issue of what field training and educational measures regarding building services engineering are necessary in (Monsberger and Fruhwirth 2018, question 14, pp. 54-56). It reaches the

[7] The table is translated from the original German by the author.

[8] Translated from the original German by the author. Original text: "Die Gebäudetechnik im österreichischem Bauprozess".

conclusion that, with a total of 393 answers, the need for training is greatest in the field of object planning (the architect). In second place follows the client or the client representative. Only a negligibly small number of respondents indicate that there is no need for training and education (see Figure 7).

Figure 7: Need for training and education. (Monsberger and Fruhwirth 2018, p.55)

3.4. Experiences in the professional life

To get insights in the working methods and experiences of the professionals, in the third part of the interviews they were asked about their collaboration, communication, decision making, positive and negative experiences in collaboration and some questions about their working progress. Moreover, the specialists were asked to rate their colleagues' knowledge about building systems compared to their own' knowledge of the subject. Another assessment shows what impact the experts' professional experiences have on the rating given by themselves. The evaluation of a further question was expected to shed light on how and why the building systems influence the architectural design process. Moreover, the professionals were asked what would change or improve if the building systems were considered to a larger extend in the design of architects and what they would suggest to make it easier to incorporate the building technology into the design. The last question in this chapter focuses on the professionals' ideas for providing the architect with a better understanding of building technology.

Not all interviewees answered all the questions and some of them gave several answers for some questions.

Questions and results

Question 3.1.: In which phase of a project does the collaboration with building service engineers/architects start? Is the primary design already completed when collaboration between architects and engineers starts?

We asked both groups when the collaboration between architects and building service engineers starts. While nearly 90% of the building service specialists reported that the primary building design is already complete when the collaboration with architects starts, only 40% of the architects stated the same.

The architects' statements varied quite widely. This discrepancy may be attributable in part to differences in project types (Rader and Mahdavi 2016a, 2016b).

Among other things, the study "Building services in the Austrian construction process" comes to the result, that decisions not taken or made late in relation to building technology are considered to be the decisive cause of construction disruption. While the building engineering companies see this as a major problem, the group of builders is not really aware of this. Likewise, the lack of coordination between professionals of technical building equipment planning with the exception of the group of specialist planners technical building equipment is a relevant cause of building failures (Monsberger and Fruhwirth 2018, question 30-19, p.99).

The involvement of the building technology planners in the concept or design phase at too late a point is seen by the builders, specialist planners and facility managers as a major cause of construction disruption. Architects see this factor as less relevant (Monsberger and Fruhwirth 2018, question 30-7, p.102).

Question 3.2.: How does the communication between architects and building system engineers work?

This question was quickly answered by the professionals. The communication between architects and building system engineers takes place by telephone, e-mail and in person. This depends on the project types, the distance between the professionals' offices and on the person.

Question 3.3.: Who makes the following decisions:

- **system decision (heating systems…)**
- **decision regarding the number and placement of -windows, -blinds, -lights, -heating, -ventilation, -thermostats, sensors, -ventilation and cooling systems**

We also wanted to know which decisions come from the architects and which from the building system engineers. Professionals agreed that the number and arrangement of windows is a matter of architects. System decisions are usually made in consultation with the client. While most of the building system engineers thought that blinds are the task of architects, only few of them stated the same. They see it as the task of the building system engineers. Placement and decisions of heating, ventilation, thermostats, sensors, ventilation and cooling systems is seen in most cases as part of the building technology in consultation with the builder, architect and other professionals (see Figure 7 and Figure 8).

The professionals' disagreements can therefore come from the fact that their projects are very different (family house, apartment house, hospital etc.).

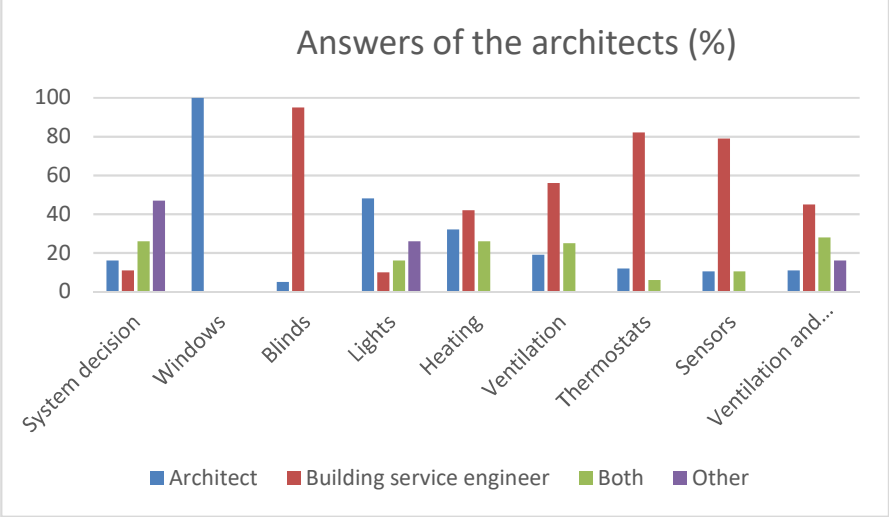

Figure 8: Interview answers of the architects "who makes the following decisions?"

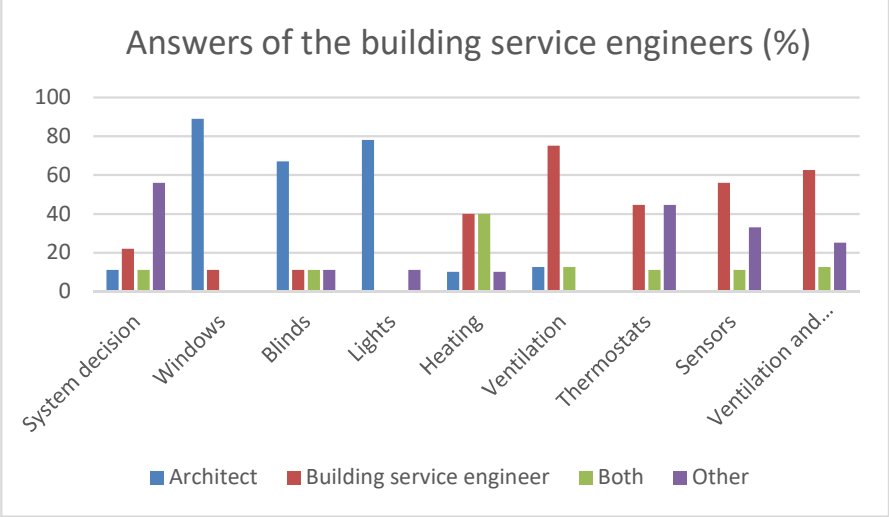

Figure 9: Interview answers of the building service engineers "who makes the following decisions?"

Table 3: Overview of professionals' questionnaire results (decisions of building systems).[9]

		Answers of the architects (%)			
Who makes the following decisions?		Architect	Building service engineer	Both	Other
System decision	Heating systems…	16	11	26	47
Decision regarding the number and placement of…	Windows	100	0	0	0
	Blinds	5	95	0	0
	Lights	48	10	16	26
	Heating	32	42	26	0
	Ventilation	19	56	25	0
	Thermostats	12	82	6	0
	Sensors	10.5	79	10.5	0
	Ventilation and cooling systems	11	45	28	16

[9] The table is translated from the original German by the author.

Table 4: Overview of professionals' questionnaire results (number and placements of building devices).[10]

		Answers of the building service engineers (%)			
Who makes the following decisions?		Architect	Building service engineer	Both	Other[11]
System decision	Heating systems…	11	22	11	56
Decision regarding the number and placement of…	Windows	89	11	0	0
	Blinds	67	11	11	11
	Lights	78	0	0	11
	Heating	10	40	40	10
	Ventilation	12.5	75	12.5	0
	Thermostats	0	44.5	11	44.5
	Sensors	0	56	11	33
	Ventilation and cooling systems	0	62.5	12.5	25

Question 3.4.: Please share your positive and negative experiences with building service engineers/architects!

To find out if and how the cooperation between architects and building service engineers works, we asked the architects the following question: "Please share your positive and negative experiences with building service engineers!" The building service engineers were asked this question: "Please share your positive and negative experiences with architects!"

This question was answered most extensively by architects and building service engineers. The majority started with the negative aspects of

[10] The table is translated from the original German by the author.

[11] "Other" means: the architect and the builder, the building service engineer and the builder, all together or only the builder.

cooperation. There is much criticism, but some also emphasize the good cooperation.

Both professional groups mentioned that the collaboration differs from case to case because it depends on the respective person and the office. They agree that a basic understanding of building systems and operation of environmental control systems facilitates the working process of the architects and the collaboration between different building professionals.

Architects' experiences:

The experiences with service engineers are partially very different and some already had similar experiences in the cooperation. Architects stated that collaboration between the professionals generally works well if the engineers participate from the beginning of the planning phase. Some architects prefer working together with the same building service engineers for each project. Architects also mentioned some difficulties in the collaboration with service engineers and criticized that engineers often concentrate only on their own concerns and neglect to consider the whole building. They also complained that some engineers focus purely on specific brands of products, which may lead to suboptimal selections. One professional stated that some building service engineers plan more building technology than necessary, to get a higher fee. This extensive concept has to be reduced, otherwise it takes up more energy than it saves. On the other hand, there are professionals, who plan the building technology too simply. A further problem in the collaboration with service engineers results from the relatively small number of sufficiently experienced building service engineers in Austria and that they often are overworked, expensive and have too little time for each project. Some make decisions on their own, without discussing with the architect. Moreover, some architects would like building service engineers to have a better understanding of the architecture (see Table 5).

Table 5: Overview of professionals' questionnaire results (experiences with building system engineers).[12]

Architect	Positive experiences with building service engineers	Negative experiences with building service engineers
1	In general, the cooperation works well, especially if the building service engineers are involved in time.	Building service engineers often do not pay attention to the optics. It often happens that the building service engineers do not care whether the execution works and do not consider other professionals. As a result, for example, floor constructions are constructed incorrectly. There are insufficient conversations with the other professionals. Some building service engineers limit themselves only to the planning. Some do not look beyond their own trade.
2	The cooperation works well. Some discussions to find a solution.	The problem is always the interface with the plan modifications and the entries regarding openings for the shafts. If you change something in the architecture later on, then this must be included in the building services plans. This often does not happen. As a result, the building service engineers work according to the old plan. In addition, the building engineers criticize that the architects leave too little space for the building technology. More understanding of the building engineers regarding the architecture would be desirable.
3	It is important that the building service engineers you work with are always up to date.	Some building service engineers do not think outside the box. Some building service engineer only wants to sell a specific product. The product selection is depending on the industry.

[12] The table is translated from original German by the author.

		Some building service engineers plan more building technology than is necessary, because the built-in volume defines their fee. These first giant concepts of the building service engineers must first be optimized step by step and reduced, so that only the necessary is installed. Otherwise, at the end, the building technology takes up more energy than it saves.
4	Some building service engineers are more experienced, so that that they are up to date regarding planning choices.	The planning is often not well enough thought out. Maybe because the building service engineers are under pressure.
5	Depends on the employees and their know-how.	
	Electrical planners are less complicated than HKLS planners.	Rigid opinions through experience. Standard tenders are often only slightly changed. Lack of flexibility and they do not want to adapt - otherwise they would have to work more.
6	Different from office to office. Depending on who you work with.	
	The building service engineer takes enough time and if you work with an office more often and everything is well attuned.	The building service engineer is overworked, takes only little time and is difficult to reach.
7	Basically it works anyway.	Often everyone only sees his own area.
8	The building service engineer is knowledgeable, has good ideas and is creative.	The building service engineer rarely comes to the construction site. A building service engineer wants to sell a specific brand / product because he receives a commission for it.
9	Different from office to office.	
	This is not a large issue with our standard residential buildings or standard office buildings, everything works well.	It may happen that large sub-planners or employees have a workload at this time and therefore too little time for each project.

10	Evades the question. No inquiries possible as the interview was in writing.	
11	Building technology and buildings become one.	Except for the University of Applied Sciences Pinkafeld, there is no university education. In Austria one is too dependent on components.
12	Cannot say, because there is too little experience.	
13	It always depends on the building service engineers.	
	The building service engineer is flexible and the cost estimate is reliable.	The building technology is little project related and there are only a few variants.
14	A good team with which you can often work together, where everyone is well attuned and in which everyone knows what he has to do.	Good building service engineers are expensive. Therefore, one has to think for which projects you hire an expensive building service engineer. If building service engineers are new in the business, it might be that they are not so anxious.
15	He cannot think of anything.	(Really digressed on this question) The building service engineers do not fulfill the claim the architect places on them. There are too less building service engineers who do the planning well. There are too less well educated building service engineers. Building service engineers who have not studied often do not want to collaborate with architects. This makes the architect to an outsider.
16	They are general planners and choose only those building service engineers whom they know and with whom they get on well.	
	Building service engineers strive to get along well with the architects, as they are the clients.	Building service engineers often want too large technical rooms.

17	Depends on the offices and employees.	
		In Carinthia, the building service engineers are not particularly strongly positioned. Innovative projects. The architect has to intervene a lot in the building technology. Cable routing inside and outside the building. Placement of solar panels.
18		Dates: very late delivery, building service engineers are overwhelmed and do not deliver their services on time, thus building service engineers often make and plan out decisions on their own and do not communicate with the architect. This can result in an inappropriate position of the building engineering. The time for planning the building technology is often insufficient.
19	Very positive experiences with the companies they work with.	"No name" or difficult to use technical devices.

Building service engineers' experiences:

Building service engineers stated that collaboration works well if the architects have good knowledge of the building technology and if they make clear and well thought out plans. They also have good experiences with architects who are flexible, ready to compromise and involve the other specialists at an early planning phase. Service engineers thought that some architects occupy themselves intensively with building systems and others do not.

The building service engineers also criticized some points in collaboration. A problem is the frequently late collaboration. In many cases the required space for technical rooms, building systems terminals and distribution networks (for pipes etc.) is calculated too small and that can lead to a loss

in quality. Moreover, the architects do not pay attention to the building technology, are not well versed, inflexible and do not want to compromise (see Table 6).

Table 6: Overview of professionals' questionnaire results (experiences with architects).[13]

Building service engineer	Positive experiences with architects	Negative experiences with architects
1	The architect is familiar with the building technology.	The architect is not well versed and the cheapest planning office is commissioned.
2	There are clear plans from the architect.	The architect is often brought in too late.
3	Most of the time everything is planned in detail.	It's hard to reconcile a building service engineer with an architect because everyone has different ideas. If you have to explain the architect, why so much space for engineering shafts is necessary.
4	Great understanding of building technology. They realize that a certain amount of space is necessary and if they also complain this to the builder.	Too little space for the building technology.
5	The architect does not concern him. Only the sanitary planner or local construction supervision.	
6	The knowledge of the architects he has dealt with is usually very good. Everything has always worked fine.	
7	Flexible architects. There are also a lot of good architects.	The technical room usually is too small. Inflexible architects.

[13] The table is translated from the original German by the author.

		Architects often believe they are better than the rest and craftsmen are worse than they are. Collaboration with architects are increasingly rare because people soon will not be able to afford that anymore.
8	Willingness to work together to find solutions.	No attention to the building technology.
9		Too much time in the planning phase and too less time in the execution phase. Shafts are dimensioned too small. The building starts before planning is complete.
10	Good experience if the building service engineer get involved early in the planning phase and if the architect makes compromises.	The architect does not want to compromise. Reduction of building technology to reduce costs.

Question 3.5.: How much do you as an architect deal with the design of building technology?

About a third of the architects stated that they do not deal with the building technology in any way or only a little, if necessary. One argued that it is important to integrate the building technology in the initial planning phases. He considers space for pipes and deals with building physics. Some discuss the right system together with the building service engineer and some pay consideration to the size of pipes and technical rooms in the draft, where necessary. One architect reads technical journals to keep up to date.

The fact that about 32% of the interviewed architects do not deal with building technology or only a little, could be due the lack of knowledge, experience and that they cannot afford the necessary time to learn and

deal with building technology. Others are aware that cross-trade planning is important. One architect would even like to have a building service engineer in his office for close cooperation.

Question 3.6.: What is the basis for decisions regarding the placement of technical devices? (experience, simulation/others)

Computational tools can provide support in detailed calculations regarding building systems. However, decisions pertaining to the placement of technical systems' terminals are made preferably based on the professionals' experience and not computational tools. While nearly two-third of the building service engineers make decisions regarding the placements of technical devices based on their experiences, 81% of the architects do the same (see Figure 9 and Table 7). Professionals argue that most computational tools and applications are expensive, time consuming, and complicated. This specifically represents a challenge for smaller companies. Another reason could be that building engineering companies in many cases merely implement tasks but are not themselves planning building service engineers. Therefore, some companies lack the necessary background knowledge to operate specific computer programs.

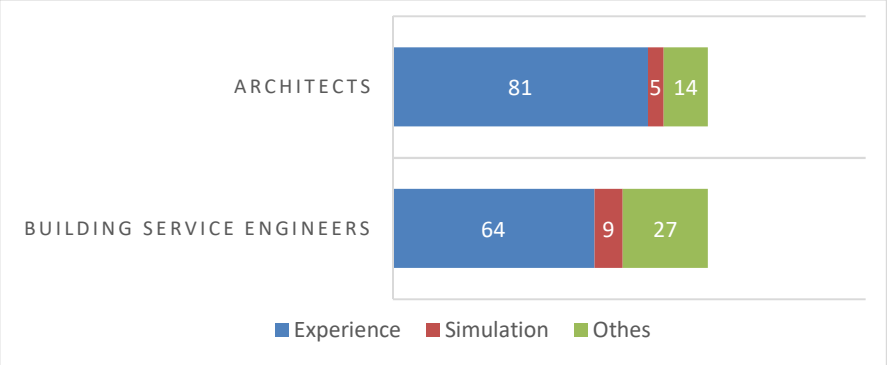

Figure 10: Decisions regarding the placements of technical devices (in %).

Table 7: Professionals questionnaire results (decisions regarding the placement of technical devices).[14]

		Architects (%)	Building service engineers (%)
What is the basis for decisions regarding the placement of technical devices?	Experience	81	64
	simulation	5	9
	others	14	27

Question 3.7.: With which programs do you work? Can the areas impacted by the technical devices be displayed in these programs?

Most architecture companies use architecture programs like Autocad, Allplan or Archicad and do not use tools to integrate building technology. Computational programs are expensive and the training time-consuming and some companies do not see the need to use tools that make it possible to represent the areas impacted by technical devices.

Building system engineers prefer Autocad, Plancal and software directly from the manufacturer. Plans drawn in 2D on the computer as well as by hand still exist. One interviewee argued that drawing by hand is less complicated and faster. Some gave the impression that drawing plans in 3D was completely alien to them and one architect did not know which drawing programs his office used and had to ask a colleague.

Question 3.8.: How do you generally rate architects' knowledge about building systems?

We asked architects to generally evaluate the professional's knowledge of building systems and their planning of these systems. 33.5% suggest that it considerably varies (due to experience and personal interest), whereas 28%

[14] The table is translated from original German by the author.

characterize it as mediocre and 33.5% as good. Colleagues' knowledge is rarely described as poor (5.5%) but it is not considered to be very good (0%) either. Half the building service engineers see significant variation in architects' knowledge of building systems, 8.3% consider it to be very good and 25% good (see Figure 11). Architects' personal interest in building technology and project experience could be a major reason why one third of the architects and half of the building engineers answered that question with "varied".

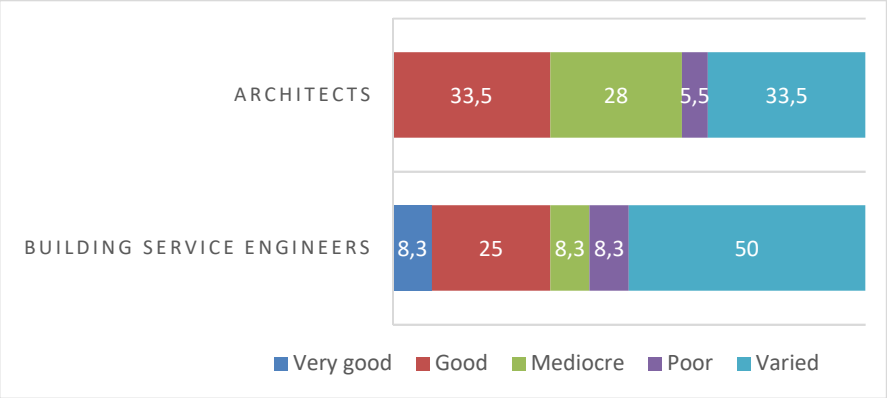

Figure 11: Architects' and building service engineers' assessment of architects' knowledge about building systems (in %).

Question 3.9.: What would change or improve if architects were (even) better acquainted with building technology?

Most architects agree that it would be an advantage if they had better knowledge of building technology. However, some argue that this is not the architects' task and it would influence the planning process negatively. A majority of building service engineers thinks that this would influence the planning and execution phase positively: reducing costs, construction time and problems, more space for technical rooms and shafts and the maintenance would become more sustainable.

Question 3.10.: How do you rate your own knowledge of building systems? (only architects)

While evaluating their own building systems knowledge, the architects appear to be somewhat more forgiving: half of the interviewed architects classify their knowledge as good and 36% as mediocre (see Figure 11).

Compared to the assessment of their colleagues in building technology, their assessment of themselves is very positive. Although no one referred to his building technology knowledge as "very good", most called it as good or mediocre.

A similar question occurs the study "Building Technology in the Austrian Building Process" (Monsberger and Fruhwirth 2018). This is: "How do you rate your expert knowledge in building technology in general?"[15] These answers are somewhat more positive. Out of 34 interviewed architects, 64.7% stated that they had good expert knowledge, 26.5% called it mediocre, 6% very good and 3% claimed they had only little expertise in building services (Monsberger and Fruhwirth 2018, question 13, pp. 51-53). Here, however, it is noticeable that the answer "good" makes for almost two thirds of all answers. This difference may be based on the fact that these architects are mostly involved in complex large-scale projects (75% over 10 million construction costs) and therefore have more experience and knowledge in the building services industry (see Figure 12).

[15] Translated from original German by the author.

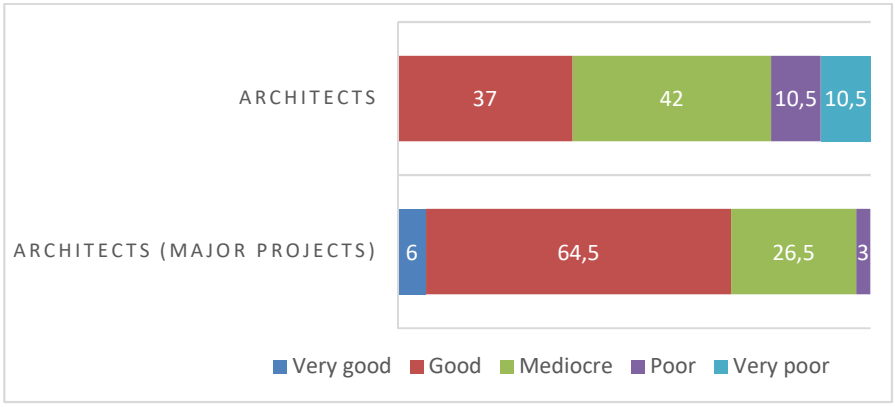

Figure 12: Architects about their own knowledge in building systems (in %).

It is noticeable that the majority of architects with longer professional experience classify their own knowledge as better than architects with less professional experience. 37% of architects with the longest professional background (over 20 years) classify themselves as good or mediocre (see Table 8). The architects with the shortest work experience (under five years) tend to rate themselves as poor and very poor. This may be due to the lack of practical experience in building technology on the one hand, and the fact that they do not feel they learned enough about this area during their training as architects on the other hand. It is noticeable that some architects with many years of professional experience also rate themselves as poor and very poor (see Table 8).

Table 8: Architects about their own knowledge in building systems and the number of years in their professional careers (results rounded).

	Up to 5 years	6-10 years	11-15 years	16-20 years	Over 20 years
Very good	0	0	0	0	0
Good	0	0	5.3%	10.6%	21%
Mediocre	0	5.3%	16%	5.3%	16%
Poor	5.3%	0	0	0	5.3%
Very poor	5.3%	0	0	5.3%	0

Question 3.11.: Does building systems influence the architectural design process? Why?

More than half of the interviewed building service engineers and architects are convinced that building systems influence the architectural design process (see Figure 13): "It is about the demand for space, availability of space and a lot more." (building engineer number ten) "it must be partly because, I speak specifically to the heating system, how large the room is, there the architect must, of course, plan according to the space requirements of the house technician provides him with, what kind of system there is [...]"[16] (building service engineer number five).

Some architects argue that strict technical specifications and requirements for building systems would limit their degrees of freedom in the design process. However, 17% of the building service engineers gave two answers to this question: they answered with "no" and with "yes". These two contrary statements can may reflect that it depends on the project type and the type of the technical systems. "Yes and no. Not on a small scale or in the private sector. […] It depends on the project type […]"[17] (building service engineer number six).

Professionals stated that, above all, technical rooms and technical shafts must be taken into account in the design.

[16] Translated from original German by the author
[17] Translated from original German by the author

Professionals' statements in details

In part two of the question "does the building systems influence the architectural design process?"[18] the interviewees were asked to comment their answers.

Building service engineer two thinks that it makes sense to consider possible additions in the future in the planning phase (photovoltaic system on the roof, etc.), and that it will make it possible to carry out changes and additions without too much effort at a later date. "If something is installed after that, the effort is very large and the outcome does not look so nice, visually"[19] (building service engineer number two). He also believes that the architect should bring the building service engineers already to a preliminary meeting before he goes into the planning. Everything can be planned correctly, and the implementation is much easier for everyone. In addition, the building service engineer should be appreciated more highly, and a site coordinator is very useful. The reason is that, when different companies work, who do not know each other, such a coordinator, who coordinates the process, is an advantage. These additional costs will be revised by a functioning object and the elimination of subsequent work after the fact.

For building service engineer number one it is clear, that the building technology should already be included at the beginning: "Because all areas are interconnected [...]"[20] (building service engineer number one).

Architect number five believes that building technology plays an increasingly important role in the design.

Architect number ten explains that room sizes depend on building technology (suspended ceilings, floor structures, building facade, which

[18] Translated from original German by the author. Building service engineer number one means the different areas in the construction industry.
[19] Translated from original German by the author.
[20] Translated from original German by the author.

requires a larger building volume and influences the external building services - for example on the roof).

Other architects believe that building technology influences the design at least a bit. "I do give a little thought to how I can accommodate something and how it can work, when I design"[21] (architect number two 2014). "Well, if the client already has an idea of what he wants, you have to take this into account, of course. Otherwise, not so much, because every house can be customized in that regard [...]"[22] (architect number four 2014). Architect number nine is the same opinion that it depends on the building, whether, for example, stronger ventilation systems, as in the catering industry, are needed. He thinks, however, that building technology does not play a role in residential buildings and office buildings.

Architect number twelve stated that the consideration of building services is somewhat more limited in terms of cost-effective construction.

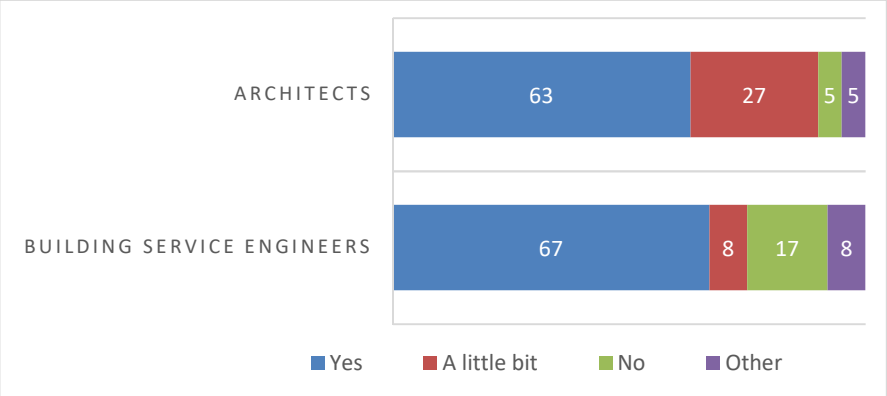

Figure 13: Architects and building service engineers about the influence of building systems in the design process (in %).

[21] Translated from original German by the author.
[22] Translated from original German by the author.

Question 3.12.: What would change or improve if the building systems were considered more in the design of architects? (Due to time constraints, not all the interviewees were asked this question.)

All but three architects and building service engineers agree that it makes sense to integrate the building technology in early planning phases. It would have a positive impact on the cost, time and dimensions of the technical rooms and shafts. Moreover, the ease of use can be increased, and user problems can be avoided.

Although most of the professionals are of this opinion, the building technology is still considered very little in the planning phase in reality.

Question 3.13.: Do you have ideas or suggestions on how to make it easier for the architects to incorporate the building technology into the design? -What methods would you suggest? (Due to time constraints, not all the interviewees were asked this question.)

Many architects and building service engineers emphasize the importance of an integral planning process and early cooperation. In addition, the builder must be convinced that the building service engineer is needed. Some stated that it would also be beneficial if the architects had better knowledge of building technology and they should learn more about building technology already during their training as an architect. Others suggest a tool for architects to integrate the building technology in the design.

Question 3.14.: Do you have any idea how to give an architect an understanding of the building technology? (Due to time constraints, not all the interviewees were asked this question.)

To increase architects' understanding of building technology, a better education, close cooperation with service engineers, practical experience and tools can be useful. One argued that architects should be informed that

there will be additional costs and potential space issues if the building service engineers are involved too late in the project.

3.5. Summary and comments

The professionals participating in the interview have between one and 20 years experience in their field. While almost all the architects attended a university, only one third of the building service engineers did so. The reasons being, on the one hand, a lack of educational options, and, on the other hand, the "missing appeal" of the studies and the profession, according to one of the interviewed building service engineers. As stated by him, the degree course is very technical and difficult, and building service engineers involved in planning face both high computer programme costs (drafting or calculation programmes etc.) and insufficient of reguary of contracts. While professionally planned building technology is vital to a functioning project, a planning building service specialist is often not hired for financial reasons.

Although most architects were educated about building systems to some degree in the course of their studies, most of them state that this was insufficient for professional life. Building service engineers stated that architects should learn more about the dimensioning of the installation shafts. According to interviewed experts, this topic of sizing is often neglected in practice, which is reflected in high subsequent costs.

Numerous real-life experiences of the professionals prove that architects should be better acquainted with the planning of the building technology or use appropriate tools and work more closely with building service engineers.

The professionals' answers regarding their experiences in professional life, planning processes, collaboration between architects and building service engineers and the role of building systems show some contradictions in their statements: Even though most professionals agree that it makes sense to have a basic understanding of building technology and to integrate it in early planning phases to avoid user problems, reduce costs and time in planning and execution phases and to increase the ease of use, about one

third of the interviewed architects stated that they do not deal with the building technology at all. Moreover, most professional in both groups make decisions regarding the placement of technical devices based on their experiences and do not use computational tools for simulating. Some argue that considering the building systems would limit their degrees of freedom in the design process. Another reason is the high cost for computer programmes and specialists. Although the majority of the architects do not deal with the building technology, most of them rate the colleagues' and their own knowledge as good or mediocre.

Similar to the statements of the professionals in our interviews, the evaluation of the study "The Building Technology in the Austrian Building Process"(Monsberger and Fruhwirth 2018) comes to the conclusion that professionals consider decisions made at a late stage in relation to building technology as a decisive cause of construction disruption. Moreover, most of the professionals see a need for change in current practices or project processes in the construction industry for building technology. More than 60% see a high demand in this field (Monsberger and Fruhwirth 2018, question 40, p.110). The evaluation of the next question of this study, in which areas the need for changes in building services engineering and execution appears most important, is as follows: The most frequently cited category was "Education and Skills". What was mentioned frequently was a lack of well-trained professionals in the building services industry for planning and execution (Monsberger and Fruhwirth 2018, question 41, pp.114-116). These answers reflect the professionals' answers to question 3.4. in our interviews with professionals. The knowledge of building technology in other fields (for example, architects, builders, project management ...) or the understanding of building technology has also been rated as being in need of change. The category "coordination" was named second. This refers to cross-trade coordination, such as the overall coordination of planning. Another category mentioned frequently was the "timely integration of technical building equipment in the planning process": The early involvement of the building service engineers in the

planning phase and the early setting of the requirements of the building technology were mentioned as important factors (Monsberger and Fruhwirth 2018, question 41, pp.114-116).

When it came to the question of positive and negative experiences, most replies started with the negative aspects of cooperation. Both architects and building service engineers could empathize to some degree but were also full of criticism for the other group's work. They often mentioned how there was a lack of understanding of their work by the other group. Therefore, a solution is urgently needed to increase cooperation and mutual understanding.

Chapter 4. Control schema generation method (introduction)

4.1. Overview

This chapter deals with the background as well as the development of the schema generation method for the distribution of the control logic regarding systems control and automation in buildings. Moreover, the control terminology is introduced und the most important terms are defined as well as the basic control loop explained. For better understanding, the control zones are illustrated based on an office space with multiple devices and multiple overlapping zones. Finally, the six rules which were developed and refined as a guideline for generating the schema (Mahdavi 2001a, Mahdavi 2012, Mahdavi and Schuß 2012, Mertz and Mahdavi 2003, Rader and Mahdavi 2014, 2016a, 2016b), are presented and then applied to a sample room.

4.2. Background

Decisions regarding the environmental control systems' type and devices, the number and extent of control zones, as well as the type, number and positions of sensors are not sufficiently explicated and are often made on an ad hoc basis. The currently prevailing practices to design buildings' environmental control systems and the associated control processes may be argued to display a number of shortcomings.

To add clarity and transparency to the building systems design process and as a communication and collaboration platform for architects and engineers, a control schema generation method was developed. The evolutionary steps to derive this schema are documented in previous publications (Mahdavi 1997, 2001a, 2004, 2005, Mertz and Mahdavi 2003, Mahdavi and Schuß 2012, Rader and Mahdavi 2014, 2016a, 2016b, Rader and Mahdavi and Pont 2015, Mahdavi and Schuß and Rader 2015, Mahdavi and Rader 2014, 2016).

4.3. Controls terminology

To facilitate the present treatment, a few terms with definitions and instances are listed in Table 9.

Table 9: Building control terminology (Mahdavi 2001a, 2004, Mahdavi and Schuß 2012)

Term	Definition	Instance
Controller	Agent that sets control actions	People, software (algorithm)
Control action	Induced change in the state of a control device's actuator	Opening a window, switching lights on/off
Actuator	Component of a device that, acting upon a control command, brings about device state changes	Valve, dimmer, people
Control device	A technical element or system whose purpose is to deliver to (or remove from) a control zone some quantity of mass and/or energy	Window, luminaire, HVAC
Control device terminal	The technical component of a control device that acts as its interface to the control zone	Diffuser
Control objective	To maintain a certain state in a control zone by keeping the respective control parameter in a certain range	Maintaining air temperature (or illuminance levels) in a control zone (a space, or a task plane) within a certain range
Control parameter	Indicator of the control zone's relevant state	Air temperature, relative humidity, carbon dioxide concentration, illuminance
Actuator state	Position of a control device's actuator	Open/close, dimming level, valve position
Control zone	Target domain of control action	Workstation, room, floor, building
Control state space	The logical space of all possible positions of all relevant actuators	All possible positions of windows, blinds, luminaires, etc.

Sensor	Reports the actual valve of a control parameter in a control zone	Thermometer, photometer

Figure 14 illustrates a basic control loop with the elements of Table 9: The task of the controller is to set control actions. It is the seat of the control algorithm and can be a person or a software. The controller receives information from the sensor and decides on the control action. The request is sent to the device actuator. This component of a device changes the device state and can be a person, a valve or a dimmer. Via the device terminal, the device delivers to (or removes from) a control zone some mass and/or energy. The sensor of the control zone reports the value of a zones' control parameter and sends the information to the controller.

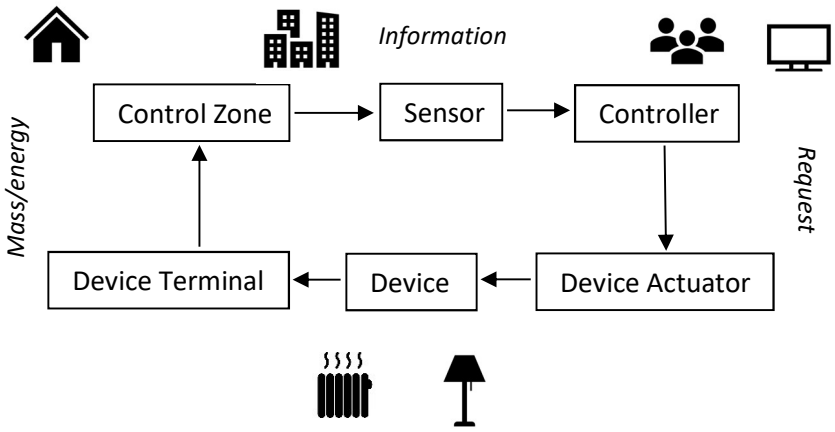

Figure 14: A control loop involving a controller, device actuator, device, device terminal, control zone and sensor.

Control zones simplify the representation of energies' influence (impact areas). They can be seen as physical targets of control actions. The boundaries of such zones are not necessarily of an architectural nature. A control zone emerges from the energy and/or mass which a device delivers and so it can be assigned to a device. Devices may have different impact zones and these zones can also be overlapping. Although impact areas are typically three-dimensional volumes, except, for example, the two-

dimensional one of illuminance control on a horizontal task surface, they can be schematically depicted in a plan. Figure 15 illustrates a simple office space with multiple devices and multiple overlapping zones. The devices may have overlapping control zones (Rader and Mahdavi 2016a, 2016b).

The office room in Figure 15-18 includes seven devices: windows W1 and W2, radiators R1 and R2, luminaires L1 and L2, external shade B. A device can be a simple stand-alone technical component like a window or a luminaire with just one actuator and only a simple set of distinct states. But in most cases, it is a complex technical system, such as a ventilation system with numerous components at multiple levels. The next figure depicts the same office space with seven devices and the associated control zones. The next step entails the positioning of the sensors (Figure 17 and 18). In this case five sensors are positioned: illuminance sensors E1 and E2, indoor temperature, relative humidity and carbon dioxide sensors θ, RH and C.

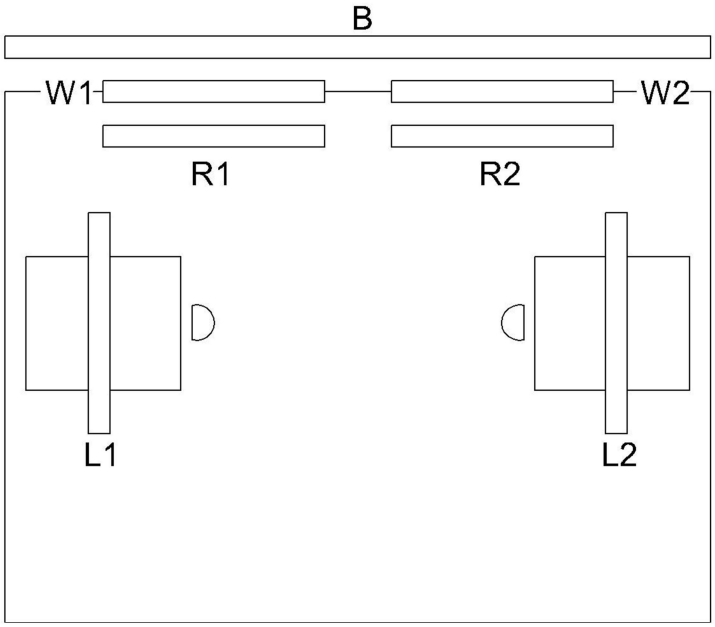

Figure 15: Office room with seven devices.[23]

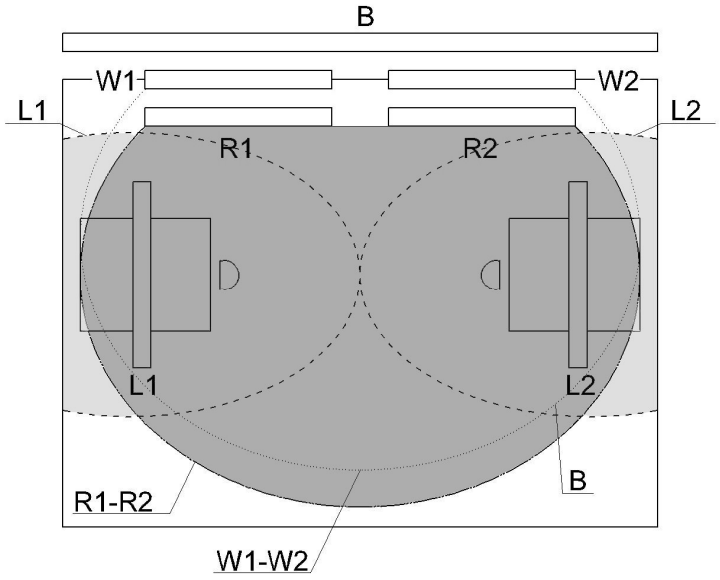

Figure 16: Office room with seven devices and the associated control zones.

[23] Source: Mahdavi 2012

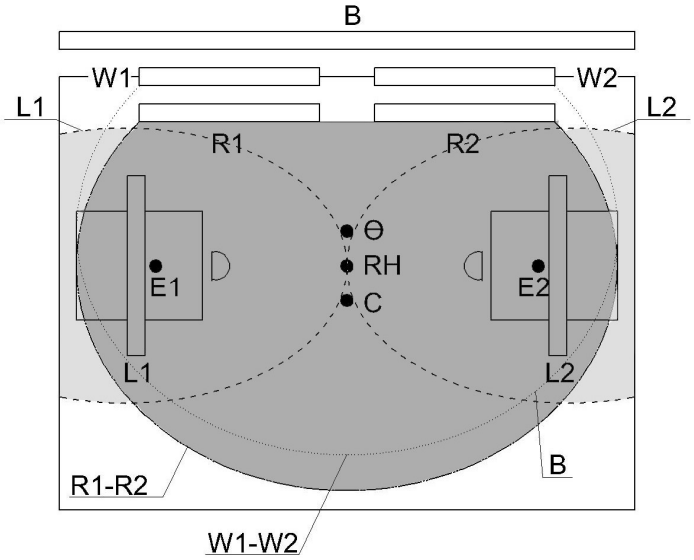

Figure 17: Office room with devices, zones and sensors.

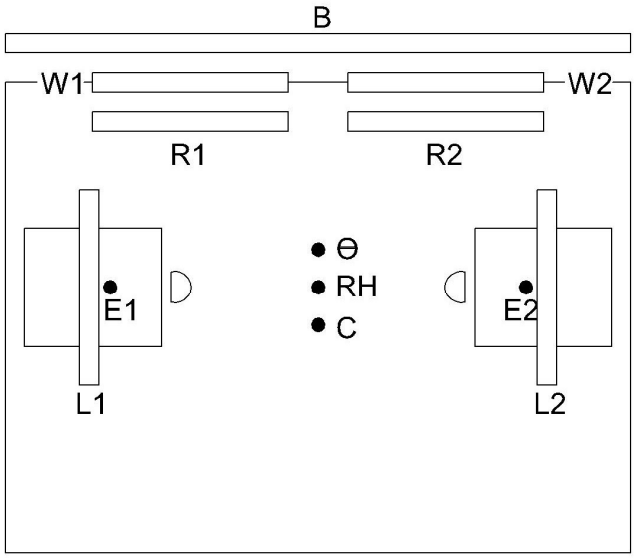

Figure 18: Office room with devices and sensors.[24]

[24] Source: Mahdavi 2012

4.4. The schema

The buildings systems control schema can be generated based on a limited set of design input data – mainly the associative links between projected device terminals and their intended spatial impact zones. The schema was tested by students and professionals and was improved and further developed. The method to derive this schema has the potential to address certain problems associated with environmental systems control. The problems with environmental systems can be the extensive initial periods of time necessary for system tuning and debugging, subpar energy performance, intensive maintenance requirements and user dissatisfaction (Mahdavi and Schuß 2012).

The schema for the distribution of the control logic regarding systems control and automation in buildings provides a structured approach to support decisions in built spaces regarding: environmental control systems' type and devices; number and extent of control zones; type, number and position of sensors. The schema can be applied to a part of a building or an entire building. Before generating the schema, two parameters must be established (Figure 18):

1) the number and positions of devices (e.g. windows, luminaires, blinds, radiators);

2) the number and positions of sensors, which represent the spatial impact zones of the devices.

If more than one device of the same type affects the same sensor, the impact areas of these devices will be represented as a single zone. As Figure 16 illustrates, the zones of the two radiators – and the two windows – are merged.

The hierarchical control schema contains different layers (Figure 19). The first layer involves zones and sensors. The second layer involves devices and actuators. The third to fifth layer depicts the controllers. The schema varies

depending on the extent of the project. In not so complex projects, a meta-controller is not necessary.

The nodes are decreasing upwards, so the schema often resembles a triangle.

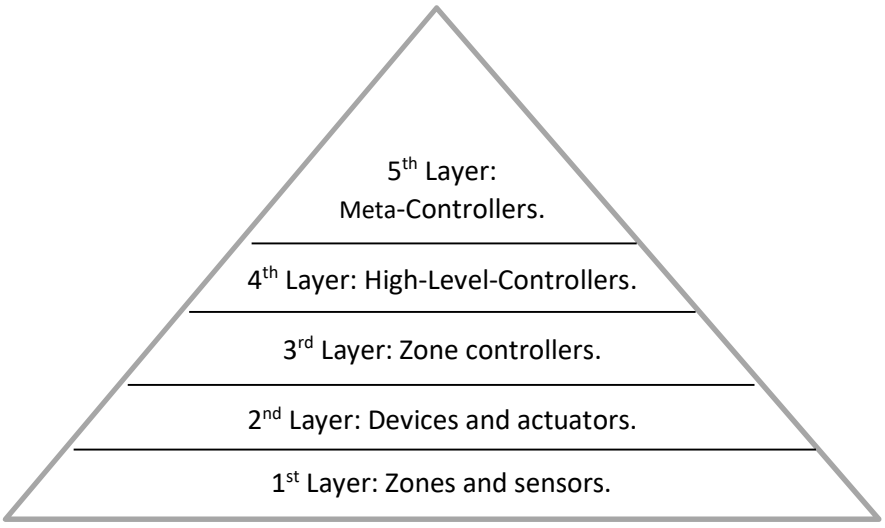

Figure 19: structure of a hierarchical control schema.

To generate the schema, six rules were developed and refined (Mertz and Mahdavi 2003, Mahdavi and Schuß 2012, Rader and Mahdavi 2014, 2016a, 2016b, Mahdavi and Schuß and Rader 2015, Mahdavi and Rader 2014, 2016). They are deployed as follows:

Step 1: Arrange distinct control zones as the base layer of the schema. The state of these zones is captured via respective zone sensors.

Step 2: Arrange device controllers (DCs) in the next layer. Every individually controllable device is assumed to have a DC.

Step 3: Connect device controllers (DCs) to the zones, whose states are appreciably influenced by the operation of DCs.

Step 4: Generate the zone controllers' layer as follows: If more than one DC influences the same zone, a respective zone controller is required to

coordinate their operation. This layer accounts thus for the need for zone-specific coordination across multiple devices.

Step 5: Generate the high-level controllers (HC) layer as needed: If a DC receives requests from more than one zone controller, a high-level controller (HC) is generated. This layer accounts thus for the need for device-specific coordination across multiple zones (high-level controllers - control helps unify an identical group of zone controllers).

Step 6: If high-level controllers overlap in terms of devices involved, merge them into one meta-controller.

In the case of a simple office space (Figure 15 - 18), the control objective is to maintain the values of a number of zone state indicators within target values. These are in this case: air temperature θ, relative humidity RH, illuminance E1, E2 and carbon dioxide concentration C. The control task is to be accomplished via the operation of windows (W1, W2), shading device (B), radiators (R1, R2) and luminaires (L1, L2). Temperature, relative humidity and carbon dioxide concentration are monitored each via one sensor. The two windows are operated in tandem, just as the two radiators. Following the six steps described above, the distributed multi-layered multi-domain systems control schema of Figure 20 emerges. Layers 1 (zones) and 2 (device actuators) result from steps 1 to 3. Layers 3 (zone controllers) and 4 (high-level controllers) result from steps 4 and 5 respectively. In projects which are more complex, also a fifth layer (meta-controller) may be necessary.

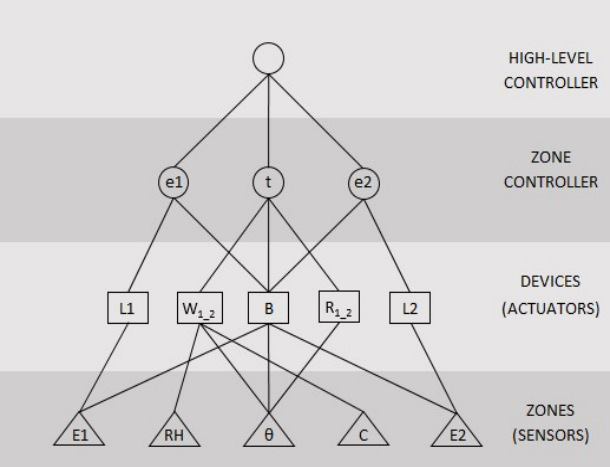

Figure 20: A control logic distribution schema for the office space from Figure 15 to 18. [25]

[25] Source: Rader and Mahdavi 2016a, 2016b

4.5. Summary and comments

The control schema generation method has been developed over the years and has reached a status suitable for introduction into the practical design process of buildings' technical (environmental control) systems. In order to make the schema applicable for professionals, they first have to familiarize themselves with the control loop. This loop involves a controller, device actuator, device, device terminal, control zone and sensor. Although control zones are not highly demarcated in nature, they are drawn in as having borders for ease of presentation and visualization. The same goes for the impact zones. In this schema, a control device is not only a technical device, it also can be a system like a window. All these are grouped together into "devices". The projects presented in this thesis show the following devices: blinds, luminaires, radiators and windows. For the generation of the schema, six rules were established and further developed during the research period.

In order to better understand the schema, one should know which devices, zones and sensors there are in a room and where they are located. Floor plans, in which these are drawn in, assist in doing so. This may possibly lead to some confusion for users, especially for larger spaces containing many devices and sensors. An automated generation of the schema by means of a programme or tool would hence be beneficial. Such a tool could point out conflicts to the expert or inform him of the optimal positions for devices and sensors. Furthermore, this programme or tool could automatically arrange the devices and sensors and draw them into the plans. In future projects, also more types of devices are likely to be added and included in the schema.

Chapter 5. Test and further development of the schema

5.1. Overview

To address the question, if a specific and new computationally supported engineering tool and schema can support a more structured and evidence-based approach to the design and configuration of buildings' environmental control system, the control schema generation method was tested and further developed. To assess the technical and educational potential of this schema generation technique, we conducted an experiment involving architecture and building system engineer students. They tested the applicability and the user friendliness of the method by applying it to real spaces and evaluated the schema. Moreover, the participants gave feedback regarding the potential and limitation of the aforementioned building systems control logic distribution schema. The results shed light on the related potential of the schema and point to directions for its future development. Furthermore, they gave a deeper understanding of the state of and improvement possibilities in collaborative design of architects and building service engineers.

5.2. Test with students

Usability testing is an essential technique to improve and develop the control schema generation method. For this reason, an experiment with students was conducted.

As part of a university course the students received in a three-hour introduction session information about the theoretical background of the method and about the schemas' generation process. After this session, the students were asked to select an architectural space without restrictions regarding the function or size of the space and to apply the control schema generation method to the selected space.

Two weeks after the introduction session, the participants presented their interim project results. After the students received feedback, they were asked to rework their project for the final submission.

Additionally the participants filled out a questionnaire, to get insights in their educational background and experiences as well as providing feedback concerning the usability assessment of the method, also problems faced while generating the schema and suggestions for improvement.

5.2.1. Students' background

As part of the experiment, the students were asked to fill out an online questionnaire. Additional to the evaluation of the task (question 8-19), the evaluation of the questionnaire was expected to give insights with regard to: the educational background of the students, experiences with building technology systems, communication with building service engineers and architects' understanding of technical issues (question 1-7).

The questions were the following:

1. What is your educational background?
2. Have you learned in your education something about building systems?
3. Have you had experience in design of buildings technology systems?
4. If you are an architect, have you in your professional work communicated to the building service engineers?
5. If the answer to the above question is yes or a bit, how would you judge the engineer`s competency and openness for suggestions?
6. If you are an engineer, do you find architects

   … are able to understand technical issues and can change the designs if necessary,

   ... are not aware of the technical issues and don't care about environmental performance,

   … others
7. Do you think architects should know more about building systems?

Altogether 29 students participated: 24 architecture and five engineering students. 25 students filed out the questionnaire: The minority (76%) stated that they did learn about buildings' technical systems in their education. The rest did not have any background in this area. 48% of the participants had at least some experience in designing building systems but most of the architecture students did not have any experience in

communicating with building service engineers. Of those students who had experience working with engineers, the majority suggested that the latter were open for system design suggestions by architects. Half of the engineering students finds that architects are able to understand technical issues and can change the design if necessary. The rest believes that architects are not aware of the technical issues and do not care about environmental performance. All participants stated that architects have to know more about buildings' technical systems (Rader and Mahdavi 2016a, 2016b).

5.2.2. The projects

After the introduction session in the university course, the students received the following tasks:

- Select and document (plan/sections/images) an actual space/room
- Document with identified devices/terminals and respective terminals (marks/symbols on the plan)
- Specify your best estimate of the spetial influence zone associated with each device/terminal (show on the plan)
- Generate the schema for distributed control logic
- Provide your comments about strengths and weaknesses of the method
- Prepare a 5-8 minute powerpoint presentation (28.11.2013)

The students worked in groups of two or independently. In the end 21 projects were submitted: Five office spaces, five lecture rooms, three seminar rooms, two kitchens, one art room, one living-dining-bedroom with included kitchen, one cafeteria, one ladys' gym, one conference room and one student dorm (see Table 10).

Table 10: The students' project spaces.

Project	**Space/room**
Project 1	Office
Project 2	Lecture room
Project 3	Lecture room
Project 4	Kitchen of dormitory
Project 5	Lecture room
Project 6	Lecture room
Project 7	Art room
Project 8	Lecture room

Project 9	Living-dining-bedroom/kitchen
Project 10	Cafeteria
Project 11	Student dorm – kitchen
Project 12	Seminar room
Project 13	Lady's gym
Project 14	Office
Project 15	Seminar room
Project 16	Conference room
Project 17	Office
Project 18	Office
project 19	Student dorm
project 20	Office
project 21	Seminar room

5.2.3. Project Results

The interim project results show that all 21 groups had problems in the schema generation process. Other problems concentrated on the zone and sensor plans. Although the device plan was mostly clear, in five projects, it was not.

After the feedback, the participants had to rework the following:

- Zone plan (13 projects)
- Sensor plan (15 projects)
- Schema (21 projects)
- Device plan (5 projects)

After getting feedback and reworking on their plans and schemes, the students finished their projects. There were still some uncertainties in the application of the method:
The first task “Select and document (plan/sections/images) an actual space/room” was clear for everyone.
The second task “Document with identified devices/terminals and respective terminals (marks/symbols on the plan)” was also clear for all students. Devices, terminals and actuators were correctly identified.

The third task “Specify your best estimate of the special influence zone associated with each device/terminal (show on the plan)” created problems in some cases: The estimation of zones seemed to be clear. But it was not clear if it is useful to merge zones together or not. In some cases the students associated each device with a zone, although the luminaires could be switched on and off only simultaneously. Hence an unnecessarily large number of zones was defined (see Figure 21). Other students associated several devices with only one zone. This seems to happen arbitrarily. It could be that the information was not clear for some students.

There were also problems with the definition of the number and location of the sensors. As a result of too many zones, too many sensors were frequently assumed. In several projects the one-to-one mapping between

zones and sensors was violated and multiple sensors covered the same zone (see Figure 22). In other projects, too few sensors were assumed: one sensor was provided to cover multiple zones (see Figure 23). In a few cases, sensors were occasionally placed outside the corresponding zones (see Figure 24).

The task "Generate the schema for distributed control logic" brought several problems (see Figure 25). In numerous projects, zone and sensor plan were still faulty and the generated schema was not correct:

- Zone plan (2 projects)
- Sensor plan (11 projects)
- Schema (20 projects)

Problems affect all layers of the schema:

1st layer: in many projects the number of zones was not correct.

2nd layer: devices were represented separately, even though they are jointly controlled and share the same device controller and influence the same sensor. Separate representation in the schema makes the schema too complicated. Individual representation of multiple individually controllable devices of the same type is only useful if there is a separate zone and sensor for each device (see Figure 26).

3rd layer: the creation of the zone controller was correct in most cases. In some projects there were too many zone controllers.

4th layer: the generation of the high-level-controller was inconsistent or simply false in certain cases. 14 projects had problems in this layer. It seemed that in some cases the 4th layer was generated in an arbitrary fashion and not by following the layer generation logic (see Figure 27).

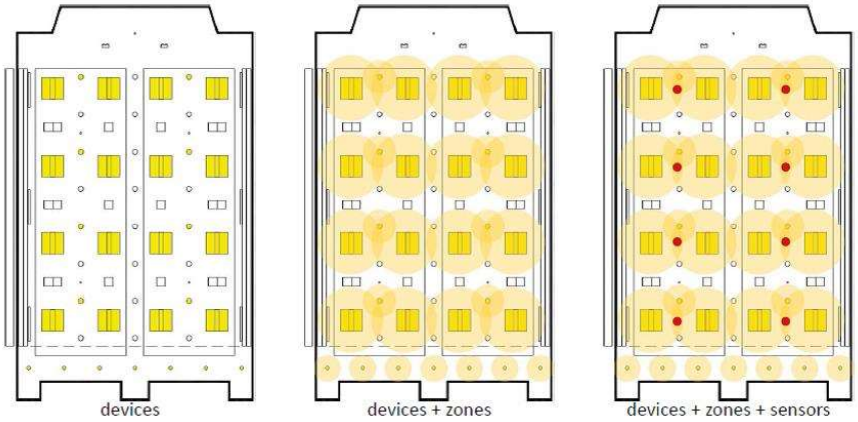

Figure 21: In this student project (lecture room in a university building) too many zones are defined.[26]

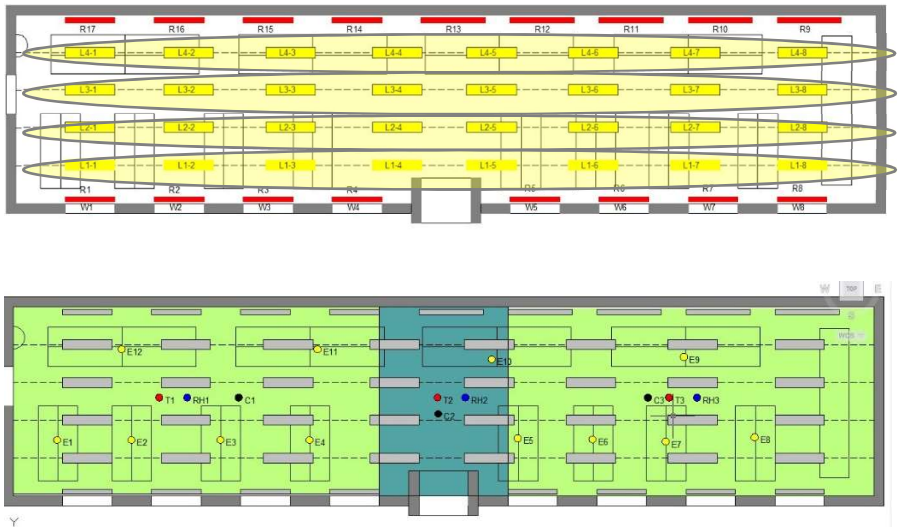

Figure 22: In this student project (drafting room in a university building) the identified lighting zones (above) and sensors (below) do not match. Three zones contain no sensor and one zone contains three sensors.[27]

[26] Source: Students` project number 3
[27] Source: Students` project number 7

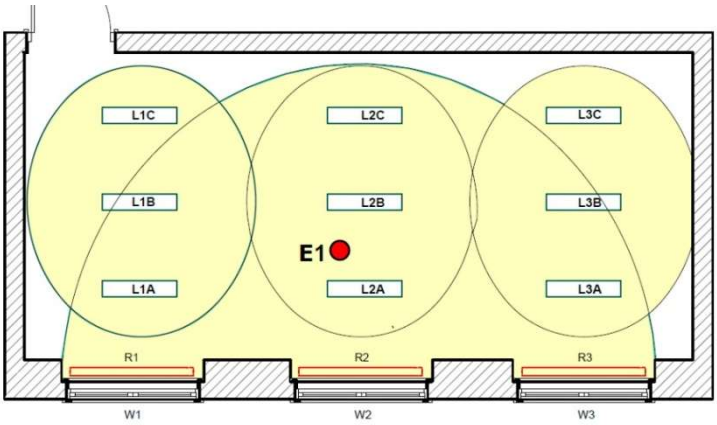

Figure 23: Only one sensor is to cover multiple zones in a student project (seminar room in a university building).[28]

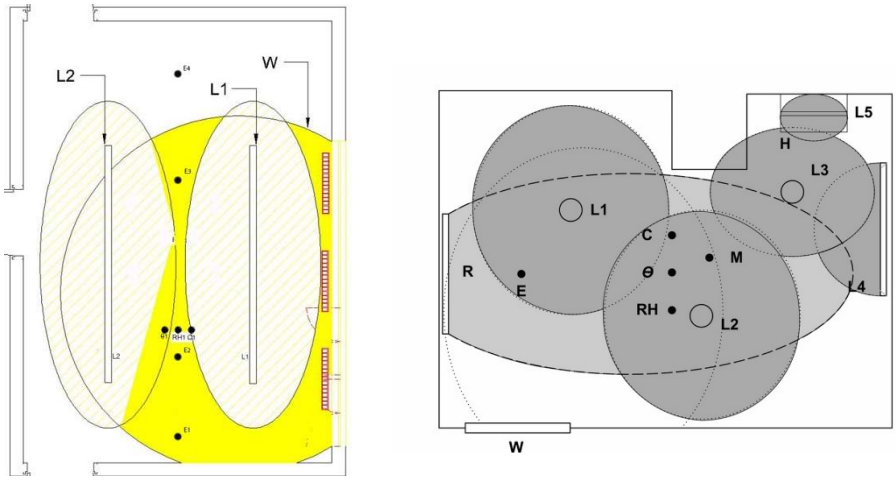

Figure 24: In two student projects the illuminance sensors are misplaced (kitchen spaces in two student dormitories).[29]

[28] Source: Students` project number 12
[29] Source: Students` project number 4

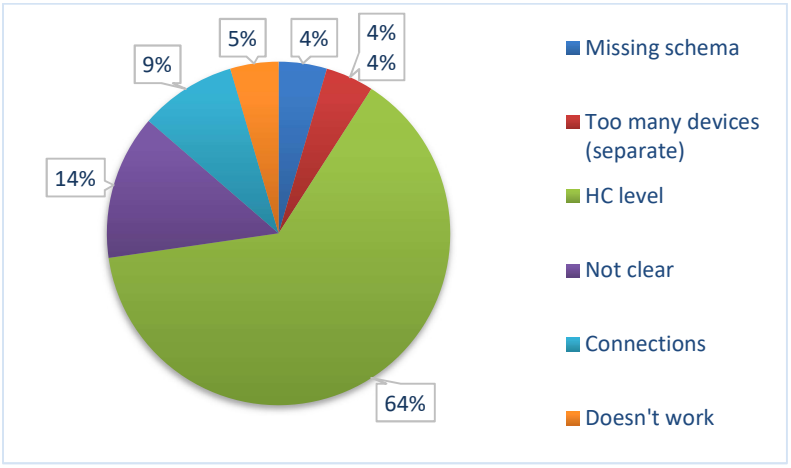

Figure 25: Problems in the generation of the schema (final submission)

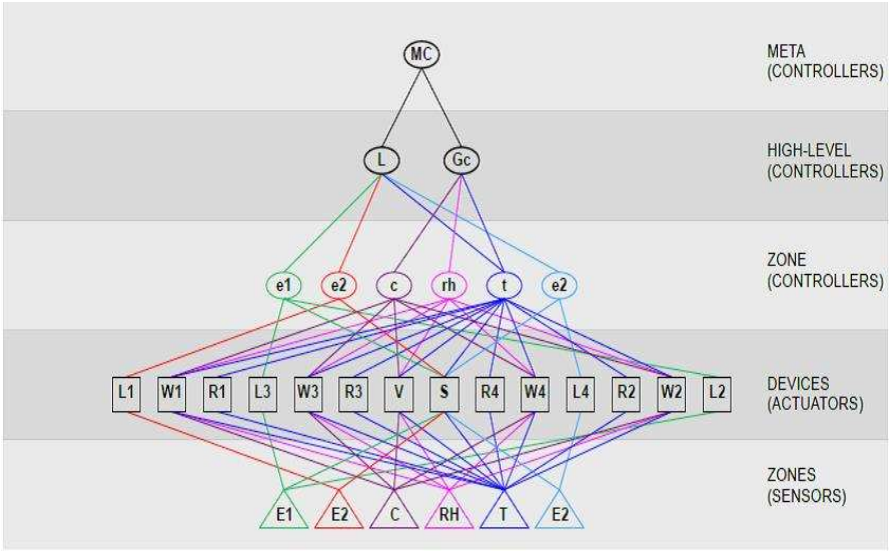

Figure 26: Too many devices are represented separately, even though they could have been combined (share the same actuator) in a student project (lecture room in a university building).[30]

[30] Source: Students` project number 6

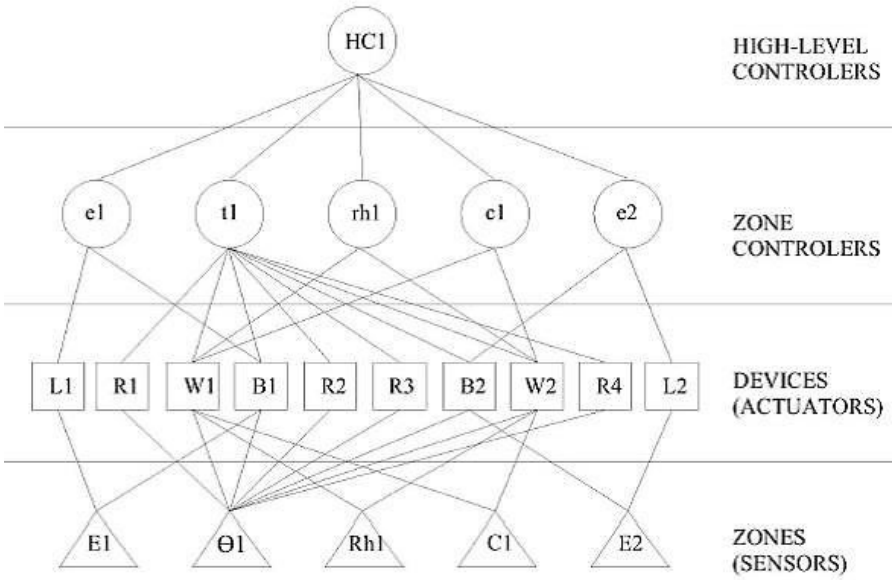

Figure 27: The high-level controller in this student project (gym in a student dormitory) is executed in a wrong fashion.[31]

[31] Source: Students` project number 13

5.2.4. Students' feedback

After generating the schema, the students had to think about the strengths and weaknesses of the method. Altogether 14 groups did this (The comments are summarized below).

The strengths prevail in the students' comments. Some mentioned that this method makes it easier to understand the placement and orientation of the devices. Moreover, the building system and the structure of the controlled rooms are easier to understand by using the method and it helps to avoid problems. In addition, some participants see a positive influence on the occupants' comfort.

Often mentioned comments about the weaknesses of the method are that generating the schema is time consuming and gets too complicated for larger areas. Moreover, users' individual needs are neglected.

Strengths mentioned by the students:

- better understanding the placement and orientation of the devices
- planner has to go through the system and find problems
- schema is easy to understand in case of small number of devices
- beneficial in complex and large buildings
- energy saving
- good visual interpretation of interconnections and links between sensors and devices
- logical way to show the structure of a controlled room or a building
- easily readable representation of building system hierarchy
- the system provides possibilities to make occupants more comfortable
- excellent method that ensures thermal and visual comfort inside the room
- the method is intuitive and can be adapted to all kinds of places
- the visualisation of the data makes the issue easily comprehensible by all the figures involved in the building design

- the method allows you to develop a linear and easy way to manage all the systems in a building
- the visualisation of the schema helps decide if and how to divide the controlled zone into two or more of them, in order to simplify the control issue.

Weaknesses mentioned by the students:

- unmeasured occupancy
- can get lost by larger systems
- takes time to define all parts (controllers, zones, sensors…)
- does not show how much influence a sensor or device has on a system
- as the number of zones and devices increases, it gets harder to interpret information from the schema
- for larger spaces the schema can get too complicated and unclear
- when there are devices with different strengths of power, it is hard to arrange distinct control zones and hard to place sensors in the right place
- a controlled building does not fulfil individual needs of all occupants.

The students were also asked to fill out a questionnaire providing feedback concerning the schema generation method (see Table 11).
In contrast to the erroneous results of the practical test, the students' evaluation of the proposed schema was encouraging. The schema and its generation method were found useful in improving the communication between architects and engineers, supporting the understanding of the buildings' technical systems and helping to improve the buildings' energy performance. More than half of the students think that the method helps identify design problems of the buildings' technical systems and support the improvement of buildings' energy performance. The majority can also see the method be applied to larger and more complex spaces and

buildings. However, some students stated that the schema would become too complicated if it were applied to larger rooms or spaces.

Although many students had problems with the schema, nearly all of them stated that the application of the method was clear and easy (12 participants stated “yes”, nine “a little bit” and only four “not so much”). We can assume that some students did not know they generated the schema in a wrong fashion.

Table 11: questionnaire results (question 8-19)

8. Does the proposed method make the understanding of the rule of technical systems in buildings easier?	2 Yes very much 15 Yes 4 A little bit 4 Not so much 0 Not at all
9. Does the proposed method help identify problems in the design of technical systems in buildings?	2 Yes very much 13 Yes 10 A little bit 0 Not so much 0 Not at all
10. Does the proposed method help save energy in the building?	4 Yes very much 14 Yes 5 A little bit 2 Not so much 0 Not at all
11. Was it clear and easy to apply the method to the room you selected?	0 Yes very much 12 Yes 9 A little bit 4 Not so much 0 Not at all
12. Can you give us examples of problems you faced?	See page 82
13. Does the method have the potential to improve the communication between architects and building service engineers?	1 Yes very much 12 Yes 11 A little bit 1 Not so much 0 Not at all

14. What kinds of problems in the selected rooms did you identify by using the method? (multiple answers possible)	13 The room did not have sufficient sensors 9 It is not clear which parts of the room are controlled by which device 9 Personal control is only possible to a limited degree in the room 3 other
If other, please provide examples:	- There are too many control points for an automated control system to be efficient. At best the sensor results can be only informative. - Hard to identify control zone, hard to place sensors
15. Most of you had selected smaller rooms. Do you think the method could also be applied to larger and more complex rooms?	3 Yes very much 15 Yes 6 A little bit 1 Not so much 0 Not at all
16. What problems do you expect when using the method for larger rooms?	See page 83
17. In order to apply the method to the room you had selected, how much time was approximately necessary?	1 Less than 1 hour 15 1-3 hours 9 3-5 hours 0 More than 5 hours
If more than 5 hours, how long?	-
18. What were the main problems using the method? Please describe a few examples:	See page 84
19. Do you have any specific suggestions for the improvement of the method? Please provide them:	See page 85

The 12th question "Can you give us examples of problems you faced?" was answered by 13 participants (answers see below). The most common problems were defining sensors and generating the schema. The participants' comments correspond with the evaluation of the results of the student projects.

- **Participant 2:** "Was not so easy, when some people were sensors and controllers at the same time (teachers)."
- **Participant 4:** "Selected rooms have a large window. There is only one wing of the window that opens or closes in the left corner. My problem was managing the right corner of the room with that area near the window!"
- **Participant 5:** "The space didn't have enough sensors and some spots didn't have enough devices. Also there was a large area of windows without blinds."
- **Participant 7:** "It was easy after the more detailed explanation with the examples from the student presentations."
  "It was hard to define the required number of sensors, but it was easy to show the existing situation afterwards."
- **Participant 11:** "Problems placing humans in the scheme, with devices that are operated only by occupants"
  "Problems defining lighting sensors depending on daylight, and integrating existing motion sensors in the scheme"
- **Participant 13:** "First tried to apply the method for the whole floor of the analysed building, however, it was very complicated then and almost impossible to define it properly on one schema."
- **Participant 14:** "If I had to do the same thing for a building (not for a room) it would be much more complicated (I have tried that but I have failed)."
- **Participant 15:** "It was a bit confusing to define Meta-controllers in a room. When the amount of sensors is higher than usual for a small room, the schema might get very complicated."

- **Participant 17:** “It was hard to identify the control zones.”
- **Participant 19:** “room had a couple of workspaces, so at the beginning it wasn't so clear where to put our light sensors”
- **Participant 21:** “It was difficult to define the number of high level controllers in the first phase”
- **Participant 23:** “-When you have control devices in different shapes and degrees of power and not uniformly distributed in the space, it’s hard to arrange distinct control zones and thus hard to place sensors in the right place where you can retrieve reliable information to transfer to the controllers.”

The question number 16 “What problems do you expect when using the method for larger rooms?” was answered in detail by the students. Some expected problems in estimating the correct number of sensors and that the diagram can become too complicated and confusing if there are so many sensors and devices. One argued that the schema would become too complex and it would be hard to keep the overview of all parts of the schema. Only one student expected no problems (entire table in the appendix).

The answers to question 18 “What were the main problems using the method? Please describe a few examples:” are summarized below (entire table in the appendix). Generating the schema, especially the high level and the zone controller, placing the sensors, defining the zones and devices were the most mentioned problems. Furthermore, some other problems were mentioned.

Problems generating the high-level controller:

- defining the high-level-controller
- estimating the number of high-level-controllers

Problems generating the zone controller:

- influences of the devices were not clear
- defining zone controller

Problems with placing the sensors:

- placing sensors and finding the right position for them

Problems with defining the zones:

- defining zones
- it was not clear which actuators belong to which zones
- overlapping influence of devices

Problems generating the schema:

- the schema gets too complicated for larger rooms
- the schema gets too complicated without simplifying

Problems with defining the devices:

- not clear how devices work automatically
- influences of devices were not clear
- finding the right position of devices

Other problems:

- manual and automated systems mixed
- automated systems often do not operate in the users' interest
- getting information about controls, especially for centrally operated systems
- understanding existing systems
- schema for existing sensors: devices are only operated manually
- schema with suggested sensors and retaining manual operation for a few devices
- some mistakes because of little experience
- too many control points for an automated control system to be efficient

The last question "Do you have any specific suggestions for the improvement of the method? Please provide them:" was answered by five participants. Two of the participants pointed out that the first layer (zones/sensors) and third layer (zone controller) in the schema are the same and can be summarized. Another one suggested that connecting lines in the schema should be adjusted to the power of influence. Other comments referred to the improvement of the interface and the need for guidance for the application of the method in large rooms and buildings.

Students' suggestions for improving the method:

- "Maybe make the influence of devices and controllers visible. For example, a blind will only have 10% influence on the temperature zone (passive heat gain) and a heater 90%. When both are connected with a line they are displayed as being equal. Maybe use colors or thicker lines to demonstrate the difference."[32]
- "improving the interface :)"[33]
- "As a suggestion, a row of zone controllers might be eliminated, as they resemble the same content and sequence of connections as zones (sensors)."[34]
- "I think that, if this method wants to be adaptable also to large buildings, there should be a clear formulation of how to deal with the complexity of information that a lager building can bring."[35]
- "As we discussed in class, the last level: zones (sensors) could be considered useless"[36]

[32] Participant number 2
[33] Participant number 7
[34] Participant number 15
[35] Participant number 21
[36] Participant number 22

5.3. Professionals' feedback about the schema

To collect insights regarding the educational and professional background of architects and building service engineers and their understanding of and views on building systems and their role in the overall planning of energy-efficient buildings, intensive interviews were conducted. Moreover, we tried to find out their attitudes regarding the feasibility and usefulness of the proposed schema.

Experienced professionals in both the architecture and engineering fields were interviewed (Rader and Mahdavi 2016a, 2016b). In total nineteen architects and ten building service engineers were interviewed, and they shared their experiences and points of views. Toward the end of the interviews, the professionals were asked to comment on the generation method for the control logic distribution schema and associated computational support.

The last question in the interview with professionals was the following:

"Now I will briefly introduce a schema that could help to, among other things, increase the understanding of the building systems as well as make possible the planning and arrangement of technical devices more easily in early planning stages. Thus, an optimal integration of the technical building equipment as well as an optimal control in the form of the right combinations of the controller positions can be achieved. I invite you to answer my questions in the following." [37]

They suggest that user-friendly graphical tools could facilitate the optimal placement of technical devices in spaces and the delineation of their associated impact zones. Moreover, such a tool should offer interactive features to the users, such that certain steps in schema generation could be taken in a semi-automated fashion and shortcomings could be

[37] Translated from original German by the author.

discovered. Schemas that are faulty or unnecessarily complex could be thus avoided.

A large fraction of the interviewed architects could imagine using the tool for design support. Particularly in case of smaller projects such a tool could reduce the dependence on building service engineers. However, the majority of building service engineers were not convinced that a computational tool could automatically generate the control schema and identify all shortcomings. Some argued that such a tool would become too complicated and complex. A challenge would be posed by the different brands of the devices with their different modes of action. Some professionals argued that this is not the architects' job and a collaboration between architects and engineers starting early in the design process is of utmost importance and cannot be replaced by computational tools.

Professionals agreed that such a tool has to be kept very simple and architects must still have knowledge of building technology to optimally operate this program.

5.4. Simplification of the schema

The generation of the method in the students' projects shows that the schema gets too complicated in larger rooms when there are more devices and more zones. Even some professionals stated that the schema seems very complicated. To facilitate the understanding, it is necessary to keep the schema simple. We developed a few simplifications of the schema.

The first simplification affects the device layer: If more than one device of the same type (eg. radiators) affects the same zone and there is one sensor for each zone, it can be assumed that they are jointly controlled and share one actuator – the devices can be combined in the second layer.

The office room in Figure 28-29 contains seven devices. The two windows affect one sensor – we can assume that they share one actuator and are jointly controlled. In that case, the two windows can be combined in the second layer (Figure 30). The two radiators also affect one sensor and are combined in the device layer. If all devices were separately represented, the schema would become too large and complex (Figure 31). Merging W1 and W2 into W1_2 and R1 and R2 into R1_2 renders the schema more compact (Figure 30).

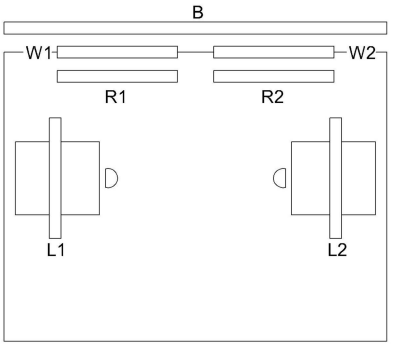

Figure 28: Office space with seven devices (windows W1 and W2, radiators R1 and R2, luminaires L1 and L2, external shade B).[38]

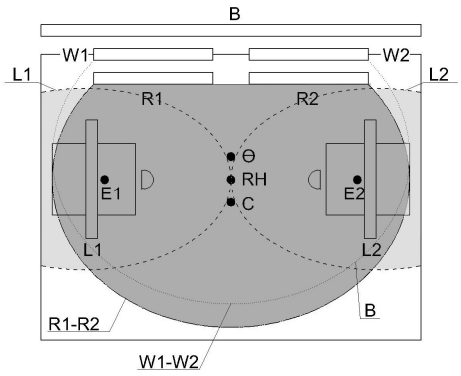

Figure 29: The office space from Figure 28 with the spatial impact zones of the devices and sensors.[39]

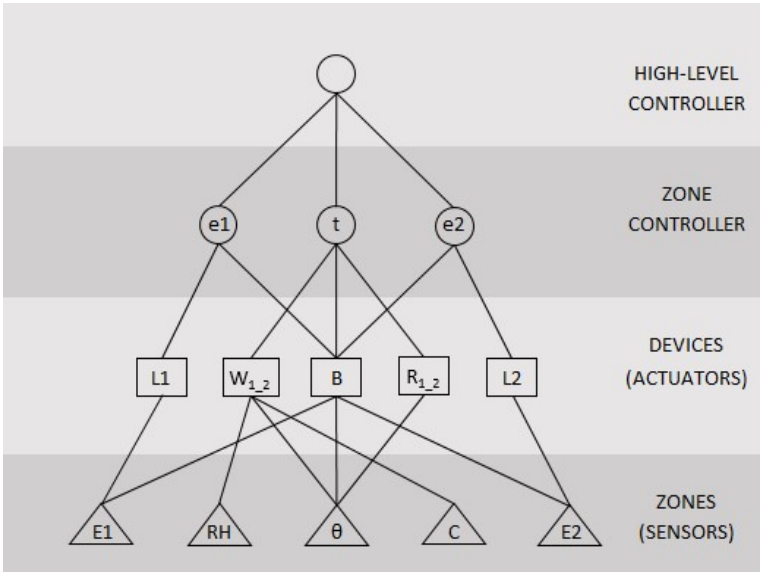

Figure 30: A control logic distribution schema for the office space from Figure 28 and Figure 29 after simplifying with grouped devices. [40]

[38] Source: Mahdavi 2012
[39] Source: Rader and Mahdavi 2016b
[40] Source: Rader and Mahdavi 2016b

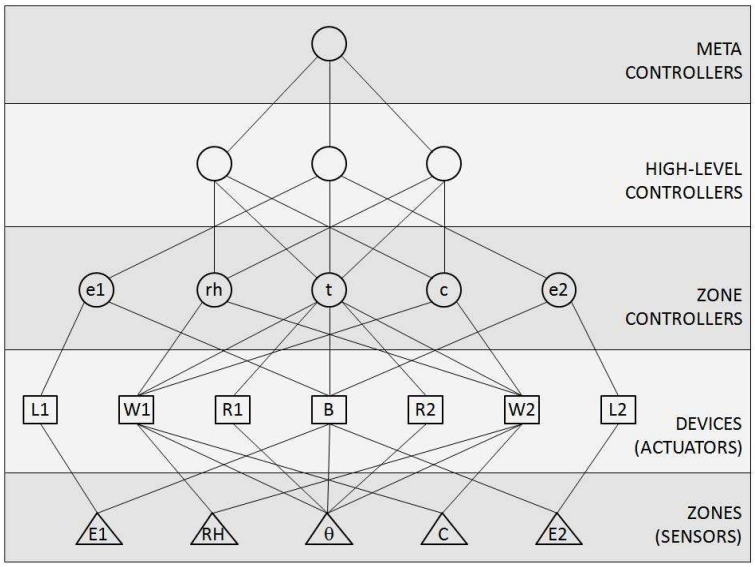

Figure 31: Generated schema for the same instance as in Figure 30 without grouped devices.[41]

As the previous example shows, the schema can be kept simple to facilitate better understanding and easier applicability.

Let us consider another example from a larger room with more devices: The conference room in Figure 32 consists of 16 devices (Figure 33) and all devices are separately represented, resulting in a rather confusing schema. The devices interact with 5 sensors, 5 zone controllers and 10 high-level-controllers. Let us combine devices of the same type, which share the same actuator (and influence the same sensor): W1 to W4 into W1_4, R1 to R4 into R1_4 and B1 to B4 into B1_4.

The second simplification affects the high-level controller layer: If windows, radiators and ventilations influence respective sensors (C, RH and θ), further schema simplification (in the high-level controller layer) is possible

[41] Source: Mahdavi and Schuß 2012

(Figure 34). Simplification of the high-level-controller is a significant factor. Otherwise it may not be possible to reduce the meta-controller.

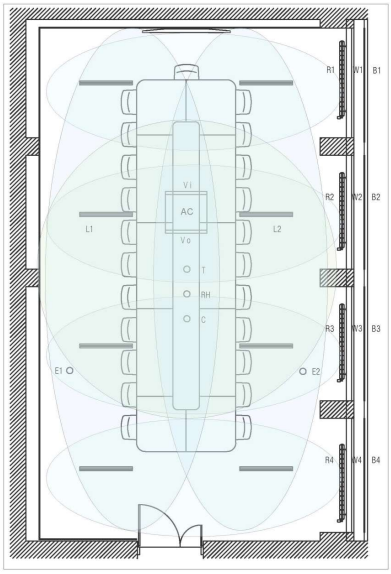

Figure 32: Floor plan of a conference room (Students' project).[42]

[42] Source: Students` project number 16

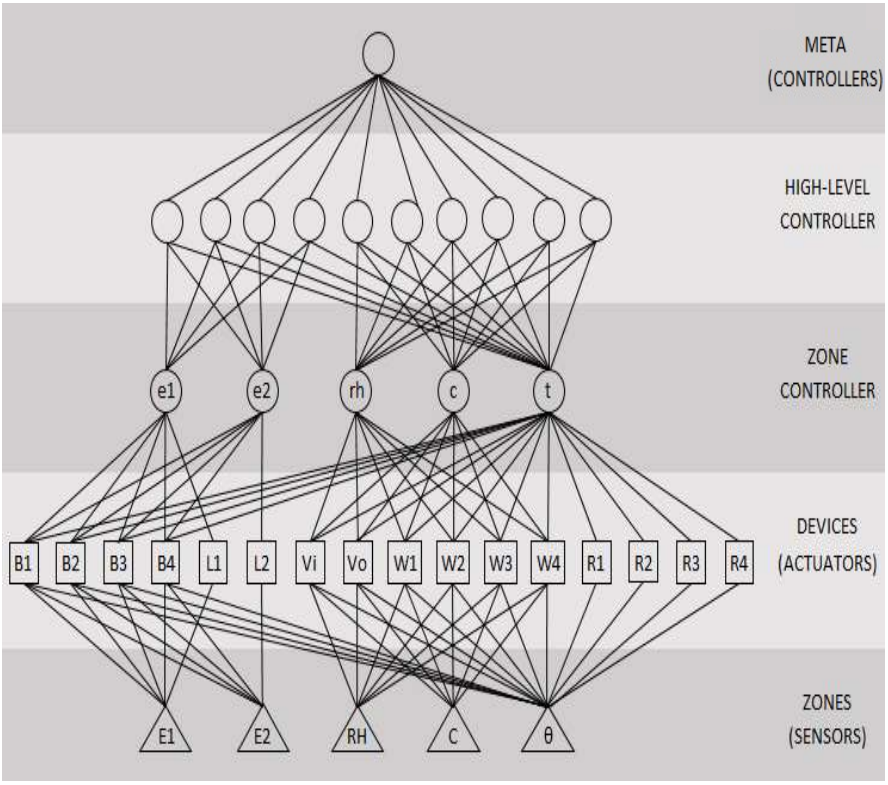

Figure 33: Generated schema without grouped devices and without grouped high-level controller of the conference room of Figure 32.[43]

[43] Source: Rader and Mahdavi 2016a

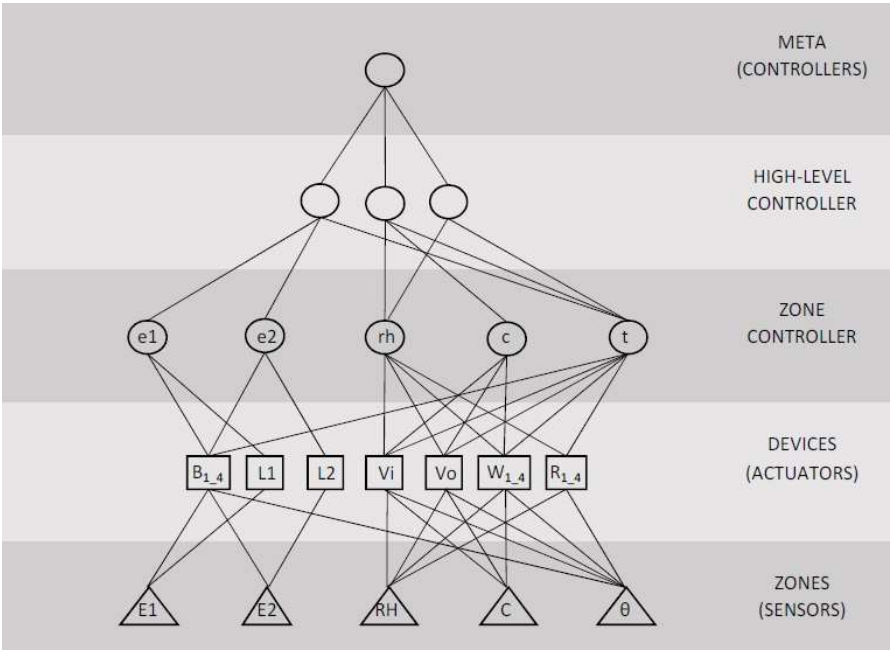

Figure 34: Generated schema (same instance as Figure 33) with simplifications.

Another procedure to create the schema was used by one student group. In this project, the participants used different colors for the connections. With the help of the colored lines they generated the correct zone controller and high-level controller layers (Figure 35). Without the colors, the generation of the high-level controller would not work. This schema would get too complicated and confusing (Figure 36). A combination of devices and simplification of the high-level-controller makes the schema clearer (Figure 37 and 38).

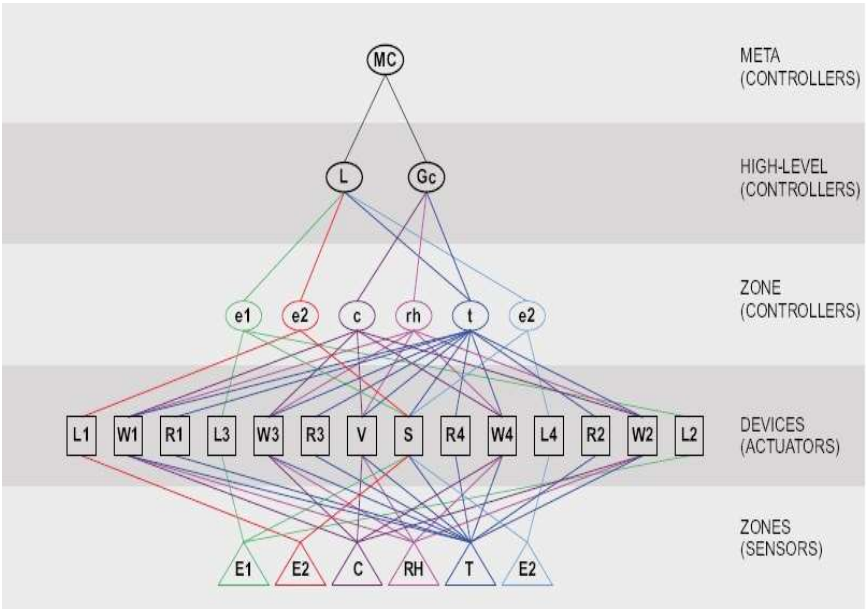

Figure 35: Students' project with colored lines.[44]

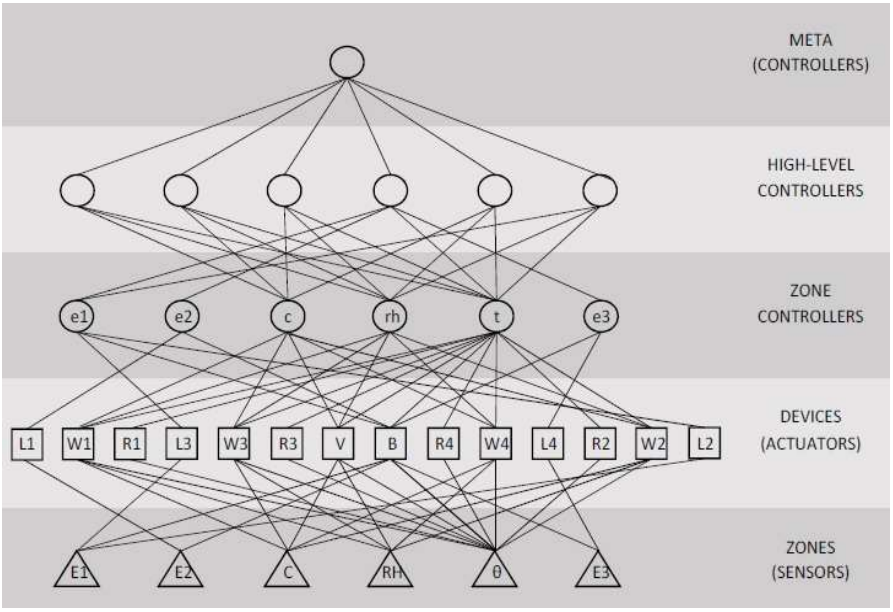

Figure 36: If all devices were arranged separately in this schema, it would get too complicated.

[44] Source: Students` project number 6

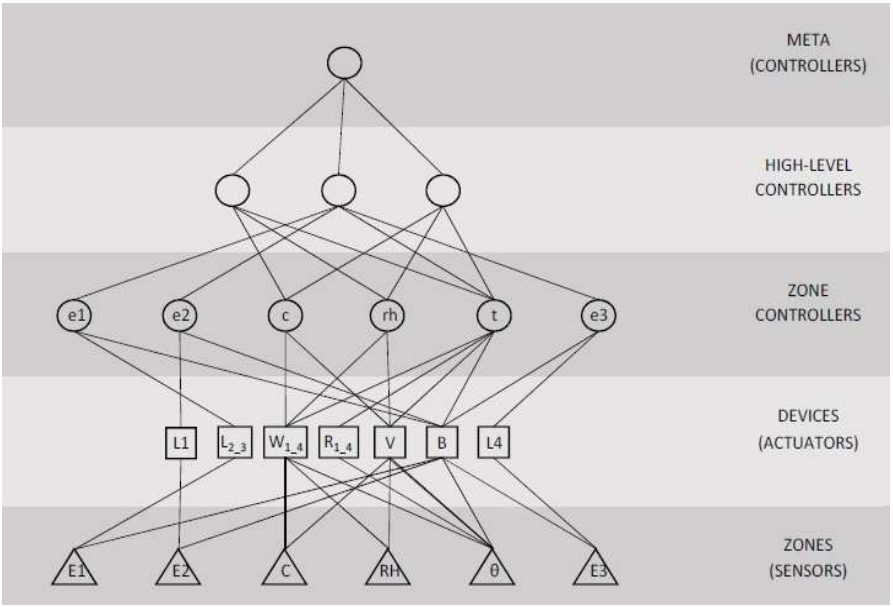

Figure 37: After combining devices, the schema gets much clearer.[45]

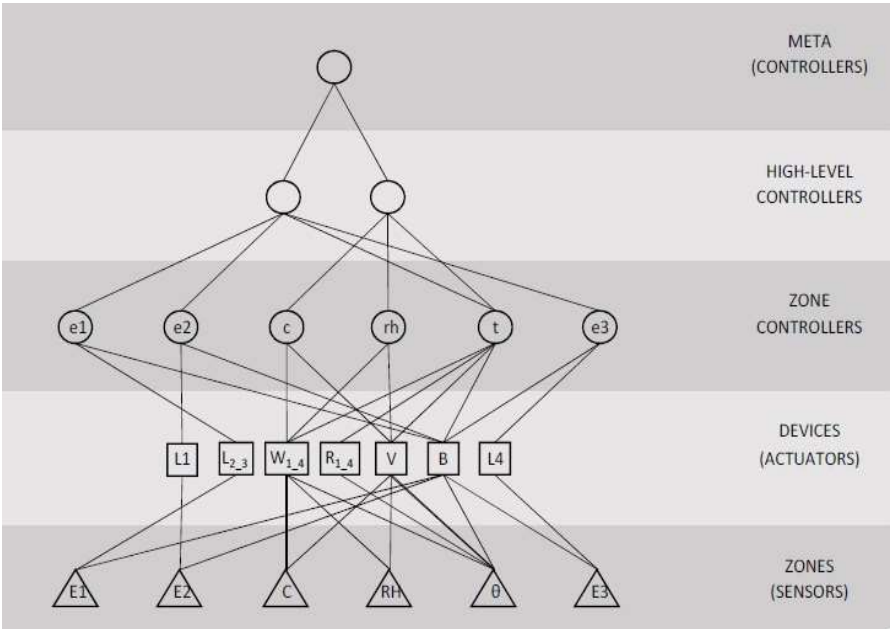

Figure 38: After simplification of the high-level-controller.

[45] Source: Rader and Mahdavi 2016a

5.5. Summary and comments

The simplification of the schema went through several development steps, based on many pilot projects. To keep the control schema simple is an important parameter for the usability of the control schema generation method to use it as a communication and collaboration platform for architects and engineers.

The control schema generation method was tested by students on existing architectural spaces in order to gain insights into its strengths and weaknesses as well as the ease of use. Furthermore, the students gave their feedback concerning problems they faced during the generation process and suggestions for improvement. To get information about their educational background and experiences in their professional lives, some questions were asked. Most of the participants stated that they learned about buildings' technical systems in the course of their education, and almost half of them had at least some experience in designing building systems. All participants answered yes to the question "do you think architects should know more about building systems?". The unanimous response to this question shows that these participants are receptive to new methods and like to think across the boundaries of individual trades.

The students were given two weeks to work on the generation process, after which participants had to present their interim project results. These results show that the generation of the schema was not completely clear for everyone. All the students had problems with the schema generation process. Moreover, the zone plan and the sensor plan were generated incorrectly in more than half of the cases. The device plan caused some difficulties, too.

After the interim project results, the students received feedback and reworked their projects. The evaluation of the final projects shows that students still had problems generating the schema (20 projects), the sensor plan (11 projects) and the zone plan (2 projects). To many students, it was

not clear that devices can combined when they are jointly controlled. Otherwise, the schema would get too complicated. The high-level-controller also posed some difficulties. It seemed that this layer was generated in an arbitrary fashion in some cases. The difficulties may have resulted from the participants' lack of intense occupation with the schema. The evaluation of the questionnaire showed that 15 students spent between one and three hours, 9 students between three and five hours and one participant only one hour familiarizing themselves with the application of the method. This may clearly be too little time for understanding and correctly applying this method.

At the end of the projects, the students gave feedback about the strengths and weaknesses of the method, and they were asked to give feedback concerning the schema generation method and suggestions for improving the method. Most participants commented positively on this schema. They stated amongst other things that the method makes it easier to understand the placement of devices and supports the understanding of building system and structure of the controlled rooms. Some students also saw a positive influence on occupants' comfort. The schema generation method was found useful in improving the communication between the professionals. Most of the participants stated that the method can help identify problems of buildings' technical systems. Criticism was centered mostly around the time-consuming nature of the the generation process and the fact that it might get too complicated for larger rooms. A computational tool would be helpful in this case, too, to solve this problem. Participants' suggestions for improving the method included the improvement of the interface, combining the first and third layer and instructions for use in larger rooms. Another participant suggested that lines in the schema should not be always be the same but differ based on the devices' influence. For example, a blind does not influence the temperature as much as a radiator. That means that some lines should be stronger than others. This comment shows that this student occupied

himself intensively with the schema and the method. [46] While this factor should be taken into account while programming the tool or programme, the manual version of the schema should be as simple as possible. Different connecting lines would probably cause more confusion than ease of application.

Professionals' feedback about the schema showed that most of the architects could imagine using a tool for design support, while the majority of building service engineers is more critical. They are not convinced that a computational tool could automatically generate the control schema and identify all shortcomings. Such a tool could become too complex. A difficulty in programming such a tool could be posed by different brands and devices with their different modes of action. Such a tool has to be kept very simple, but architects still have to possess basic knowledge about building technology to operate this tool or programme. Moreover, professionals emphasize the importance of good collaboration between the professionals.

The faulty execution by the students and the professionals' comments led to a further development and simplification of the schema. Students and professionals especially think that there could be problems in the generation process of larger rooms. To simplify the schema and make it clearer, devices were grouped together in the second layer. As a consequence, the third layer was reduced, too, and is not the same as the first layer anymore. In order to design a compact schema, one has to know in advance which devices share the same actuator and are jointly controlled. These then require one joint sensor only.

A further simplification affects the high-level controller. When different devices influence the same sensors (e.g. windows and ventilation both

[46] Participant number 7

influence the sensors C, RH and θ), they can be summarized in the high-level controller.

Another idea on how to provide the schema with a clearer structure came from a group of students. The participants used different colours for the connections, which made it possible to generate the correct zone controllers and high-level controllers even without grouped devices. However, this option of coloured lines is only of limited use to the general applicability, since it can easily cause ambiguities, and black-and-white printing does not allow for a distinction of colours either.

Chapter 6. Conclusion

6.1. Overview

This dissertation examined two research questions:

I. What is the state of professional collaboration between architects and engineers?

II. Can specific and new computationally supported engineering tools and schemes support a more structured and evidence-based approach to the design and configuration of buildings' environmental control systems?

To answer the first research question, extensive interviews with professionals on both sides, architects and building service engineers, were conducted. The professionals were not only asked about their collaboration, we also wanted to get insights into their education and professional lives. The evaluation of the interviews shows that architects may be receiving only insufficient training regarding building technology in the course of their university training. Likewise, building service engineers receive little to no information on the working style and design attitudes of architects in the course of their studies. Inefficiencies and disagreements in collaboration between professionals were recognized in both groups.

To answer the second research question, a method for generating a schema for the distribution of control logic of buildings' technical systems was described. This schema allows for a breakdown of the structure of a complex control task into five layers: zones, devices, zone controllers, high-level controllers and meta controllers. To test the proposed schema and evaluate its usability, a group of architecture and engineering students applied it to real buildings. The students' impressions of the schema

generation method were largely positive. However, the application of the method revealed some difficulties.

Another effort to improve and develop the control schema generation method involved extensive interviews with professionals: Architects and building service engineers gave feedback concerning the scope and potential of the schema. While the bulk of the interviewed architects could imagine using such a tool for design support, some building service engineers were sceptical. Most of them were not convinced that a computational tool could automatically generate the control schema and identify all shortcomings. They argue that such a tool cannot replace a close cooperation between architects and building service engineers.

Based on the evaluations of the students' experiment and the professionals' statements, the schema was further developed and simplified. This, in turn, provides the basis on which the schema can be digitized and a computer tool developed.

6.2. State of professional collaboration

The first research question is dedicated to the topic “what is the state of professional collaboration between architects and building service engineers”. The evaluation of the interviews with professionals shows that serious differences can already be observed in the course of people’s education. While several universities in Austria offer an education for architects, training for building services is very rare and unpopular, which is also reflected in the interviewees’ education: While almost all architects attended a university, only about 30% of the building service engineers did so. The other building service engineers trained as installateurs or had a degree from a higher technical school. Building technology is often neglected in architects’ training.

Most companies do not use computer programs and tools to integrate building technology. Decisions regarding the environmental control systems’ type and devices, the number and positions of control zones and the type, number and positions of sensors are in most cases made on an ad hoc basis. This can cause inefficiencies in the design and operation of buildings and their systems. Some companies do not see the need to use such tools and argue that they are expensive and time consuming to learn.

Furthermore, the collaboration between architects and building service engineers often starts when the primary building design is already complete. One reason for this is the high cost for specialists and computer programs, and furthermore, some argue that considering the building system would limit their degrees of freedom in the design process.

To find out if and how the cooperation between architects and building service engineers works, we asked the professionals about their positive and negative experiences. The professionals answered very extensively and there was much criticism. Professionals on both sides agree that there are many problems in the collaboration between building designers and building service engineers during the planning and execution phase.

Nevertheless, some praise the cooperation. The collaboration depends on the respective person and office. Architects prefer choosing a building services office for collaboration themselves, based on previous good experiences and smooth cooperation. Yet, in most cases the employer chooses the building services office, not allowing the architect to choose.

More than half of the building service engineers and architects are convinced that building systems influence the architectural design process. Almost all professionals agree that it makes sense to integrate the building technology in early planning phases and that a basic understanding of building systems and operation of environmental control systems is necessary for a good collaboration. Nevertheless, about a third of the architects stated that they do not deal with the building technology in any way or only a little, if necessary.

Architects are largely satisfied with the cooperation with the building service engineers when the engineers participate from the beginning. But they also criticized the relatively small number of experienced building engineers. These engineers are often expensive, overworked and have too little time for each project. Another point of criticism was that some engineers make decisions on their own, do not take the whole building into consideration and only concentrate on their own concerns. Architects also mentioned that some building engineering offices focus purely on specific brands of products, which may lead to suboptimal selections. Moreover, some architects would like for building service engineers to have a better understanding of the working processes of architects.

Building service engineers consider it positively when architects are flexible, are ready to compromise and make clear and well thought out plans. They appreciate it when architects involve the other specialists in early planning phases and when they have good knowledge of the building technology. A frequently mentioned problem is the late collaboration and that the space calculated for technical devices is too small. This can lead to a loss in quality.

Although many architects do not deal with technical systems, most of them rate the colleagues' and their own knowledge as good or mediocre. The building service engineers, too, rate the architects' knowledge very positive. Architects with longer professional experience classify their own knowledge as better than architects with less experience.

While building service engineers are typically only involved in the planning phase at a rather late stage, many architects and building service engineers emphasize the importance of an integral planning process and early cooperation. The professionals also agree on the significance of good education to allow for cooperation on an equal footing. To that effect, students should start thinking beyond the boundaries of their own field already in the course of their education and be trained in the other professionals' activities and methods. Moreover, both the profession as a building service engineer and the training as such should become more attractive in Austria. The professional involved has to be aware of the necessity of involving a building service engineer already in the early planning phases, but the same goes especially for the building contractor or employer.

6.3. New computationally supported engineering tools and schemes

The method of deriving this control schema generation method has gone through a series of evolutionary steps, based on many pilot projects. It has been developed over the years and has reached a status suitable for introduction into the practical design process of buildings' technical (environmental control) systems. The steps in the further development of the schema were continually published in papers and presented. Before the schema can be digitalized in further consequence, it first has to be developed in an analogous manner and tested for its user-friendliness and applicability.

To apply the schema in an analogous way, users have to familiarize themselves with a few terms with definitions and examples (table 9, p. 56). The illustration of a basic loop (figure 14, p.57) can make the terms more understandable. Moreover, they should know the positions of devices, zones and sensors. An example of an office space serves to illustrate the application. The representation of devices, control zones and sensors in this room shows how the method can be applied to a real space. In order to generate the schema, six rules were developed. By following these rules, the schema can be generated.

While these instructions allow for the generation of the schema, the test with students on existing architectural spaces shows that the schema generation process leads to some confusion for users, especially for larger spaces containing many devices and sensors. Even though the participants were introduced to the schema generation method, the process was not completely clear for everyone. In the first attempt, all the students had problems generating the schema. In more than half of the projects, the zone and sensor plan were generated in a wrong fashion. After receiving feedback and reworking their projects, a large part of the participants had still problems with the generation process of the schema. One reason for

the erroneous application may be that the participants have not occupied themselves with it long enough – a fact that is also supported by the evaluation of the working hours. One can conclude from said evaluation that the analogous schema can only be applied correctly after people have occupied themselves with it intensively. Despite the faulty application of the schema, most participants commented positively on it. They think that the method makes it easier to understand the placement of devices, supports the understanding of building systems and structure of the controlled rooms and can help identify problems of buildings' technical systems. It is also useful in improving the communication between architects and building system engineers.

The results of the test with students and the professionals' comments led to a further development and simplification of the schema. These measures made the presentation and applicability of the schema more compact and clearer. Still, the method will need to be digitalized in order to practically apply it. A computational tool would address the problems of applicability. This tool could automatically generate the control schema and identify shortcomings. While the majority of building service engineers is still sceptical and not convinced that such a tool can fulfil these tasks, most of the architects can imagine using such a tool.

6.4. Future research

In future, the schema can be tested by architects and be further developed with a more effective communication framework (user interface) for the selection of devices and marking of the zones. Moreover, the envisioned environment shall offer interactive features to the users, so that certain steps in schema generation could be taken in a semi-automated fashion, thus reducing the probability of generating schemas that are faulty or unnecessarily complex. This tool could be designed to be integrated into architectural computer programs. Such a tool could point out conflicts of control and inefficient building system operation to the expert and inform him / her of the optimal positions for devices and sensors. Furthermore, this program or tool could automatically arrange the best positions of devices and sensors and draw them into the plans. This would allow professionals to take building technology into consideration from the beginning of the planning phase, requiring a relatively little time. Communication between architects and building service engineers would improve due to reduced misunderstandings and increased clarity in the planning phase. Building service engineers could directly take over the architect's planning materials and further develop them, even if they are only involved at a later stage in the planning.

A difficulty in programming such a tool could be posed by different brands and devices with their different modes of action. Such a tool has to be kept very simple. Nevertheless, architects must have basic knowledge about building technology to operate this tool.

In future research, installation shafts and building technology rooms should be taken into consideration in this tool. These are often neglected during the planning phase, thus leading to serious issues in the further planning and execution. Not only does this lead to conflicts between the professionals, but it also causes significant extra costs for the client and prolongs the planning and construction phases. The tool can be further

developed and added to in such a way that adequate sizes for shafts and technology rooms will be pointed out to the user.

6.5. Publications

Publications on this topic:

Mahdavi A. & Rader B. 2014. Testing a method for the generation of the systems control schemes for buildings. Proceedings of the 2nd ICAUD International Conference in Architecture and Urban Design Epoka University, Tirana, Albania, 08-10 May 2014.

Mahdavi A. & Rader B. 2016. Integrated buildings and systems design: approaches, tools and actors. Proceedings of the ECPPM 2016 eWork and eBusiness in Architecture, Engineering and Construction, Limassol, Cyprus; 07-09 September 2016, Christodoulou & Scherer – Balkema. ISBN: 9781138032804; pp. 57 - 64.

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Rader B. & Mahdavi A. 2016b. Supporting integrated approaches to the design of buildings and their technical systems. Clima 2016 - 12th REHVA

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Mahdavi A. & Schuß M. & Rader B. 2015. A Multi-Zonal Schema for Systematic Compartmentalisation of Building Systems Control Logic. www.ticon.org – Journal of Information Technology in Construction, 20 (2015), Special Issue; pp. 121 – 131.

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7.2. Tables

7.3. Figures

Chapter 8. Appendix

8.1. E-Mail to the professionals

Interviewanfrage zur Doktorarbeit "Architektur und Gebäudetechnik"

Sehr geehrte……..

im Zuge meiner Dissertation an der technischen Universität Wien am Institut für Architekturwissenschaften, Abteilung Bauphysik und Bauökologie, betreut durch Prof. DI Dr Ardeshir Mahdavi, möchte ich eine Umfrage in Architektur- sowie Gebäudetechnikbüros durchführen.

Meine Doktorarbeit mit dem Titel „architecture and building systems“ beschäftigt sich mit dem Thema der Trennung zwischen Architektur und Gebäudetechnik in den Planungs- und Errichtungsphasen eines Gebäudes. In der entstehenden Arbeit wird untersucht, ob und inwiefern es solch eine Trennung wirklich gibt, welche Gründe dazu führen und welche Auswirkungen diese hat. Des Weiteren werden Methoden erarbeitet, die es dem planenden Architekten erleichtern sollen, die Gebäudetechnik bereits im Entwurf zu berücksichtigen und die Kommunikation zwischen Gebäudetechnikern und Architekten zu verbessern.

Interviews sollen dazu beitragen, praxisnah die Perspektiven von Architekten und Gebäudetechnikern zu dieser Thematik zu erforschen.

Ich würde mich freuen, wenn Sie Zeit für dieses Interview hätten und werde mich in den nächsten Tagen telefonisch bei Ihnen wegen der Terminabsprache in Verbindung setzen.

Vielen Dank im Voraus für Ihre Mitarbeit,

freundliche Grüße Birgit Rader

DI Birgit Rader

0699/17197874

8.2. Questionnaire architects

Fragebogen für Architekten/Planer

1. Allgemeine Angaben
1.1. Wie viel Jahre sind Sie bereits in der Baubranche tätig? ○ bis 5 ○ 6 – 10 ○ 11 – 15 ○ 16 – 20 ○ über 20
1.2. Wie viel Mitarbeiter sind in Ihrem Büro/Unternehmen beschäftigt? ○ alleine ○ bis 5 ○ 6 – 10 ○ 11 – 15 ○ über 15
1.3. Sind in Ihrem Büro/Unternehmen ausschließlich Architekten/Planer mit den Entwurfs- und Planungsaufgaben beschäftigt? ○ Ja ○ Nein *Wenn nein, welche Fachdisziplinen noch?*
2. Ausbildungsspezifische Fragen
2.1. Welche Ausbildung(en) haben Sie absolviert? ○ Lehre *welche?* ○ HTL *welche?* ○ Studium *welches?* ○ andere Ausbildung *welche?*
2.2. Haben Sie in Ihrer/Ihren Ausbildung(en) etwas über Gebäudetechnik gelernt? ○ Ja ○ Nein ○ Weiß nicht mehr *Wenn ja, was haben Sie gelernt und wie genau?* *War dies Ihrer Meinung nach ausreichend für den Berufsalltag?*
2.3. Besuchten Sie nach Ihrer zuletzt abgeschlossenen Ausbildung Fortbildungen oder Schulungen betreffend dem Bereich Gebäudetechnik? ○ Ja *Wenn ja, welche und wann?* ○ nein

2.4. Sollte Ihrer Meinung nach in der Ausbildung zum Architekten/Planer auch etwas über Gebäudetechnik gelehrt werden?

- Ja
  Wenn ja, was und wie genau?
- Nein
  Wenn nein, wieso nicht?

3. Praxisbezogene Fragen

3.1. In welcher Phase eines Projektes beginnt in Ihrem Büro die Zusammenarbeit mit Gebäudetechnikern?

-Wieso genau zu diesem Zeitpunkt und nicht *von Beginn an?*

-Steht zu diesem Zeitpunkt die Entwurfsplanung schon?

- *Ja*
- *Nein*
- *teilweise*

3.2. Wie erfolgt die Kommunikation zwischen Architekten und Gebäudetechnikern?

3.3. Welche der folgenden Entscheidungen kommen vom Architekten und welche vom Gebäudetechniker:

- Systementscheidungen (Heizsysteme…)?

- Entscheidungen über die Anzahl und Anordnung von:

- Fenster
- Beschattung
- Leuchten
- Heizkörper
- Ventilatoren
- Thermostate
- Sensoren
- Lüftungs- und Kühlungssysteme

Spielt der Elektrotechniker bei diesen Entscheidungen eine Rolle?

3.4. Wie werden Entscheidungen getroffen wo die zuvor erwähnten technischen Geräte platziert werden?

- *Erfahrungswerte*
  Berücksichtigen diese Erfahrungswerte die Einflusszonen der technischen Geräte? Wenn ja, inwiefern?
- *Simulationsprogramm*
  Berücksichtigen diese Programme die Einflusszonen der technischen Geräte? Wenn ja, inwiefern?
- *Andere (Welche?)*

3.5. Bitte erzählen Sie mir etwas über Ihre positiven und negativen Erfahrungen im Zuge der Zusammenarbeit mit Gebäudetechnikern!

3.6. Inwiefern beschäftigen Sie sich als Architekt/Planer mit der Planung der technischen Gebäudeausrüstung?

3.7. Mit welchen Programmen arbeiten Sie?
Können in diesen Programmen die Einflussbereiche der technischen Geräte dargestellt werden?

3.8. Wie ist Ihrer Meinung nach das Wissen der Architekten/Planer über Gebäudetechnik und die Planung technischer Systeme?

- Sehr gut
- Gut
- Mittelmäßig
- Schlecht
- Verschieden, je nach Berufserfahrung

Bitte begründen Sie diese Bewertung!

3.9. Was würde sich ändern oder verbessern, wenn sich Architekten/Planer *(noch)* besser mit der Gebäudetechnik auskennen?

3.10. Wie schätzen Sie Ihr eigenes Wissen über Gebäudetechnik und die Planung technischer Systeme ein?

- Sehr gut
- Gut
- Mittelmäßig
- Eher schlecht
- Schlecht

Bitte begründen Sie diese Bewertung!

3.11. Beeinflusst die Gebäudetechnik den Entwurfsprozess des Architekten/Planer?

- Ja
  Inwiefern?
- Nein
  Wieso nicht?
- Teilweise
- Weiß nicht
- Sonstiges

Bitte begründen Sie diese Bewertung!

3.12. Was würde sich ändern oder verbessern, wenn die GT im Entwurf (mehr) Berücksichtigung findet?

3.13. Haben Sie Ideen oder Vorschläge wie es dem Architekten/Planer erleichtert werden kann, die Gebäudetechnik schon im Entwurf mit einfließen zu lassen?

Welche Methoden würden Sie vorschlagen?

3.14. Haben Sie eine Idee wie man einem Architekten/Planer das Verständnis zur GT näher bringen kann?

3.15. Im Folgenden werde ich Ihnen kurz ein Schema vorstellen mit dem unter anderem das Verständnis zur GT erhöht werden kann sowie das die Planung und Anordnung technischer Geräte schon in frühen Planungsphasen leicht ermöglicht. Damit kann eine optimale Integration der technischen Gebäudeausrüstung sowie eine optimale Steuerung in Form der richtigen Kombinationen der Reglerpositionen erreicht werden. Dazu bitte ich im Anschluss um Ihre Meinung. *(Schema und das Tool/Programm wird kurz erläutert)*

Zusatzfragen, wenn noch Zeit vorhanden ist:

-Glauben Sie, dass diese Methode hilft, Schwachstellen des Gebäudetechniksystems (der Steuerung, Programmierung) zu erkennen?

-Glauben Sie, dass solch ein Schema die Logik der Entscheidungen eines Gebäudetechniksystems verständlicher macht?

-Wer programmiert das Gebäudetechniksystem?

8.3. Questionnaire building service engineers

Fragebogen für Gebäudetechniker

1. Allgemeine Angaben
1.1. Wie viel Jahre sind Sie bereits in der Gebäudetechnikbranche tätig? ○ bis 5 ○ 6 – 10 ○ 11 – 15 ○ 16 – 20 ○ über 20
1.2. Wie viel Mitarbeiter sind in Ihrem Büro/Unternehmen beschäftigt? ○ alleine ○ bis 5 ○ 6 – 10 ○ 11 – 15 ○ über 15
1.3. Sind in Ihrem Büro/Unternehmen ausschließlich Gebäudetechniker mit der Planung technischer Gebäudesysteme beschäftigt? ○ Ja ○ Nein *Wenn nein, welche Fachdisziplinen noch?*
2. Ausbildungsspezifische Fragen
2.1. Welche Ausbildung(en) haben Sie absolviert? ○ Lehre *welche?* ○ HTL *welche?* ○ Studium *welches?* ○ andere Ausbildung *welche?*
2.2. Haben Sie in Ihrer/Ihren Ausbildung(en) etwas über die Arbeitsbereiche der Architekten/Planer (Prozesse des Entwerfens der Architekten/Planer) gelernt? ○ Ja ○ Nein ○ Weiß nicht mehr *Wenn ja, was haben Sie gelernt und wie genau?* *War dies Ihrer Meinung nach ausreichend für den Berufsalltag?*
2.3. Besuchten Sie nach Ihrer zuletzt abgeschlossenen Ausbildung Fortbildungen oder Schulungen? ○ Ja *Wenn ja, welche und wann?* ○ nein

2.4. Sollte Ihrer Meinung nach in der Ausbildung zum Architekten/Planer auch etwas über Gebäudetechnik gelehrt werden?

- Ja
  Wenn ja, was und wie genau?
- Nein
  Wenn nein, wieso nicht?

3. Praxisbezogene Fragen

3.1. In welcher Phase eines Projektes beginnt in Ihrem Büro die Zusammenarbeit mit Architekten/Planern?

-Wieso genau zu diesem Zeitpunkt und nicht von Beginn an?

-Steht zu diesem Zeitpunkt die Entwurfsplanung schon?

- *Ja*
- *Nein*
- *teilweise*

3.2. Wie erfolgt die Kommunikation zwischen Architekten und Gebäudetechnikern?

3.3. Welche der folgenden Entscheidungen kommen vom Architekten und welche vom Gebäudetechniker:

- Systementscheidungen (Heizsysteme…)?

- Entscheidungen über die Anzahl und Anordnung von:

- Fenster
- Beschattung
- Leuchten
- Heizkörper
- Ventilatoren
- Thermostate
- Sensoren
- Lüftungs- und Kühlungssysteme

Spielt der Elektrotechniker bei diesen Entscheidungen eine Rolle?

3.4. Wie werden Entscheidungen getroffen wo die zuvor erwähnten technischen Geräte platziert werden?

- *Erfahrungswerte*
  Berücksichtigen diese Erfahrungswerte die Einflusszonen der technischen Geräte? Wenn ja, inwiefern?
- *Simulationsprogramm*
  Berücksichtigen diese Programme die Einflusszonen der technischen Geräte? Wenn ja, inwiefern?
- *Andere (Welche?)*

3.5. Bitte erzählen Sie mir etwas über Ihre positiven und negativen Erfahrungen im Zuge der Zusammenarbeit mit Architekten/Planern!

3.6. Bitte beschreiben Sie Ihre Vorgehens- und Arbeitsweise um eine technische Gebäudeausrüstung zu planen?

3.7. Mit welchen Programmen arbeiten Sie?
Können in diesen Programmen die Einflussbereiche der technischen Geräte dargestellt werden?

3.8. Wie ist Ihrer Meinung nach das Wissen der Architekten/Planer über Gebäudetechnik und die Planung technischer Systeme?

- Sehr gut
- Gut
- Mittelmäßig
- Schlecht
- Verschieden, je nach Berufserfahrung

Bitte begründen Sie diese Bewertung!

3.9. Was würde sich ändern oder verbessern, wenn sich Architekten/Planer *(noch)* besser mit der Gebäudetechnik auskennen?

3.10. Beeinflusst die Gebäudetechnik den Entwurfsprozess des Architekten/Planer?

- Ja
  Inwiefern?
- Nein
  Wieso nicht?
- Teilweise
- Weiß nicht
- Sonstiges

Bitte begründen Sie diese Bewertung!

3.11. Was würde sich ändern oder verbessern, wenn die GT im Entwurf (mehr) Berücksichtigung findet?

3.12. Haben Sie Ideen oder Vorschläge wie es dem Architekten/Planer erleichtert werden kann, die Gebäudetechnik schon im Entwurf mit einfließen zu lassen?

Welche Methoden würden Sie vorschlagen?

3.13. Haben Sie eine Idee wie man einem Architekten/Planer das Verständnis zur GT näher bringen kann?

3.14. Im Folgenden werde ich Ihnen kurz ein Schema vorstellen mit dem unter anderem das Verständnis zur GT erhöht werden kann sowie das die Planung und Anordnung technischer Geräte schon in frühen Planungsphasen leicht ermöglicht. Damit kann eine optimale Integration der technischen Gebäudeausrüstung sowie eine optimale Steuerung in Form der richtigen Kombinationen der Reglerpositionen erreicht werden. Dazu bitte ich im Anschluss um Ihre Meinung. *(Schema und das Tool/Programm wird kurz erläutert)*

Zusatzfragen, wenn noch Zeit vorhanden ist:

-Glauben Sie, dass diese Methode hilft, Schwachstellen des Gebäudetechniksystems (der Steuerung, Programmierung) zu erkennen?

-Glauben Sie, dass solch ein Schema die Logik der Entscheidungen eines Gebäudetechniksystems verständlicher macht?

-Wer programmiert das Gebäudetechniksystem?

8.4. Questionnaire students

QUESTIONNAIRE

concerning zones – devices – controls toward an scheme

for distribution of building systems control logic

1. What is your educational background?

o o o

architect mechanical engineer others

If others, please specify:

2. Have you learned in your education something about building systems?

o o o

yes a bit no

3. Have you had experience in design of buildings technology systems?

o o o

yes a bit no

4. If you are an architect, have you in your professional work communicated to the building service engineers?

o o o

yes a bit no

5. If the answer to the above question is yes or a bit, how would you judge the engineers competent and open for suggestions?

○	○	○
open for suggestions of the architects	not interested in understanding the intentions of the architects	others

If others, please explain:

6. If you are an engineer, do you find architects

○ ...are able to understand technical issues and can change the designs if necessary

○ …are not aware of the technical issues and don't care about environmental performance

7. Do you think architects should know more about building systems?

○	○	○
yes	a bit	no

8. Does the proposal method make the understanding of the rule of technical systems in buildings easier?

○	○	○	○	○
not at all	not so much	a little bit	yes	yes, very much

9. Does the purpose method helps identify problems in the design of technical systems in buildings?

○	○	○	○	○
not at all	not so much	a little bit	yes	yes, very much

10. Does the purpose method helps to save energy in the building?

○	○	○	○	○
not at all	not so much	a little bit	yes	yes, very much

11. Was it clear and easy to apply the method to the room you selected?

○	○	○	○	○
not at all	not so much	a little bit	yes	yes, very much

12. Can you give us examples of problems you faced?

13. Has the method the potential to improve the communication between architects and building service engineers?

○	○	○	○	○
not at all	not so much	a little bit	yes	yes, very much

14. What kinds of problems in the selected rooms did you identify by using the method?
(multiple answers possible)

- ○ The room did not have sufficient sensors
- ○ There is not enough personal control possibility in the room
- ○ It is not clear which parts of the room are controlled by which device
- ○ Others

If others, please provide examples:

15. Most of you had selected smaller rooms. Do you think the method could be also applied to larger and more complex rooms?

○	○	○	○	○
not at all	not so much	a little bit	yes	yes, very much

16. What problems do you expect in using the method for larger rooms?

17. In order to apply the method to the room you had selected, how much time was approximately necessary?

○	○	○	○
less than 1 hour	1-3 hours	3-5 hours	more than 5 hours

If more than 5 hours, how long?

18. What were the main problems in using the method?
Please describe a few examples:

19. Do you have any specific suggestions for the improvement of the method?
Please provide them:

8.5. Interview with an architect

Fragebogen für Architekten/Planer A19_20160810[47]

1.	**Allgemeine Angaben**
1.1	Wie viel Jahre sind Sie bereits in der Baubranche tätig? ○ bis 5 ○ 6 – 10 ○ 11 – 15 ○ 16 – 20 ○ über 20
1.2.	Wie viel Mitarbeiter sind in Ihrem Büro/Unternehmen beschäftigt? ○ alleine ○ bis 5 *(2)* ○ 6 – 10 ○ 11 – 15 ○ über 15
1.3.	Sind in Ihrem Büro/Unternehmen ausschließlich Architekten/Planer mit den Entwurfs- und Planungsaufgaben beschäftigt? ○ Ja ○ Nein *Wenn nein, welche Fachdisziplinen noch?*
2.	**Ausbildungsspezifische Fragen**
2.1.	Welche Ausbildung(en) haben Sie absolviert? ○ Lehre *welche?* ○ HTL *welche?* ○ Studium *welches? Architektur* ○ andere Ausbildung *welche?*
2.2.	Haben Sie in Ihrer/Ihren Ausbildung(en) etwas über Gebäudetechnik gelernt? ○ Ja *Ganz wenig* ○ Nein ○ Weiß nicht mehr *Wenn ja, was haben Sie gelernt und wie genau?* *War dies Ihrer Meinung nach ausreichend für den Berufsalltag?* *A: „Nein“*

[47] Relevant statements in long answers are marked in grey.

2.3. Besuchten Sie nach Ihrer zuletzt abgeschlossenen Ausbildung Fortbildungen oder Schulungen betreffend dem Bereich Gebäudetechnik?

- ○ Ja

  Wenn ja, welche und wann?
- ○ nein

2.4. Sollte Ihrer Meinung nach in der Ausbildung zum Architekten/Planer auch etwas über Gebäudetechnik gelehrt werden?

- ○ Ja

Wenn ja, was und wie genau?

A: „Ich bin der Meinung, dass es einen theoretischen Block geben sollte, dass man die Grundlagen im Bereich Elektro und die Grundlagen im Bereich Sanitär – also Sanitär ist einfacher […], aber gerade im elektrischem Bereich bin ich von der Uni gekommen und konnte keine Lampe aufhängen, weil ich nicht mal wusste was eine Phase ist, geschweige was ein Nullleiter ist. Und ich bin der Meinung, dass man jeweils zu diesen zwei Blöcken Installation und Elektro jeweils ein Praxismonat machen sollte. Weil nur in der Praxis siehst du wies wirklich funktioniert."

I: „Also wirklich in einer Elektrofirma oder einer…"

A: „Ja, als Praktikant, weil du das auf der Uni nie so gelernt bekommst. […]"

(Anm. wir sprechen noch über die Uni und darüber, dass das Gelernte auf der Uni zum Großteil realitätsfremd ist).

A: „[…] Fakt ist, dass die Uni 20 Jahre hinten nach ist."

- ○ Nein

  Wenn nein, wieso nicht?

3. Praxisbezogene Fragen

3.1. In welcher Phase eines Projektes beginnt in Ihrem Büro die Zusammenarbeit mit Gebäudetechnikern?

A: „Eben nicht in der Entwurfsphase, weil ich da mit meinem Mann spreche. Man muss da etwas vorausschicken, der Beruf meines Mannes ist Maschinenbaukonstrukteur, er hat die HTL für Maschinenbau gemacht, er ist irrsinnig lange schon auf der Baustelle, kennt sich im Bereich Elektrotechnik und Installation sehr gut aus. Also überhaupt kein Architekt, keinen Entwurf, er ist nur im Bereich der Technik tätig. Dadurch kann ich mich mit ihm relativ gut absprechen im Bereich des Entwurfs. Da brauche ich dann niemanden."

I: „Also wann holst du deinen Mann dazu, wann zeigst du ihm den Entwurf?"

A: „Relativ zügig. Bevor ich ihn überhaupt einem Kunden zeige, gehe ich ihn vorher mit ihm durch, wie mache ich die Leitungen, wie machen wir das und das."

I: „Also während der Entwurfsplanung?"

A. „Ja. Damit wir eben dementsprechend wenig Leitungsführung brauchen. Elektro ist eine zweite Geschichte, weil da das ist recht stark für mich als

	Architekt. Wie positioniere ich das Licht, welches Licht…das kommt immer später. Das erste ist immer die Installation, die ist im Rohbau ganz stark drin. Bei der Elektrik wird ja das meiste geschlitzt und das tust ja eigentlich nachträglich dann installieren und das kommt dann eigentlich im Bereich des Polierplans in Kombination mit dem Kunden, wie er einrichten will und da kommen so viele Faktoren dazu." *-Wieso genau zu diesem Zeitpunkt und nicht von Beginn an?* *-Steht zu diesem Zeitpunkt die Entwurfsplanung schon?* ○ *Ja* ○ *Nein* ○ *teilweise*
3.2.	Wie erfolgt die Kommunikation zwischen Architekten und Gebäudetechnikern? *A: „Direkt." (Anm. Ihr Mann, der für die Gebäudetechnik zuständig ist, arbeitet im gemeinsamen Büro)*
3.3.	Welche der folgenden Entscheidungen kommen vom Architekten und welche vom Gebäudetechniker: *- Systementscheidungen (Heizsysteme…)? Gebäudetechnik +Kunde (Anm. Gebäudetechnik klärt den Kunden auf, welche Möglichkeiten vorhanden sind und welche Preisklassen diese haben. Und welchen Erfahrungswert die Heizung hat.)* *A: „Dieses Gespräch kommt schon, bevor der Entwurf anfängt. Das ist eines der ersten Gespräche. Weil das geht immer parallel. Der Kunde kommt und erzählt mir von seinem Traumhaus, und dann, beim gleichen Termin kommt mein Mann betreffend der technischen Daten. Dadurch dass wir sehr viel Kunde aus dem Bereich […] sind die technisch sehr versiert. Und da ist dann meistens so, die Frau, die das Bild des Hauses vor sich hat und die im Gespräch, Ästhetik, Haus, wie funktionell ist das Haus…da spricht mehr die Frau. Und der Mann, der sich im Freundeskreis schon relativ viel Gedanken gemacht hat über die Technik, der spricht dann mit meinem Mann. Und deshalb ist es ein Kombinationsgespräch, bevor ich überhaupt zum Entwurf gehe. Weil man muss ja schon vor dem Entwurf wissen, wie groß brauche ich die Technik, was kommt wo dazu, weil ich kann ja nicht den Technikraum dazuerfinden im Entwurf. Aber das passiert eben, bevor überhaupt der erste Strich gemacht wird. Und dann grenzt man halt ein, entweder das oder das. […]"* *- Entscheidungen über die Anzahl und Anordnung von:* ○ Fenster *A* ○ Beschattung *A* ○ Leuchten *A* ○ Heizkörper *A* ○ Ventilatoren *bis jetzt noch nie eingebaut* ○ Thermostate *GT* ○ Sensoren *GT* ○ Lüftungs- und Kühlungssysteme *GT*

3.4. Bitte erzählen Sie mir etwas über Ihre positiven und negativen Erfahrungen im Zuge der Zusammenarbeit mit Gebäudetechnikern!

A: „Also ich sage jetzt einmal, mit meinem Mann, aber auch mit der ausführenden Firma, wenn man sich die dementsprechend aussucht, wir haben jetzt nicht 15 verschieden Firmen, wir greifen eigentlich auf die zurück, bei denen wir wissen, dass es funktioniert."

I: „Sagt der Bauträger, ihr sollt vorschlagen wer die ausführenden Firmen sein sollen, oder legt das der Bauherr fest, oder ist das verschieden?"

A: „Wir holen wohl Angebote ein, ich frage den Bauherren vorher: ‚Hast du eine favorisierte Firma? Oder mehrere?', die kommen dann mit dazu. Entweder kennst du sie sowieso oder….dann erfährst du den Preis – dann kommen die Angebote rein, und dann siehst du auch schon an der Art und Weise wie er anbietet, ob seriös oder nicht seriös. Und dann wird mit dem Bauherren gemeinsam entschieden welches man nimmt. Also zu 99% sagt der Bauherr: ‚nimm bitte den der für dich passt, mit dem du die besten Erfahrungen gemacht hast. Er baut nur einmal im Leben, ich baue 15 Mal im Jahr. Und genau das passiert dann auch. Außer es ist der Bruder vom Bauherren, das ist dann überhaupt kein Thema. Da wird dann diese Firma genommen, da brauchen wir überhaupt nicht nachdenken. Die Frage war jetzt noch Mal?"

I: „Positive und negative Erfahrungen."

A: „Also eigentlich…also mit den Firmen mit denen wir arbeiten haben wir sehr viel positive Erfahrungen gemacht. Für mich ist das Wichtigste: ist etwas, kommt er? Und zwar nachdem die Baustelle abgeschlossen ist? Das ist einmal eine Grundvoraussetzung. Und eher negative Erfahrungen im Bereich Industrie. Was weiter geht in den Bereich des Gerätes das geliefert wird. Da kommt es ganz stark darauf an, welchen Betreuer du hast. Wann der Techniker kommt, wie der Techniker kommt. Weil da kann dann der ausführende Installateur nicht weiterhelfen. Das heißt, du bist dann im Bereich Industrie, der das Gerät liefert […]. Und dann kommt es auch noch darauf an, bei den Geräten selbst, von der Bedienbarkeit, wie einfach sie zu bedienen sind, je einfacher, desto besser, weil der Kunde ist kein…nicht immer ein super Techniker, und natürlich auch wie viel Anschlüsse wir brauchen, ist das für jedes Gerät gleich anzuschließen, von der elektrischen Seite, das ist wieder eine Geldsache. So wird das dann ausgewählt. Aber prinzipiell nie ein No-Name Produkt, weil die Servisierung ist nicht kalkulierbar."

I: „Und wenn der Bauherr sagt, er will ganz ein Billiges?"

A: „Dann bekommt er einen Aktenvermerk, dass ich ihm ein anderes Empfohlen hätte, aber der Bauherr ist immer der, der schlussendlich das Sagen hat. Wenn er das will dann ja, aber mit Hinweis."

3.5. Inwiefern beschäftigen Sie sich als Architekt/Planer mit der Planung der technischen Gebäudeausrüstung?

A: „Also ich ganz wenig, mein Mann ist hauptsächlich für das da. Also das heißt, wir haben im Büro eh alles."

	I: „Aber du als Architektin nicht?“ *A: „Gar nicht.“*
3.6.	Wie werden Entscheidungen getroffen wo welche technischen Geräte platziert werden? ○ Erfahrungswerte Berücksichtigen diese Erfahrungswerte die Einflusszonen der technischen Geräte? Wenn ja, inwiefern? ○ Simulationsprogramm Berücksichtigen diese Programme die Einflusszonen der technischen Geräte? Wenn ja, inwiefern? ○ Andere (Welche?)
3.7.	Mit welchen Programmen arbeiten Sie? *A: „AVIS, oder je nachdem.“* *I: „Hat dein Mann ein Programm für die technische Gebäudeausrüstung?“* *A: „Er macht das mit der Hand. Weil er sagt, weil er mit der Hand viel weniger übersieht als am Computer. Er macht vieles so, dass er es sofort auf 50 bringt, ausschnittsweise sich das größer herauszeichnet und er damit dann auch auf die Baustelle geht. Also das ist alles so, ist zwar noch urzeitlich, aber es funktioniert viel besser als im Bereich PC. Und er ist schneller, du wirst es nicht glauben! Wenn du von der Entwurfsplanung bis zur Polierplanung das aufbauend hast, dann ist es mit dem Computer schneller, aber wenn du die Leitungen oder den Regenwasserkanal einzeichne, dann brauch ich Punkterle, Stricherle, und so weiter. Da bin ich mit der Hand 15 Mal schneller. “* *Können in diesen Programmen die Einflussbereiche der technischen Geräte dargestellt werden?*
3.8.	Wie ist Ihrer Meinung nach das Wissen der Architekten/Planer über Gebäudetechnik und die Planung technischer Systeme? *A: „Das ist ja allgemein, das kann ich dir gar nicht beantworten. Es gibt sicher Architekten, die kennen sich super aus. Ich bin der Meinung, ich war mit der Kammer in Vorarlberg […] und wenn du dir anschaust, wie in Vorarlberg die Zusammenarbeit auch im öffentlichen Bau zwischen Architekten und Fachplanern funktioniert, die schon seit Jahrzehnten Fassaden und Heizsysteme zusammengeführt hat, wie es bei uns…da hat man noch gar nicht gewusst, dass es dieses System gibt. Dann kann der Architekt, der in diesem Bereich arbeitet, viel profitieren, denn du lernst als Architekt viel dazu, es ist nicht so, dass es bei dir spurlos vorübergeht. Du brauchst ja keine Schule dafür, es bringen dir genau solche Kooperationen ja auch viel. Ich kenne aber auch andere Architekten, für die wir die Bauleitung machen da in Kärnten, die in Salzburg zuhause sind, und einfach diese Strecke zu lange ist, da machen wir die Bauleitung. […]“* *I: „Also verschieden?“* *A: „Ja, ganz verschieden.“* ○ Sehr gut ○ Gut

- Mittelmäßig
- Schlecht
- Verschieden, je nach Berufserfahrung

Bitte begründen Sie diese Bewertung!

Kommt auf das Interesse darauf an.

3.9. Was würde sich ändern oder verbessern, wenn sich Architekten/Planer *(noch)* besser mit der Gebäudetechnik auskennen?

I: „Würde sich etwas ändern?“

A: „Natürlich, ja, aber du hast als Architekt schon so vielfältige Felder die du abdecken musst, und du kannst nicht alles abdecken, das ist nicht möglich. Was du brauchst ist ein gewisser Überblick, was ist möglich, was ist nicht möglich. Ich glaube, dass unser ganzes Bausystem verändert werden müsste. Von Grund auf. Mehr Vorlaufzeit. Wenn du die nicht hast, und nur so ein System hast wie wir, wenn du mit einem fremden Elektroplaner, einem Installationsplaner zugreifen musst, dann brauchst du mehr Vorlaufzeit. Dann bin ich der Meinung, dass die Elektroplaner und die Installationsplaner bei uns schlecht ausgebildet sind. Weit weg von dem, dass du sagen könntest, dass die in das Gespräch viel Know-How mitnehmen. Gerade in Kärnten, ich kann jetzt nur von Kärnten reden. Es gibt in Wien vielleicht top Gebäudeplaner, bei uns gibt’s das nicht – das sind kleine Installateure, die sich nicht im Installationsbereich selbstständig gemacht haben, sondern halt dann in diese Richtung gegangen sind […]. Also ich sage einmal, das muss sich grundsätzlich ändern. Richtige Techniker die sich mit der Gebäudetechnik identifizieren, oder es müsste dementsprechende Ausbildungen dafür geben. Aber vorranging müsste es auch einen Bauherren geben, der diese auch bezahlt. Da scheitert es! Keiner meiner Bauherren, der nicht im öffentlichen Bereich ist, habe jetzt gerade ein Beispiel: Planung eines wirklich großen Hotels am Wörthersee. Angebot Nebenplaner…der will nicht einmal einen Statiker zahlen. Kein Geld der Baufirma. Das heißt, grundsätzlich lehnen die Planer ab, weil sie können alles selbst. Grundsätzlich ist bei einem Planer das Problem: Da ist noch kein Stein am Boden und sie müssen schon eine Rechnung zahlen. Den Architekten, ja, weil sie etwas Schönes haben wollen, das geht gerade noch. Aber das Rohr, das ist ihnen genau egal. Und das Licht, das macht eh der Architekt und das eine macht auch der Architekt, weil den zahlen wir eh, also für was brauche ich einen Nebenplaner.“

I: „Also dem Bauherren ist es nicht bewusst, dass sie von Anfang an einen Gebäudetechnikplaner brauchen würden, damit dann auch alles funktioniert?“

A: „Nicht nicht bewusst, sie lehnen ab.“

I: „Auch wenn du als Architektin ihm sagst, dass das notwendig ist?“

A: „Ja.“

I: „Auch wenn du ihnen sagst, dass dann später Mehrkosten auf sie zukommen?“

A: „Das sehen sie nicht. Das wollen sie auch nicht sehen. Anders ist es im öffentlichen Bereich. Im öffentlichen Bereich kann ich aber nicht so mitreden, weil ich im öffentlichen Bereich nichts mache und ich absolut ablehne bei Wettbewerben mit zu machen, weil eh schon alle vorher wissen wer es gewinnt. […] Es kann sein, dass sie sagen, OK, das interessiert mich jetzt gar nicht (Anm. die Gebäudetechniker).“

I: „Also es ist jetzt wirklich eine Kostenfrage, dass die Bauherren sagen, nein das interessiert mich nicht, der Architekt der macht das eh?

A: „Gehen wir von einem kleinen Einfamilienhaus aus. Da braucht man es meines Erachtens auch nicht. Aber lassen wir es einmal sein. Der Nebenplaner, also der Installateur, kostet Hausnummer 35.000 Euro. Und der Nebenplaner 7.000 Euro. Also Nebenplaner mit Planung, mit Bauaufsicht, der fährt ja zu kleinen Häusern genauso oft hin wie zu großen. Kostet. Und für was? Das sieht er nicht. Das geht da unter. [...]“

I: „Mir hat das letzte Mal ein Gebäudetechnikplaner erzählt, dass er es nicht versteht, dass er erst so spät hinzugeholt wird.“

A: „Weil er vielleicht erst hinzugeholt wird wenn es ein Problem gibt. Sonst wird er gar nicht hinzugeholt.“

I: „Er sagte, er wird erst ganz späte hinzugeholt, erst wenn der Entwurf schon steht. Wenn die Einreichung erst..“

A: „Am ehesten holt ihn der Architekt dazu zum Ausschreiben. Weil da kennt er sich nicht aus. Und vorher will er ihn nicht sehen. Genau, das ist so.“

3.10. Wie schätzen Sie Ihr eigenes Wissen über Gebäudetechnik und die Planung technischer Systeme ein?

- Sehr gut
- Gut
- Mittelmäßig
- Eher schlecht
- Schlecht

Bitte begründen Sie diese Bewertung!

Ganz klare Aufgabenteilung und sie hat nichts damit zu tun.

3.11. Beeinflusst die Gebäudetechnik den Entwurfsprozess des Architekten/Planer?

- Ja
  Inwiefern?
- Nein
  Wieso nicht?
- Teilweise
- Weiß nicht
- Sonstiges

Bitte begründen Sie diese Bewertung!

A: „Meistens nicht.“

I: „Kommt wahrscheinlich auf das Projekt darauf an?“

	A: „Ja, im Allgemeinen ist man in der Entwurfsphase mit der Gebäudetechnik nicht […] (Anm. nicht verstanden)“
3.12.	Was würde sich ändern oder verbessern wenn die GT im Entwurf (mehr) Berücksichtigung findet? *A: „[…] ich habe jetzt noch keinen Gebäudetechniker kennengelernt, der jetzt wirklich…also Sinn macht es ja in dem Bereich Passivhaus, Niedrigstenergiehaus und so weiter. Weil da solltest wirklich ein bisschen was berechnen. Diese Berechnungen sind auch mit Vorsicht zu genießen, weil die Realität und die Berechnung gehen halt auch so auseinander. Aber prinzipiell, was wäre vielleicht wirklich interessant, aber das setzt halt auch voraus, dass der Gebäudetechniker, also dass man sich gut kennt. Weißt du was ich meine?! Da kannst du jetzt irgendwen anrufen und sagen: So, jetzt komme oder ich gehe zu 3 und sage: biete mir an und schaue was du kostest und nehme den Günstigsten. Das ist dann schon…deshalb gibt es bei mir im Büro ja meinen Mann…man braucht jemand den man kennt. […] Er muss auch wissen, wie du arbeitest. Welche Richtung du gehst. Er müsste sich auch mit dem Entwurf auseinandersetzen, und warum was wie geplant ist. Damit er das dann in seinem Metier dementsprechend sagen kann: das können wir aber nicht, weil. Aber auch versteht warum es da ist und was gibt es für Alternative. Diese Gemeinsamkeiten die gibt es nicht, das habe ich noch nie gesehen. Da gibt es den Plan und der Plan wird per Email in sein Büro geschickt. Dort zeichnet er seine Durchbrüche und so ein und dann geht das Ganze wieder zurück und das war es. Das ist ja keine Zusammenarbeit. Aber, unterm Strich, sagen wir mal so, er vom Honorar am Ende hinuntergedrückt, schnell schnell. Du hast das Problem, wenn der Kunde zu bauen anfangen will, dann will er morgen den Plan fertig haben, weil vorher kommt er ja nicht zu dir. Das heißt, du hast keine Zeit. Du musst schnell sein. Das heißt, eine Vorlaufphase für die Planung, für das Projekt, das gibt es bei uns ganz selten. Da hakt es.“* *I: „Das heißt, es müsste mehr Zeit da sein um…“* *A: „Gibt es. In Vorarlberg habe ich das gehabt, vor allem im öffentlichen Bereich, dass das funktioniert und ganz stark im Bereich wo die Gemeinde dahinter steht, wo im Vorfeld viel geplant wird, viel Geld fließt und das Ganze dann zügig umgesetzt wird. Aber einfach, dass die Vorlaufzeit da ist bei einem Projekt. Gerade bei den größeren Projekten. Bei den Kleinen nicht: Da hat er das Sparbuch voll, und jetzt baut er. Da hat er das Grundstück und jetzt baut er. […]“*
3.13.	Haben Sie Ideen oder Vorschläge wie es dem Architekten/Planer erleichtert werden kann, die Gebäudetechnik schon im Entwurf mit einfließen zu lassen? *A: „Es muss halt jemand zahlen. […] Der Architekt ist glaube ich der Letzte, der sich dagegen spreizen würde mit einem Gebäudetechniker zusammenzuarbeiten, wenn es gezahlt werden würde.“* *I: „Das heißt, es muss klar sein, dass der Gebäudetechnik von Anfang an notwendig ist und er von Anfang an zu zahlen ist.“*

	A: „Genau, weil was ist das erste, was der Bauherr, wenn er bei dir bei der Türe hereinkommt fragt? Was kostet das. Jetzt hast du die Möglichkeit, den Gebäudetechniker mit einzurechnen, dann bekommst du den Auftrag nicht. Jetzt rechnest du deins und sagst: ‚Ich brauche vielleicht noch einen Gebäudetechniker.' ‚Nein, für was?' Das funktioniert nicht! Du musst beim Kunden anfangen. Der Kunde muss das Gefühl haben, einen Gebäudetechniker zu brauchen. Gar kein Problem. Aber wenn der Kunde von Anfang an sagt: ‚für was brauche ich das?', dann hast du keine Chance." *-Welche Methoden würden Sie vorschlagen?*
3.14.	Haben Sie eine Idee wie man einem Architekten/Planer das Verständnis zur GT näher bringen kann? *A: „Also im Bereich der Ausbildung. Da gibt es zwar…wie hat das Fach bei mir geheißen…egal…ein Fach, da hat man einen Kanalplan gezeichnet und einen Elektroplan und das war es. Und das in fünf Jahren. Welches Verständnis hat man da? Das war vorgegeben, das ist nicht einmal aus deinem Entwurf entstanden. Weil es gibt ja eh den Nebenplaner, brauchen wir ja eh nicht. Aber ich glaube, wenn wir mehr über die Gebäudetechnik gelehrt bekommen würden, dann würden wir mehr verstehen, warum wir den Gebäudetechniker brauchen."*
3.15.	Im Folgenden werde ich Ihnen kurz ein Schema vorstellen mit dem unter anderem das Verständnis zur GT erhöht werden kann sowie das die Planung und Anordnung technischer Geräte schon in frühen Planungsphasen leicht ermöglicht. Damit kann eine optimale Integration der technischen Gebäudeausrüstung sowie eine optimale Steuerung in Form der richtigen Kombinationen der Reglerpositionen erreicht werden. Dazu bitte ich im Anschluss um Ihre Meinung. (Schema wird kurz erläutert) *A: „Wo der Kunde dabei sein muss, weil er bedient es. Das ist ein Schema das du mit dem Kunden aussucht und an alle Techniker weitergibst. Damit würdest du ihm seine Arbeit sehr erleichtern. Und der Kunde kann dann sagen, ich mache vom Wohnzimmer aus mit dem Schalter das, das und das. Das soll eingeschaltet werden, wenn das ausgeschalten wird. Wir sind da ja stark im Bereich des Bussystems. Das natürlich auch wieder ein Kostenfaktor ist. Aber das Schema brauchst du, wenn du das installierst, weil du dann genau wissen musst, wo du was positionierst."* *I: „Glaubst du würde das angenommen werden von Architekten, oder glaubst du, das wäre zu kompliziert oder sagen, das ist jetzt nicht…"* *A: „Für so einen kleinen Raum brauchst du das nicht. Für einen Großen, muss das Programm so was von einfach sein […]"* *I: „Genau, so einfach wie möglich, ohne dass man sich zeitintensiv einlernen muss. Denn für die komplizierten Programme gibt es die Gebäudetechnik."* *A: „Man muss es relativ zügig einbringen können, wo was zu schalten ist. Was ich wo haben möchte an Wärme, an elektrischen…was weiß ich…Jalousien, rauf, runter, Beschattung, Markise […] das ist das was der*

Elektroplaner braucht, und dann…ja…die einzelnen Raumtemperaturen. Im Schlafraum ist eine andere Raumtemperatur als im bewohnten Raum, bei der kontrollierten Wohnraumlüftung geht das System teilweise in einem, also eher schwieriger, aber das ist das was eigentlich dargestellt werden muss. […] Dann könnte der Gebäudetechniker wieder einen Input an die Industrie geben, was eigentlich gefragt wäre am Markt. Weil so gibt ja immer die Industrie vor. Der Weg ist ja der falsche. Die Industrie: ‚das gibt es und ihr müsst jetzt handeln.' Die Industrie weiß aber nicht, was der Endverbraucher jetzt wirklich will. Der Planer weiß die Situation vom Endverbraucher, der gibt das an den Gebäudetechniker weiter und dieser hat den Kontakt zur Industrie. Die Industrie entwickelt dann wieder für den Endverbraucher. Dann wäre das sehr wohl ein interessantes Tool. So wie das jetzt ist, ist es schwierig. Ich sage mal, ja in größeren Bereichen. Also Hotelbau, dort wo du vieles an Technik drin hast. Von der Lüftung, von der Klima […]."

I: „Also für größere Objekte ja, für kleinere Objekte…"

A: „Ja, natürlich auch, wenn wir den Zugang zu dem Thema ändern […] Also es scheitert bei uns halt alles am Geld."

8.6. Interview with a building service engineer

Fragebogen für Gebäudetechniker 10_05082016[48]

1. Allgemeine Angaben
1.1. Wie viel Jahre sind Sie bereits in der Gebäudetechnikbranche tätig? ○ bis 5 ○ 6 – 10 ○ 11 – 15 ○ 16 – 20 ○ über 20
1.2. Wie viel Mitarbeiter sind in Ihrem Büro/Unternehmen beschäftigt? ○ alleine ○ bis 5 ○ 6 – 10 ○ 11 – 15 ○ über 15
1.3. Sind in Ihrem Büro/Unternehmen ausschließlich Gebäudetechniker mit der Planung technischer Gebäudesysteme beschäftigt? ○ Ja ○ Nein *Wenn nein, welche Fachdisziplinen noch?*
2. Ausbildungsspezifische Fragen
2.1. Welche Ausbildung(en) haben Sie absolviert? ○ Lehre *welche? Koch/Kellner* ○ HTL *welche?* ○ Studium FH Gebäudetechnik in Pinkafeld *welches?* ○ andere Ausbildung *welche?*

[48] Relevant statements in long answers are marked in grey.

2.2. Haben Sie in Ihrer/Ihren Ausbildung(en) etwas über die Arbeitsbereiche der Architekten/Planer (Prozesse des Entwerfens der Architekten/Planer) gelernt?

- Ja
- Nein (Anm. er sagt zu erst ja, widerspricht sich jedoch dann im Gespräch)
- Weiß nicht mehr

Wenn ja, was haben Sie gelernt und wie genau?

GT: „In der Fachhochschule hast du ja einen Teil Bautechnik. Da hast du Vorlesungen in Bautechnik. Da war vom Design und so weiter nichts – und Projektsteuerungsgeschichten. Kann man so sagen – und ja, naja, also richtig viel haben wir da mit den Architekten, über die Architekten und über die Vorgangsweise der Architekten nicht gelernt. Sondern wie so ein Projekt abläuft von der Entwicklung, vom Wettbewerb weg, bis zum Entwurfsplan. Oder Vorentwurf – Entwurf. Dann diese Projektpläne, Einreichpläne und wie der Prozess abläuft. Aber wie ein Architekt arbeitet – das weniger. Das ist mir heute oft noch unklar."

War dies Ihrer Meinung nach ausreichend für den Berufsalltag?

GT: „Ja, für meine Sachen schon. War es schon ausreichend. Gut wäre, wenn der Architekt einen Vorentwurf macht, sich schon überlegt, oder schon Haustechniker kontaktiert und sagt, was werden wir für ein Heizungssystem nehmen und dann schon den Platzbedarf mit einplant. Weil gerade der Platzbedarf für irgendwelche Technikräume – das kommt immer zu kurz und wird immer vernachlässigt und dann wird eigentlich irgendeine Notlösung gefunden, dass man zum Beispiel aus einem Archiv einfach einen Technikraum dann macht. Und der ist meistens zu klein und dass vorher nicht klar definiert ist was man eigentlich genau will. Weil oft einmal plant der Architekt ein schönes neues Objekt, ich sage jetzt einmal einen Kindergarten, und spricht mit dem Bauherren nicht ab, ob er eine Lüftung will, eine kontrollierte Wohnraumlüftung, wie das System ausgeführt werden soll, es wird eher auf das Design und nicht auf den Betrieb Wert gelegt. Da gibt es oft – also wir kommen eigentlich immer zu spät dazu. Beim Projekt ist mindestens schon der Vorentwurf / Entwurf schon alles fertig meistens noch vor der Einreichung – weil er einreichen sollte – dann noch die technische Beschreibung der Haustechnik noch dazukommen. Oder, das ist meistens auch so, dass die Emissionswerte sind von einem Kessel oder so Lärm, also meistens Luft- und Lärmemissionen sollten da dann drinnen sein (Anm. in der Baubeschreibung für den Entwurf)."

2.3. Besuchten Sie nach Ihrer zuletzt abgeschlossenen Ausbildung Fortbildungen oder Schulungen?

- ○ Ja

Wenn ja, welche und wann?

Brandschutzmanagement postgradual in Krems, Brandschutzmanager, diverse Seminare für Lüftungstechnik, Klimatechnik, Heizungstechnik. Bei der Ziviltechnikerkammer meistens.

A: „Hast du das alles freiwillig gemacht?“

GT: „Ja, weil es einfach dazu gehört. Sachverständigenausbildung noch gemacht..was noch? Bau KG Ausbildung gemacht.“

- ○ Nein

2.4. Sollte Ihrer Meinung nach in der Ausbildung zum Architekten/Planer auch etwas über Gebäudetechnik gelehrt werden?

- ○ Ja

Wenn ja, was und wie genau?

GT: „Was Gebäudetechnik ist. Was das alles abdeckt, das man Grundzüge hat, was der Gebäudetechniker macht und dass man ein bisschen die Systeme kennenlernt. Eine Fußbodenheizung, eine Wandheizung, eine Deckenheizung. Heizkörper, die oben sind…klar aber zum Beispiel bei der Lüftung gibt es viele Sachen – Klimatechnik zum Beispiel, mit den großen Glasfassaden gibt es oft das Thema mit Überwärmung. Dadurch dass man schon sehr viele Geräte, gerade im Büro haben, dass man hohe interne Lasten hat, dass man solche Sachen schon ein bisschen berücksichtigt beziehungsweise dass jemand ein Gefühl bekommt, was benötige ich an Heizleistung pro m² zum Beispiel so wie es jetzt ist, 50 Watt pro m², wenn es besser gedämmt ist dann halt ein bisschen weniger. Und für was brauche ich eine Kühlleistung? Zum Beispiel solche Sachen.“

I: „Und wissen das die Architekten zu wenig, deiner Meinung nach?“

GT: „Die haben überhaupt keine Ahnung davon. Und, vom Platzbedarf, wie groß zum Beispiel Rohre sind. Solche Sachen. Ich meine, dass man Schächte braucht, das ist schon klar und dass man das Wasser nicht aufwärts rinnend bewegen kann, sondern dass man Sanitärgruppen möglichst übereinander anbringen muss.“

I: „Wissen das die Architekten auch zu wenig, deiner Meinung nach?“

GT: „Naja, wir haben sehr viele Baustellen, die, wie soll ich sagen, da ist kein WC über dem anderen. Das heißt, du hast jetzt 4 oder 5 Geschoße und du musst mit dem WC jedes Mal kreuz und quer springen und dann hast du zu wenig Fußbodenaufbau und bekommst das Gefälle nicht zusammen. Grundsätzlich ist alles möglich, nur du kannst dort dann auch nicht mehr reinigen, wenn verstopft ist. Wenn eine Verstopfung ist, hast du dann keine

Möglichkeit mehr das zu reinigen. Weil in jedem Geschoß musst du 5 oder 6 Meter in einer fremden Wohnung sein, dass du wieder zur nächsten Sanitärgruppe kommst. Das ist halt vom Betrieb, und wenn mal was ist, eine Verstopfung, musst du fast aufstemmen."

I: „Und wenn du bei der Entwurfsplanung oder nach der Entwurfsplanung dazugeholt wirst, und das dann sagst?

GT: „Dann ist meistens schon zu spät, weil das ganze Grobkonzept schon so viel Zeit und das ist Geld, investiert worden ist, und das wird dann selten noch geändert. Ich habe etwas vergessen: Eigentlich muss ich schon bei der Budgetierung von solch einem Projekt, wenn der Architekt den Auftrag bekommt so etwas zu planen, und dann sagt er gleich, das wird so und so viel kosten, dann muss er gleich ja oder nein. Und da gehört eigentlich schon der Haustechniker dazu, dass er sagt, was wird das jetzt kosten. Weil auf das wird sehr oft vergessen: ´Eine Lüftung? Und das und das brauchen wir auch?` Und dann gehen die Kosten davon und dann wird immer gespart und dann ist das Budget eh nicht mehr da. Dann wird es vielleicht noch einmal aufgestockt und dann kommt etwas anderes weg – für die Haustechnik wird sowieso immer am wenigsten, wie soll ich sagen, Budget zur Verfügung gestellt. Es wird immer bei der Haustechnik mehr oder weniger eingespart."

I: „Wieso ist das deiner Meinung nach so?"

GT: „Weil es am Anfang, beim ersten Entwurf, oder beim Vorentwurf, Kostenschätzung schon nicht berücksichtigt wird."

I: „Wieso nicht? Wieso wirst du nicht von Anfang an dazugeholt?"

GT: „Keine Ahnung! Keine Ahnung. Ich habe bei ein paar Wettbewerben mit gemacht, in Graz mit Grazer Architekten beziehungsweise das war mehr so ein Konsortium. Da war der Architekt, der Bautechniker und da bin ich schon dazugekommen, da haben sie mich schon gefragt wie ich was machen könnte und was es kostet. Das hat super funktioniert. Leider haben wir nie einen Wettbewerb gewonnen, wir sind immer zweiter oder dritter geworden."

I: „Das sind dann wahrscheinlich immer die spezielleren Sachen, oder?"

GT: „Ja. Aber dort wird bei der Auslobung schon definiert, du brauchst einen Haustechniker. Also da war von vornherein klar, da brauchst einen Haustechniker. Damit sind die gezwungen, dass sie einen Haustechniker anführen und das in dem Wettbewerb mit angeben. Aber das ist halt nur sehr sehr sehr sehr selten. Also ich habe jetzt gerade da den Architekten […] aus Graz, da geht es um eine Burg in […] die komplett revitalisiert werden soll und da bin ich jetzt schon in der Vorentwurfsplanung schon voll dabei. Er nimmt schon meine Sachen mit auf, wie kann man die Versorgung gestalten und so weiter. Und viele machen sich da ja überhaupt

keine Gedanken, wie bekomme ich die Heizung dort hin, oder was mache ich für Heizung? Was habe ich überhaupt für Möglichkeiten? Reden alle von Wärmepumpen, und ich habe nicht mal die Möglichkeit Wärmepumpen aufzustellen."

I: „Also hängt das vom Architekt wahrscheinlich auch ein bisschen ab, ob er dich gleich hinzuzieht oder erst später wenn es dann sein muss?"

GT: „Genau. Das ist die Erfahrung, die ich gemacht habe, dass wir immer zu spät dran sind. Und aus dem ergibt sich dann das Konfliktpotenzial. Weil der Kostenrahmen steht, du musst eine Haustechnik planen, die etwas kostet, das ist dann meistens teuer. Das musst du dann irgendwo billiger werden, oder der Platzbedarf ist nicht da. Wenn das dann da ist – oft ist das dann eingereicht, mit der Geschoßflächenzahl und so weiter. Dann hast du aber keine Möglichkeit mehr. Dann muss der Architekt irgendetwas aufgeben, und am wenigsten gerne gibt er sein Konzept, sein architektonisches Grundkonzept beziehungsweise die Optik, also die äußerliche Gestaltung auf. Wenn du dann sagst, du brauchst ein Lüftungsgitter auch noch, in der Fassade, dann fallen sie aus allen Wolken. Ja…weil mit dem hat niemand gerechnet. Und…also ich habe ja nicht Architektur studiert, aber mir kommt vor, das wird auf der Hochschule auch zu wenig transportiert. Das ist eben…was brauch ich für eine Lüftung, ich brauche eine Ansaugung, ich brauche eine Ausblasung und einen Raum. Ein Lüftungsgerät für 3.000 Kubikmeter, das ist eben zum Teil fünf Meter lang und zwei Meter hoch und 80 Zentimeter breit."

(Anm. ich erkläre kurz wie zu meiner Zeit Gebäudetechnik an der Uni gelehrt wurde und dass sehr wenig gelehrt wurde)

GT: „Das ist danach dann vielleicht im Architekturbüro, wenn man dann damit zu tun hat, dann kommt man mit Haustechnikern in Kontakt. Das merkt man auch bei den Architekten, die eher technisch sind, es gibt welche…in Wien kannst du ja auf der Kunst, auf der Technik oder auf der normalen Uni studieren. Nur du merkst sofort wo einer herkommt, weil die einen anderen Zugang haben. Die machen einfach mehr. […] In Wien gibt es welche die auf der Kunst studieren, das sind dann die Magister Architekten. Da geht es um die Raumgestaltung, die Oberflächen und alles Mögliche, das Design, nur da kann man damit nichts anfangen. Da gibt es für die Haustechnik überhaupt keinen Platz."

I: „Planen die richtig Gebäude oder ist das nur Innenarchitektur?"

GT: „Die planen richtig Gebäude. Zumindest habe ich die Erfahrung gemacht, dass die richtig Gebäude planen beziehungsweise den Umbau von einem Hotel machen. Der plant einen Umbau wo alles dabei ist. Nur, da gibt es kein Verständnis. Und auch keine Bereitschaft irgendetwas zu machen. Das ist leider so."

I: „Ich spreche ja auch mit Architekten, und manche sagen, dass sie die Gebäudetechnik im Entwurf einfach einschränkt."

GT: „Es gibt bei der Haustechnik einen Spruch: `das was der Architekt in seiner Planung verbockt, das muss der Bauphysiker wieder gut machen und das was der Bauphysiker schon nicht mehr gut machen kann, das muss der Haustechniker retten.` Ja! Das zum Beispiel ist ein Betriebsgebäude." (Anm. spricht über das Gebäude indem sein Büro ist). „Da hörst du die Dachrinnen, da hörst du alles Mögliche, da hörst du den Ablauf. Aber wenn ich so ein Büro plane und einen ordentlichen Schacht mache und der Schacht gedämmt ist, dann ist es überhaupt kein Problem, dass ich nichts mehr höre. Das ist eigentlich ganz etwas Leichtes. […] (Anm. spricht noch über das Gebäude)"

I: „Ich habe auch schon gehört, dass Gebäudetechniker oft erst später hinzugeholt werden, weil ihn früher keiner zahlt?"

GT: „Ja, wenn es ein Generalplaneurauftrag ist, dann wird es sowieso schwierig. Dann versucht man das bis zum Schluss hinauszuschieben, dass man dem Gebäudetechniker möglichst wenig zahlen muss, weil ich selbst das Honorar brauche."

- Nein

Wenn nein, wieso nicht?

3. Praxisbezogene Fragen

3.16. In welcher Phase eines Projektes beginnt in Ihrem Büro die Zusammenarbeit mit Architekten/Planern?

GT: „Manchmal ist es schon beim Wettbewerb, und manchmal ist es schon bei der Einreichung. In der Regel ist die Entwurfsplanung schon abgeschlossen und dann kommt die Einreichung und man sagt dann, das und das braucht man für die Einreichung."

I: „Kommt es dann vor, dass man Abstriche von der Gebäudetechnik und nur mehr das notwendigste macht, weil dann oft kein Platz mehr dafür ist?"

GT: „Es ist schon vorgekommen, dass der Gebäudetechniker gesagt hat, wir haben keinen Platz für die Lüftung und wir haben dann auf die Lüftung verzichtet. Es war jetzt gerade bei einem Projekt, das wird in Passivhausweise gebaut, ein Kindergarten, wunderschöne Verglasung, alles Holzbau, toll gedämmt, und und und, und jetzt dann hat es geheißen, wir können mit der Lüftung die Gruppenräume nicht bedienen, weil wir haben zu wenig Zwischendecke, weil die Entwurfsplanung, beziehungsweise die Einreichplanung schon fertig war und die Geschoßflächenzahl und alles was da dazukommt, dann hat es geheißen: ja dann lassen wir die Lüftung weg. Wobei das bei einem heutigen Gebäude, wenn ich sage, ich baue auf Niedrigenergiestandard einen Kindergarten, wo die Kinder im Sommer oder im Winter nur drin sind – oder in Schulgebäuden, das ist eigentlich Standard, dass es eine Lüftung

gibt. Jetzt machen wir halt nur eine WC-Lüftung und eine Garderobe-Lüftung. Meiner Meinung nach nicht so optimal. Da ist das einfach nicht fertig gedacht. Und da ist es wirklich um die Zwischendeckenhöhen gegangen. Weil der Architekt gesagt hat, er braucht mindestens die und die Höhe und hat keine Abstriche gemacht. Ich muss ja dort irgendwie vorbeifahren. Und dann hat er sich quasi erweichen lassen, weil der Elektriker dann gesagt hat: Die Lampen, die Sie haben wollen, haben eine Einbautiefe von 12cm, die bekomme ich in eine Decke mit 9cm nicht hinein. Dann ist er von seiner Raumhöhe etwas hinuntergegangen. Jetzt sind wir halt auf 2m85, statt auf 2m90. Ich weiß nicht welche Vorschriften bei einem Kindergarten sind, wie hoch da die Räume sein müssen. Klar ist ein hoher Raum schöner. Da wird halt sehr viel Wert aufs Äußerliche gelegt und nicht auf den Betrieb und den Nutzer selbst."

-Wieso genau zu diesem Zeitpunkt und nicht von Beginn an?

-Steht zu diesem Zeitpunkt die Entwurfsplanung schon?

- *Ja*
- *Nein*
- *Teilweise*

3.17. Wie erfolgt die Kommunikation zwischen Architekten und Gebäudetechnikern?

GT: „Hauptsächlich per E-Mail, weil heutzutage musst du ja alles schon schreiben, weil per Handschlag kannst du ja nichts mehr ausmachen. Dann bei Baubesprechungen, und vielleicht gibt es am Anfang ein paar Sitzungen, ein paar Sitzungen bei denen man sich mit dem Gebäudetechniker zusammensetzt und dem Architekten und sagt welches Heizsystem man braucht, wie viel Platz es brauchen darf, dass man Varianten gegenüberstellt, was kostet das. Wir haben auch schon gehabt, dass man zum Beispiel Systeme komplett ändern haben müssen, weil das Budget dann nicht mehr da war. Da hat der Architekt gesagt: machen wir eine Wärmepumpe, eine Wärmepumpenanlage und dann sind wir drauf gekommen, dass die Wärmepumpenanlage viel zu teuer ist, weil wir ja die Tiefenbohrung brauchen und die Flächenverlegung und der Platz nicht da war und die Kosten. Dann ist eine Pelletsheizung gemacht worden, weil die kann man kleiner und kompakter machen, da braucht man nur einen Heizraum mit 15m² und einen Lagerraum mit 15m². Und jetzt müssen sie den Lagerraum aber im Jahr 2 bis 3 Mal füllen, was ja auch schwachsinnig ist, weil du hast ja 3 Mal dann die Anreise. Das heißt, der kommt anfang Winter, mitte Winter und wenn das Frühjahr etwas kälter ist, dann muss der ein drittes Mal kommen in der Heizperiode. Eigentlich schachsinnig. Aber es ist so. Es ist nicht mehr anders gegangen."

3.18. Welche der folgenden Entscheidungen kommen vom Architekten und welche vom Gebäudetechniker:

- Systementscheidungen (Heizsysteme…)?

A+BH (besprechen es gemeinsam)

- Entscheidungen über die Anzahl und Anordnung von:

- Fenster A
- Beschattung A
- Leuchten A
- Heizkörper A oder GT in Abstimmung mit A
- Ventilatoren GT
- Thermostate GT+ET
- Sensoren GT
- Lüftungs- und Kühlungssysteme GT

- Spielt der Elektrotechniker bei diesen Entscheidungen eine Rolle?

3.19. Wie werden Entscheidungen getroffen wo die zuvor erwähnten technischen Geräte platziert werden?

Das macht der Architekt – der gibt die Platzierung vor

- *Erfahrungswerte*
  Berücksichtigen diese Erfahrungswerte die Einflusszonen der technischen Geräte? Wenn ja, inwiefern?
- *Simulationsprogramm*
  Berücksichtigen diese Programme die Einflusszonen der technischen Geräte? Wenn ja, inwiefern?

3.20. Bitte erzählen Sie mir etwas über Ihre positiven und negativen Erfahrungen im Zuge der Zusammenarbeit mit Architekten/Planern!

GT: „Gute Erfahrungen, wenn man früh mit eingebunden wird, dass man eine gute Zusammenarbeit mit dem Architekten hat, dann kann man Kompromisse eingehen. Dann gibt es Architekten, da ist man zwar früh eingebunden, aber der geht keinen Kompromiss ein, der sagt: ich will das so haben! Weil das will ich so haben! Dann frage ich, wieso? Dann werden fadenscheinige Argumente ausgepackt die nichts bringen, aber das Ganze erheblich erschweren. Zum Beispiel letztens bei einer Baustelle, da ist es darum gegangen, Unterputzgestelle für WCs aufzustellen. Und er sagt, er will alle eingestemmt haben. Und ich sage, wieso? Wenn man die bei der normalen bestehenden Wand hinstellt, dann eine Gipskartonwand aufstellt, dann erspart man sich eine Menge Arbeit beim Einstemmen. Und die bestehenden Leitungen sind auch alle dort, da haben wir dann einen Kunstgriff machen müssen, um das in die bestehende WC-Nische hineinzuziehen. Er will das so haben, weil er verliert sonst beim Raum 10cm oder 12 cm was das Gestell hat, plus die Gipskartonwand, also sagen wir 15cm. Dann sage ich, das spielt ja in einer WC-Gruppe eigentlich nicht wirklich eine Rolle, ob ich bei meinem Waschtisch 1m40 oder nur mehr 1m30, weil 1m30 ist eh so viel. Die WC-Nische müssen eine Normgröße haben, aber ob der Platz zwischen Leichtbauwand und WC-Waschtischvorderkante 1m30 oder 1m40 oder

1m50 ist, ist meiner Meinung nach vernachlässigbar. Weil wenn ich nur zwei Waschplätze habe, und nur 2 Leute nebeneinander vorbeigehen, brauche ich ungefähr 1m20 […]"

I: „Also kommt es wirklich auf den Architekten drauf an, ob er aufgeschlossen ist Kompromisse einzugehen oder nicht…"

GT: „Ja, ich habe ganz unterschiedlich Erfahrungen. Das ist aber dann das Konfliktpotenzial. Dass es oft einmal zu einer Schreierei kommt, sowie jetzt bei einer Baubesprechung. Der Architekt schreit: ´Sie zerstören mein ganze Konzept!` Sage ich zum Architekt: `wenn Sie keine Haustechnik haben einplanen lassen und wir dann erst was finden müssen, wo wir das Gerät hinstellen können, dann zerstöre ich kein Konzept.` […] (Anm. erzählt noch, dass der Architekt meint, das Gerät in einen Zwischenraum mit 1m Höhe zu geben wo der Gebäudetechniker zur Wartung hineinkriechen muss, weil so wenig Platz ist. Daraufhin ist der Gebäudetechniker gegangen, weil er so nicht weiterdiskutieren wollte. Es ist unmöglich in so einem kleinen Raum einen Ventilator mit 150kg herauszuziehen."

I: „Wie einigt man sich dann, wie findet man eine Lösung?"

GT: „Ich bin dann gegangen und habe gesagt, es wird so gemacht, wie ich euch das vor 6 Wochen schon geschickt habe und Sie wissen das ganz genau, und wenn Ihr Mitarbeiter das nicht weitergibt, dann ist das nicht mein Problem, dann stimmt die Kommunikation bei euch nicht. Ich kann mich ja auch nicht verbiegen. Es muss dann schon für den Betreiber auch möglich sein das zu warten. Wenn der jedes Mal so einen hohen Aufwand hat um das zu warten, dass das in die tausende Euro geht, dann sage ich, dann lassen wir es weg. Ich habe ja nicht gesagt, sparen. Das ist ja meistens, das war auch wieder so eine Geschichte: Es hat eine Kostenschätzung gegeben, und dann müssen wir sparen. Wir haben bei der Kostenschätzung von 220000 oder 230000 auf 160000 heruntergespeckt. Das heißt, 70000 ist jetzt nur bei der Haustechnik gespart worden. Nicht bei den anderen – bei der Haustechnik. Bei einem anderen Projekt, da habe ich eine Kostenschätzung abgegeben von 180000 für die Haustechnik, nach der ersten Ausschreibung waren wir bei 190000, dann hat es geheißen: das Gesamtprojekt ist zu teuer. Dann haben wir es zum dritten Mal ausgeschrieben und jetzt sind wir bei der Haustechnik in Summe bei 120000. Das heißt ich habe 70000, mehr als 30% abspecken müssen. Das schlägt sich halt nieder, dass wir jetzt keine schönen Waschtische mehr haben, sondern billige, dass die Klodeckel billig werden, dass wir bei der Urinalsteuerung keine Elektronik mehr haben, sondern normale Druckknöpfe, also da wird dann beim Komfort oder bei der Ausstattung eingespart. […] (Anm. erzählt noch, dass bei einem Projekt die Urinalsteuerung eingespart wurde, was zur Folge hat, dass viele Leute nicht spülen, sich ein Urinstein bildet und das die Leitungen belegt.) Oder sie vergessen ganz auf die Haustechnik. Ja…ich dachte das ist der Praktikant, dabei war es der Chef von dem

Architekturbüro. Dann sage ich: Herr Architekt, wir können die Leitungen gerne frei verlegen, machen wir einen schönen Alumantel herum, dann hat es ein bisschen einen retro-Style wie in Russland. War er auch nicht so begeistert, da hat er sich persönlich angegriffen gefühlt."

I: „Das war wahrscheinlich ganz ein Neuer, der noch nie ein Projekt gehabt hat?"

GT: „Freilich war er jung, hat aber zumindest eine Ziviltechnikerprüfung schon gehabt, das heißt er muss schon mindestens fünf, sechs Jahre Erfahrung gehabt haben, tschuldigung, drei Jahre Erfahrung gehabt haben, aber der hat wahrscheinlich nur designed. Ich weiß nicht, was der gemacht hat."

I: „Wahrscheinlich hat er mit dem noch nichts zu tun gehabt. Aber für die Ziviltechnikerprüfung müsste das ja gelernt werden."

GT: „Wahrscheinlich. Also bei meiner Ziviltechnikerprüfung die Architekten, da hat es einen Stundenplan gegeben und die sind aufgeteilt worden und die sind dann in einen anderen Vortrag gegangen oder die haben frei gehabt. Bauordnung haben wir ja zum Beispiel nicht lernen müssen, oder die haben dann das Kesselgesetz und solche Sachen nicht lernen müssen. Ja…also."

I: „Aber hat er dann umgeplant, der der die Schächte vergessen hat?"

GT: „Wir haben dann gesagt, wir brauchen sie. Wie stellt er sich die Energieversorgung vor? Dann hat er halt so Nischen und Erker die er gehabt hat genommen und künstliche Schächte gebildet."

I: „Spannend."

GT: „Mich würde interessieren, was die Architekten dazu sagen."

[…] (Anm. ich erzähle, dass einige Architekten das Problem darin sehen, dass es wenig planende Gebäudetechniker gibt, sie sich oft nicht auskennen – vor allem Installateure – und auch die entsprechenden Gebäudetechnikprogramme nicht besitzen.)

GT: „Richtig, kann ich alles bestätigen. Was sehr oft ist, das ist aber die Branche, der technischen Büros, die haben sich die Preise selbst zusammengehauen. Und wenn es Leute gibt, die um 2% der Herstellungskosten die Planung mit der Bauausführung machen, dann weißt du, wo die Qualität ist. Wenn ich nach der Honorarrichtlinie gehe, dann ist er bei mindestens 11 bis 12%. Viele bieten ja nach der Honorarrichtlinie an, und geben dann 50-60% Nachlass. Da muss irgendetwas darunter leiden. Und das ist in 99,9% der Fälle die Qualität. Weil so wie du gesagt hast kenne ich Fälle, Großprojekte in Graz, […] von […], da hat der Haustechnikplaner ein Schema entworfen, das hat er von der Industrie geholt und adaptiert. Dann hat er die Pläne, mehr oder weniger wie Strichmännchen ein Konzept vorgegeben und hat dann eine Ausschreibung gemacht. Die Ausschreibung und die Planung hat schon gar nicht mehr er gemacht. Sondern das hat schon ein Installateur gemacht – ein Großinstallateur. Der hat dann die Pläne

gezeichnet. Das muss man sich auf der Zunge zergehen lassen: Bei einem Projekt von über 30 Millionen Euro, hat die Haustechnikfirma vor der Baufirma den Auftrag gehabt. Da hat der dem Bauherren das so eingeredet, dass er den Installateur jetzt schon beauftragen muss, dass der jetzt schon alles umsetzten muss. In Wirklichkeit ist darum gegangen, dass der Installateur genug Zeit gehabt hat diese Planungsgeschichten alles durchzuführen. Die haben ein Einkaufszentrum geplant ohne zu wissen wie viel Kühlleistung sie brauchen. Die haben pro m² irgend etwas angenommen. Also komplett abstrus und dann haben wir eine Kühllastberechnung eingefordert und dann bekommst du eine Liste wo die m² oben stehen, nicht einmal ein Raumbuch sondern eine Excel Liste, und dann haben sie die Fassade, die nach Süden geht, haben sie die Fensterflächen ausgerechnet. Aber sie haben keine Lampen gerechnet, sie wissen bis heute nicht, wie viel Energie sie brauchen. Im Sommer ist oft das Problem, dass die ganze Anlage überhitzt, weil die Anlage zu klein ist und und und. Weil das ganze Schema nicht zusammenpasst. Und dann gibt es Architekten, die sagen, es gibt keine gescheiten Haustechnikplaner. Ja, wenn einer so billig anbietet, da bringt er die anderen in Verruf. Das war auch der Grund wieso ich Ziviltechniker geworden bin, ich zahle als Ziviltechniker doppelt so viel Kammerbeitrag wie bei der Wirtschaftskammer. Aber ich will mit den normalen Haustechnikplanern nicht in einen Topf geworfen werden. Weil wenn es so ist, dann verlange ich das. Und wenn das einer nicht zahlen will, dann zahlt er das nicht. Deswegen, ich habe die letzten Jahre keine Planung gemacht. Deshalb habe ich auf Brandschutz umgestellt. Und heuer habe ich auf einmal drei Planungen bekommen, weil es keine Haustechnikplaner mehr gibt. Weil die anderen gesagt haben: die sind so mies, mit dem kann ich nicht."

I: „Ja das habe ich auch schon gehört, dass es keine richtigen Haustechnikplaner gibt und die wenigen die es gibt, verlangen sehr sehr viel, weil sie wissen, sie können das verlangen, nur ist die Frage ob das der Bauherr das dann zahlt."

GT: „Naja, meistens ist es so, es geht dann nicht direkt über den Bauherren, sondern da geht es über den Architekten. Der bekommt einen Generalplanerauftrag. Und der will aber dem Haustechniker nichts zahlen. Dann geht er so lange hausieren, bis er einen findet, der bereit ist das für den Preis zu machen. Was absolut der falsche Weg ist. Wenn er gleich sagt, er will das haben und er bekommt ein anständiges Angebot vom Haustechniker, dann kann er das mitkalkulieren. Da sind wir dann wieder bei der Planungsphase. Und im Nachhinein bleiben für ein Projekt, für das die Haustechnik 200000 ausmacht, 10000 Planungshonorar über. Und was ist das…5%. Und da sollst du planen, Bauleitung machen, Ausschreibung machen, alles. Da muss irgendetwas darunter leiden. Es geht gar nicht anders. Weil, er verlangt es ja auch. Deshalb habe ich auch gesagt, ich mache das nicht mit dem

Architekten, ich mache nur mit dem Bauherren direkt den Vertrag. Und die Planungen, die ich habe, die drei, sind alles Planungen, eine ist vom Architekten, weil ich den kenne, weil ich den gut kenne und da hat das super funktioniert, das ist ein Generalplaner, das passt, und die anderen sind direkt vom Bauherren beauftragt. Da sage ich: tut mir leid, wir machen das vom Architekten getrennt. Weil sonst bin ich mit dem Architekten immer verbandelt. Da heißt es: ihr müsst euch zusammenstreiten. Das interessiert mich nicht mehr. Ich arbeite auch für gewisse Architekten nicht mehr. Das ist einfach so. Der braucht nicht einmal mehr anfragen, weil der eh schon weiß, dass wir zusammenkrachen. Dann sollen sie wieder ihre anderen nehmen. Und vor allem sind die Architekten oft sehr eitel. Das ist leider so. Wenn du sagst: deine Pläne sind falsch oder deine Pläne sind…weißt du wie der an die Decke springt? Wenn er einen Fehler macht, dann muss er dazu stehen. Bei den Architekten ist das in den seltesten Fällen so. Bei vielen ist es auch so: der Architekt hat einen guten Namen und ein großes Team hinter sich. Und alle kann er nicht überwachen. Und dann ist das Team aber oft sehr jung. Weil er ja auch wenig zahlen will. Weil in der Architektur verdient man ja so wenig, aber selber haben wir ein großes Haus und schöne Autos und fahren drei Mal im Jahr segeln. Aber die Mitarbeiter, die dann dort sitzen, sind oft HTL Abgänger und der ist ein Jahr dort, dann bekommt er schon ein Projekt. Dass der das alleine nicht machen kann ist klar. Bei den Fachhochschülern nichts anderes. Fachhochschüler sind oft einmal, wenn sie von der Architektur-Seite kommen, die sind dann oft so überheblich und glauben sie haben die Weisheit mit dem Löffel gefressen, tschuldigung, weil er das halt studiert hat, aber er hat überhaupt keine Ahnung. Irgendwelche Details die man einmal gezeichnet hat auf der Uni, ein Fensteranschlussdetail mit einem Fensterbank, Standard, das kann ich aber heutzutage bei jeder Fensterfirma herausholen, brauch ich nur abzeichnen, brauch ich selbst nichts mehr entwickeln. Und mit denen krache ich halt auch öfters zusammen. Und ich nehme mir ja dann kein Blatt vor den Mund. Und wenn ich vom Architekten der Subunternehmer bin und er macht einen Fehler und ich weise ihn ein paar Mal darauf hin und es passiert nichts, dann setzte ich die Bauherrin oder den Bauherren mit auf den Verteiler. Ich habe das schon einmal gehabt, da hat mir der Architekt den Auftrag entzogen. Sage ich: ist kein Problem. Weil ich mir erlaubt habe zu schreiben, dass seine Pläne falsch sind. Ja wieso ich die Bauherrin mit rauf setze, sage ich: ist mir halt zufällig passiert. Ich meine, war ja nicht so, habe ich ganz bewusst hinaufgesetzt. Und was war: meine Kosten haben komplett gehalten bei der Haustechnik. Von der Schätzung bis zur Umsetzung, beim Architekten haben sie eine 40%ige Überschreitung gehabt, weil der nicht fähig war, die Bestandsaufnahme richtig zu machen. Da werden halt, auch bei den Architekten, sehr viele Jungtechniker verheizt. Und bei der Gebäudetechnik ist es halt so, es

gibt nur zwei Schulen, zur HTL, die Gebäudetechniker ausbilden. Das ist Vöcklabruck, da gibt es Maschinenbau Gebäudetechnik und Pinkafeld. Nur dort gehen die Studentenzahlen oder Schülerzahlen so stark zurück, weil das niemand mehr machen will."

I: „Gebäudetechnik?"

GT: „Ja, deswegen kommt auch niemand mehr nach."

I: „Ich dachte es werden eher mehr?"

GT: „Nein, es werden immer weniger. Die Gebäudetechnik hat vor 30 Jahren bei einem Haus, einem Objekt zwischen 15 und 20% ausgemacht. Oder sagen wir, zwischen 12 und 15%. Mittlerweile sind wir, was Heizung und Kühlung anbelangt, ohne Elektro, sind wir schon, je nach Aufwand, bei 30%. Das heißt, das hat sich fast verdoppelt der Aufwand und auch der Kostenstellenwert, was die Haustechnik schon alles braucht. Weil der Komfort ja so gestiegen ist. Früher hat es einen Heizkörper gegeben mit einem Handrad. Jetzt haben wir eine Fußbodenheizung mit einem elektronischem Regelgerät. Es sinken die Schülerzahlen und auf den Fachhochschulen die Studentenzahlen. Es gibt die Fachhochschule in Kufstein, die Energie- und Umwelttechnik macht und in Pinkafeld. Und ich bin selbst in Pinkafeld gegangen und ich habe selbst in Pinkafeld unterrichtet, Heizungstechnik und Gastechnik, früher waren es 45 Studenten Gebäudetechnik, jetzt schaffen es gerade einmal 20 Studenten. Und das sind dann aber auch die, die dann meistens selbst einen Installationsbetrieb oder so etwas zuhause haben. Die wandern dann direkt ab. Das heißt, da wird dann kaum jemand Haustechnikplaner. Von meinen Studienkollegen, wir waren noch 45 […] da weiß ich jetzt genau, keiner ist noch Planer, also wir sind jetzt noch zwei Planer, einer ist in der Planungsabteilung von einem Installateur, einer ist bei der […], in der Planungsabteilung, und die anderen sind entweder bei Großkonzernen im Marketing, Vertrieb, Produktion, ja…solche Sachen. Die haben zwar eine haustechnische Ausbildung, aber jetzt ist er halt Produktmanager für Heizkessel. Also das sind ganz ganz wenige die wirklich noch mit der Planung etwas zu tun haben. Es gibt einige, die zu einem Installateur gegangen sind. Die sind dort Niederlassungsleiter oder Gruppenleiter bei Großinstallateuren die Großprojekte machen. Nur die haben relativ wenig Planungsauftrag, sondern Umsetzung. Nur das ist eh schon fast Planer, weil der muss die ganze Vorgaben auch umsetzen. Mit denen kann man eh gut reden. Aber das ist übrig geblieben von 45. Viele machen überhaupt ganz etwas anderes."

I: „Aber wieso deiner Meinung nach?"

GT: „Einerseits ist es schlecht gezahlt, dann ist das Studium nicht unbedingt einfach, weil du sehr viele Grundlagen lernen musst, in der Fachhochschule musst du es einfach durchziehen in der Zeit, für das ist es eigentlich schwierig, das ist sehr technisch."

I: „Machen das dann viele gar nicht fertig das Studium diejenigen die anfangen?“

GT: „Die fangen gleich gar nicht an. Weil zu technisch ist. Die machen den ersten Abschnitt, das Bakk Gebäudetechnik, das sind aber nur Grundlagen, dann machen sie Gebäudemanagement. Das heißt, die planen dann nicht weiter, die sind dann bei einer Genossenschaft, Facility Manager oder solche Sachen. Der kann dann Heizzähler ablesen und dann bekommt er den Auftrag: wir müssen Energie sparen, was machen wir, wir drehen halt die Temperatur zurück. Ja…aber das kann jeder Installateur auch. Meiner Meinung nach ist es für viele schon zu schwierig, und vor allem, wenn du jetzt Gebäudetechnik machst, musst du Heizung von A bis Z beherrschen, dann kommt das Sanitäre dazu, Versorgung und Entsorgung, dann kommt die Lüftungstechnik dazu, dann kommt noch dazu die Klimatechnik, also Kälte- und Klimatechnik, und dann kommt noch dazu Messststeuerungs- und Regelungstechnik. Messststeuerungs- und Regelungstechnik ist jetzt eh schon so, dass es kein Planer mehr selbst macht, sondern es wird ausgelagert. Da holt man sich dann einen Sub dazu. Nur, das ist meistens auch eine ausführende Firma. In Kärnten hat es den […] gegeben als Regelungsplaner, in Graz kenne ich den […] und in Wien den […]. Das sind drei Messsteuerungs- Regelungstechnikplaner, alles andere macht die Industrie.“

I: „Und von den Absolventen, also die die das Studium wirklich fertig machen, also so wie du, warst du der einzige, der sich selbstständig gemacht hat?“

GT: „Mittlerweile sind wir zu zweit. Einer hat den elterlichen Betrieb übernommen als Installateur. Ja zu zweit, ein Kollege, der ist in Niederösterreich, der hat auch ein Planungsbüro.“

I: „Wieso die anderen nicht? Du hast jetzt gesagt, weil man nicht so gut verdient…OK. Was sind sonst noch die Gründe? Weil notwendig wäre es ja.“

GT: „Ah, ja…selbst und ständig. Die anderen arbeiten…die haben ein Angestelltenverhältnis. Haben eine Überstundenpauschale, wissen, sie arbeiten nie mehr als 50 Stunden in der Woche. Fünf Wochen Urlaub, Krankenstand, alles bezahlt natürlich. Als selbstständiger Planer musst du als erstes einmal den ganzen Krempel kaufen, dann musst du schauen, dass du Aufträge hast, du hast natürlich auch viele Vorteile, aber in der Anfangsphase hast du viele viele Nachteile, weil…oder du hast halt viele Sorgen, wie läuft es […] und du musst es am Laufen halten. Zum Beispiel die Programme, die ich da habe, ich zahle im Jahr vier oder 5.000€ nur Supportkosten. Das Ausschreibungsprogramm, Energieausweisprogramm, Zeichenprogramm, Berechnungsprogramm für Heizung. Ich bin in Kärnten der glaube ich einziger, der ein Kühllastprogramm hat. Der wirklich eine Kühllast selbst rechnen kann von den Planern. Die anderen schätzen das. Ich rechne zum Teil auch für

andere Planer das. Weil die das bei mir dann anfragen. Oder geben das der Industrie…da ist dann wieder das Problem, die Industrie rechnet dann die Kühllast auf ihr Produkt und das funktioniert dann nicht. Da brauchen wir dann wieder ein Gutachten. Ja, schau, da sind zwei Gerichtsakte (Anm. zeigt auf einen Stapel).“
3.21. Bitte beschreiben Sie Ihre Vorgehens- und Arbeitsweise um eine technische Gebäudeausrüstung zu planen? *(Anm. wegen Zeitmangel nicht gestellt)*
3.22. Mit welchen Programmen arbeiten Sie? *Autocad, Brixcad (Billigversion von Autocad – kostet nur 1/5 davon, kann aber das selbe), Solarcomputer von der Firma Grüner (Heiz- und Kühllastberechnung, Rohrnetzberechnung, Kostenschätzung, Wirtschaftlichkeitsberechnung), GIQ (Energieausweisprogramm), Citun Core (Ausschreibungsprogramm), Winafa, Officeprogramme, diverse Programme von Herstellern wie z.B. von Helios, TA (von Firmen zur Verfügung gestellt).* *Können in diesen Programmen die Einflussbereiche der technischen Geräte dargestellt werden?*
3.23. Wie ist Ihrer Meinung nach das Wissen der Architekten/Planer über Gebäudetechnik und die Planung technischer Systeme? ○ Sehr gut ○ Gut ○ Mittelmäßig ○ Schlecht ○ Verschieden, je nach Berufserfahrung *Bitte begründen Sie diese Bewertung!* *GT: „Gut und schlecht. Mittel gibt es eigentlich nicht. Es gibt welche, die sind gut informiert und es gibt welche, die sind schlecht informiert.“* *I: „Die gut informierten sind wahrscheinlich die, die sich selbst dafür interessieren?“* *GT: „Ja, weil…ja, die reden auch mit den Leuten. Die sind nicht von sich so voreingenommen. […]“*
3.24. Was würde sich ändern oder verbessern wenn sich Architekten/Planer *(noch)* besser mit der Gebäudetechnik auskennen? *GT: „Die Kommunikation auf jeden Fall. Wahrscheinlich würden sich…es würde dann nicht mehr so viele Kostenüberschreitungen geben, also die Kosten würden niedriger gehalten werden, glaube ich, und…das wars.“*
3.25. Beeinflusst die Gebäudetechnik den Entwurfsprozess des Architekten/Planer? ○ Ja *Inwiefern?* *GT: „Da geht es um den Platzbedarf, Raumangebot und und und.“* ○ Nein

	Wieso nicht? ○ Teilweise ○ Weiß nicht ○ Sonstiges *Bitte begründen Sie diese Bewertung!*
3.26.	Was würde sich ändern oder verbessern, wenn die Gebäudetechnik im Entwurf (mehr) Berücksichtigung findet? *GT: „Der ganze Ablauf wäre ein bisschen einfacher und der Gebäudetechniker könnte sich…hat dann auch ein bisschen mehr Planungszeitraum zur Verfügung und kann sich ein bisschen mehr vertiefen. Vielleicht Sachen gegenüberstellen und der Platzbedarf ist dann auf jeden Fall gegeben. Schächte, Zugang zu Schächten. Weil es nützt mir ja nichts, wenn da der Haustechnikerraum ist und der Schacht ist erst nach dem Gang. Das heißt, ich muss mit meiner ganzen Haupttrasse am Gang werden. Und dann brauche ich drei Meter Raumhöhe, ja wie soll denn das gehen, wenn ich mit allem dort hinüber muss. Also wenn man so etwas berücksichtigt, der Schacht im Geschoß, da tu ich mir leichter, weil da benötige ich nur mehr kleine Leitungen. Oder wenn beim Schacht dann gleich die Nassgruppen sind. Oder die Verbraucher. Weil oft machen sie es genau so: dort ist der Schacht und das WC ist ganz wo anders. So wie ich vorher gesagt habe, diese Terrassenbauweise. Gut, wenn es so ist, dann ist es so. Nur, wenn es so ist dann ist es oft sehr schwierig.“*
3.27.	Haben Sie Ideen oder Vorschläge wie es dem Architekten/Planer erleichtert werden kann, die Gebäudetechnik schon im Entwurf mit einfließen zu lassen? *GT: „(Anm. überlegt) Wenn er generell schon ein Verständnis hat für den Gebäudetechniker, dann lädt er ihn automatisch schon früher ein. Den Auftrag bekommt immer vorher der Architekt. Ich bekomme nicht den Auftrag eine Heizung zu planen und dann bekommt erst der Architekt den Auftrag…das gibt es ganz selten. So gut wie nie. Deswegen ist es wirklich schwierig, es geht eigentlich immer vom Architekten aus. Der Architekt weiß, dass es die Haustechnik und die Gebäudetechniker gibt, dass er sie auch braucht. Nur das Verständnis allein…da hoffe ich, dass er so gescheit und wiff ist, dass er früh genug den Gebäudetechniker mit ins Boot holt. Dass er sagt: gib mir noch ein paar Informationen, kann ich das machen, oder, was wird es kosten? Aber das passiert halt in den wenigsten Fällen.“* *-Welche Methoden würden Sie vorschlagen?*
3.28.	Haben Sie eine Idee wie man einem Architekten/Planer das Verständnis zur GT näher bringen kann?
3.29.	Im Folgenden werde ich Ihnen kurz ein Schema vorstellen mit dem unter anderem das Verständnis zur GT erhöht werden kann sowie das die Planung und Anordnung technischer Geräte schon in frühen Planungsphasen leicht ermöglicht. Damit kann eine optimale

Integration der technischen Gebäudeausrüstung sowie eine optimale Steuerung in Form der richtigen Kombinationen der Reglerpositionen erreicht werden. Dazu bitte ich im Anschluss um Ihre Meinung.
(Schema und das Tool/Programm wird kurz erläutert)
I: „Glaubst du würde das angenommen werden, wäre das eine Hilfestellung, würde das die Zusammenarbeit erleichtern, wenn dann der Gebäudetechniker hinzukommt?“
GT: „Erleichtern würde es auf jeden Fall. Nur, wenn jemand mit so einem Programm arbeitet, dann muss er schon so speziell geschult sein, dass er eigentlich kein Architekt mehr ist. Du musst, wenn du den Raum jetzt zum Beispiel Richtung Süden hast, nach Osten oder nach Westen, hast du immer andere Anforderungen. Und da geht es auch darum, da muss er wissen, ah (überlegt) wie viel Heizlast brauche ich, von der Umgebungstemperatur, wenn zwei Personen sind, kann ich überhaupt noch lüften, bei der Sonneneinstrahlung, welche Beschattung nehme ich? Das heißt, nicht Beschattung, da muss ja das Fenster mit der Beschattung schon zusammenpassen. So wie wenn ich eine innenliegende Beschattung habe, reflektiert mir meine Beschattung auf die Fensterscheibe und das Fenster lässt das nicht mehr durch, weil die Frequenz der Wellen – das Glas das verhindert, und dann bekomme ich einen Hitzestau. Von der Beleuchtung, Raumfühler…(überlegt), wenn er das alles eingeben kann, könnte, dann wäre das sicher kein Architekt mehr. Ich kann mir vorstellen, dass das ein Gebäudetechniker in einem Architekturbüro macht. Dass der so etwas bearbeitet und sagt: Hier stellen wir ein graphisch dargestelltes Raumbuch, wo ich alle Parameter darin habe, die eingegeben wird und wenn irgend etwas nicht zusammen passt, dann schreit er sofort. Weil es macht ja einen Unterschied, ob ich da einen Eckraum habe. Oder unter dem Raum ist eine Durchfahrt. Oder oben ist nichts, oben ist ein Balkon. Und das kann so ein innenliegender Raum sein, der aber trotzdem sehr viele Außenflächen hat. Jetzt hat er auf einmal drei Mal so viel Heizlast wie der danebenliegende Raum. Oder genau mit den Heizkörpern. Mein Chef hat Wirtschaftsingenieurwesen studiert und hat dann Haustechnikplanung gemacht, mein ehemaliger Chef, und dann haben wir in einem Büro zwei solche Heizkörper gehabt (Anm. Radiatoren), der Raum hat gehabt 30m², oder eigentlich nur einen Heizkörper, und im WC, das 5m² gehabt hat, haben wir einen Heizkörper gehabt, der doppelt so groß war. Jetzt hat der Bauherr gefragt, wie kann das sein? Mein Chef hat die Heizlastberechnung gemacht, nur was er nicht berücksichtigt hat war, dass er gesagt hat, er braucht so und so viel Luft und die strömt von außen nach, über ein geöffnetes Fenster. Nur, wenn ich einen Ventilator habe im Winter, so einen WC Ventilator, dann strömt die Luft ja nicht über das Fenster nach, sondern aus dem Vorraum. Und jetzt hat er berechnet, der Ventilator saugt bei durchgehendem Betrieb, 24 Stunden, saugt immer 100 Kubikmeter mit

minus 14 Grad an, jetzt muss er die Luft natürlich erwärmen, das ist in den Heizkörper mit eingeflossen. Sage ich, nichts gegen meinen Chef damals, aber er hat das nicht verstanden, wie das System funktioniert. Das heißt, es kommt ja immer das heraus, was man eingibt. Und wenn jemand einen Blödsinn eingibt, weil er das nicht weiß, dann kommt ein Blödsinn heraus. Also wenn du so etwas machst, dann musst du eigentlich schon ein Haustechnikspezialist sein. Dann solltest du eigentlich ein Haustechniker sein, der ein bautechnisches Verständnis hat. Wenn das ein Architekt machen kann, ist das absolut zu begrüßen. Der scheint dann sofort auf, weil er hat dann nur dieses System, diese Kennzahl, die ja irgendwo hinterlegt sein müssen, wie viel Heizlast brauche ich, wie viel Beleuchtung brauche ich, was habe ich für eine Beschattung, wie viel Kühlung benötige ich."

I: „Das Ziel wäre nämlich, das wirklich so einfach wie möglich zu machen, dass das für den Architekten verständlich ist, denn wenn es kompliziert ist, da hat man eh Gebäudetechnikprogramme für den Gebäudetechniker. Es geht wirklich darum, es so einfach wie möglich zu machen, damit der Architekt mit wenig Wissen über Gebäudetechnik es auch benutzen kann."

GT: „Das passt auch. Wenn ich sage, ich habe zwei Personen und zwei Computer, das kann ich alles über Listen eingeben, und da sind hinterlegt: der Mensch gibt so und so viel, zwischen 300 und 500 Gramm Feuchtigkeit in 24 Stunden ab, das kann ich mir ausrechnen, was der dann abgibt. Kann ich lüften, ja oder nein. Wenn ich nein habe, dann brauch ich eine Lüftung. Pro Person 35m³. Diese Sachen muss ich alles hinterlegen. Bei der Heizlast wird schon wieder schwierig. Da muss ich dann schon wieder sagen wie viele Außenflächen habe ich. Würde aber auch noch gehen, weil da kann ich sagen – bei einer Außenfläche habe ich [….] Kühllast – Sonneneinstrahlung, welche Richtung, Glas, wie viel Personen, wie viel Computer. Das sind nur Tabellenwerte. Das kann ich in einer Excel Liste eingeben und der stellt das dann grafisch dar. So etwas kann ich mir vorstellen. Nur – das ist eine erste Abschätzung…wirklich eine erste Abschätzung…er weiß dann nur ungefähr, wie viel Heizenergie brauche ich, oder wie viel Kühlenergie brauche ich und wie viel Luft brauche ich. Wenn er bereit ist dieses Verständnis aufzunehmen, wenn man sagt, ich habe ein geschlossenes Bürogebäude mit 100 Mitarbeitern, die brauchen 3500m³ oder 35000³ je nachdem, wie auch immer…dann weiß er das ja schon. Nur er weiß nicht, was das für ein Gerät ist. Wo das Gerät sitzt und so weiter. Die Erstabschätzung, es gibt ja so Raumbuchprogramme, die haben das ja schon alles drin. Aber das gibt ja der Architekt meistens auch erst sehr sehr sehr spät ein. Wenn wirklich…bei einem Krankenhaus haben wir es jetzt, erst wenn er wirklich weiß, was ist da jetzt drin. Welche Geräte sind drin, und und und. Das ist meistens erst in der Einreichphase oder erst danach. Erst in der Einreichphase kommt das Raumbuch zu tragen.

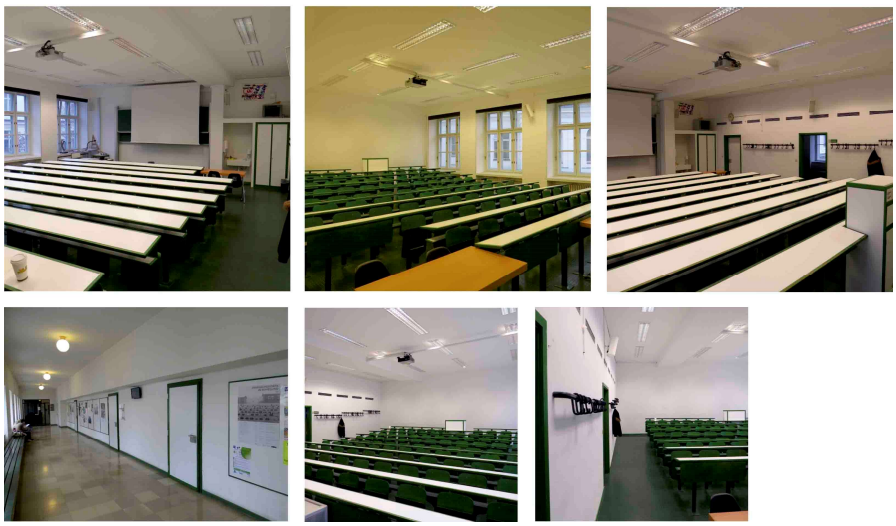
Aber ansonsten eine super Geschichte. Ich arbeite jetzt mit einem Architekturbüro zusammen, […] da planen wir gerade ein Krankenhaus, da werden 100 Millionen investiert und da gibt es einen Haustechnikplaner. Mit dem Haustechnikplaner ist der Architekt nicht zufrieden und beauftragt mich zur Kontrolle der Haustechnikplanung. Ich kontrolliere den, weil schon alles in die falsche Schiene läuft. Ich schaue, dass der nicht einfach irgend etwas erzählen kann, was der Architekt selbst nicht überprüfen kann. Das ist ein großes Büro, die haben über 50 Leute in Summe. Aber sie haben keinen Haustechniker. Und das ist halt…vielleicht sollte man auch in den großen Architekturbüros sich einen Haustechniker anstellen, der kann ja auch andere Sachen machen. Die haben so viel Wettbewerbe, die haben so viel Sachen, und wenn der nur den dann beauftrag, den Haustechniker auf die Finger schaut, dann hat sich der, der im Jahr 50 oder 60000 Euro kostet ja gerechnet. […] Ein kleiner Architekt wird das nicht machen, aber ein großes Büro…dann kann ich solche Sachen auch in der Projektentwicklungsphase von der Abschätzung her…geht das überhaupt?!" […] (Anm. wir sprechen noch darüber, dass in großen Büros versch. Fachdisziplinen in einem Büro oder in einem Haus sind)

8.7. Examples of student projects

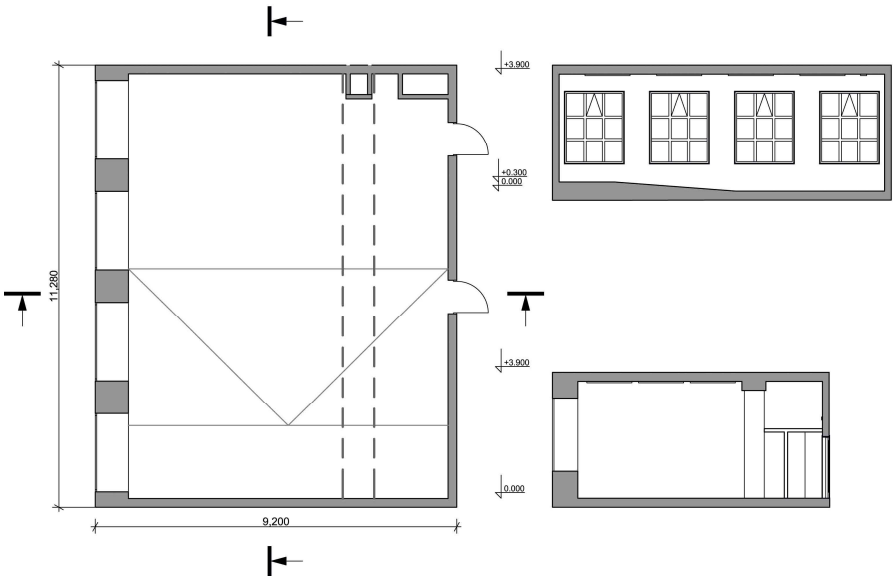
Project number 6: lecture room

Control logic scheme of the Lecture room 14A
259.315 Building Systems and Controls

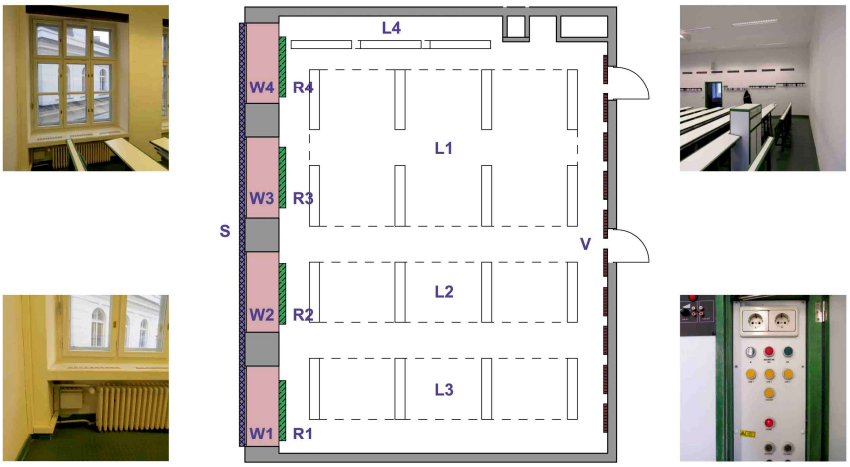
Lecture room 14A



Lecture room 14A

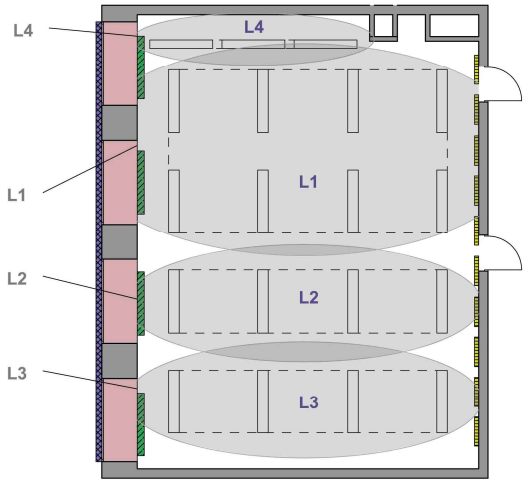


Lecture room space plan with multiple devices

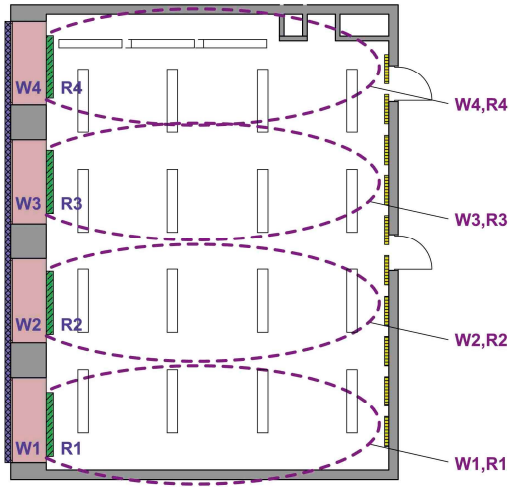


V - diffuser R - radiator L - luminaire W - window S - shading

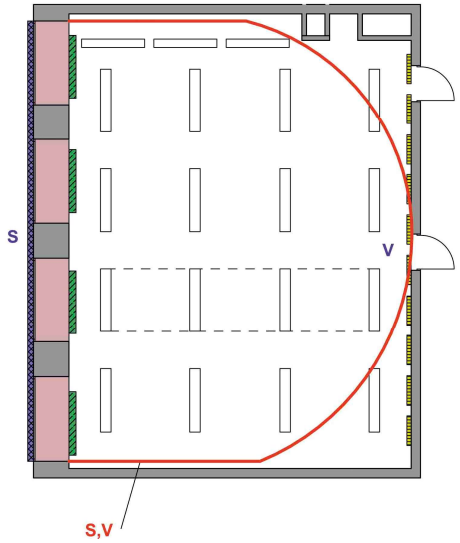
Lecture room space plan with multiple devices and associated control zones
Light zones



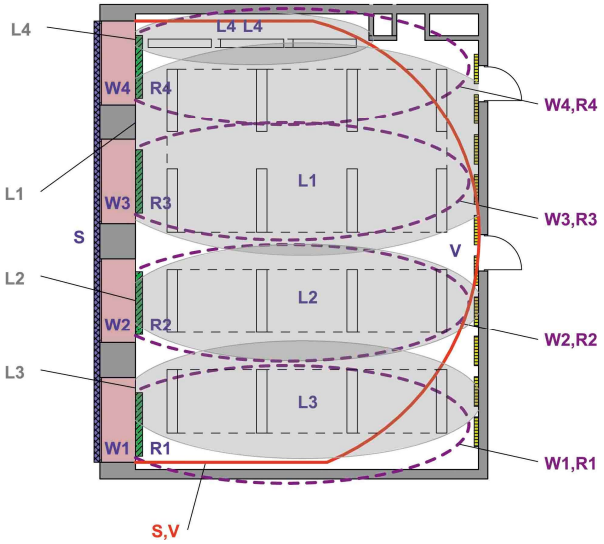
Lecture room space plan with multiple devices and associated control zones
Windows and radiators zones



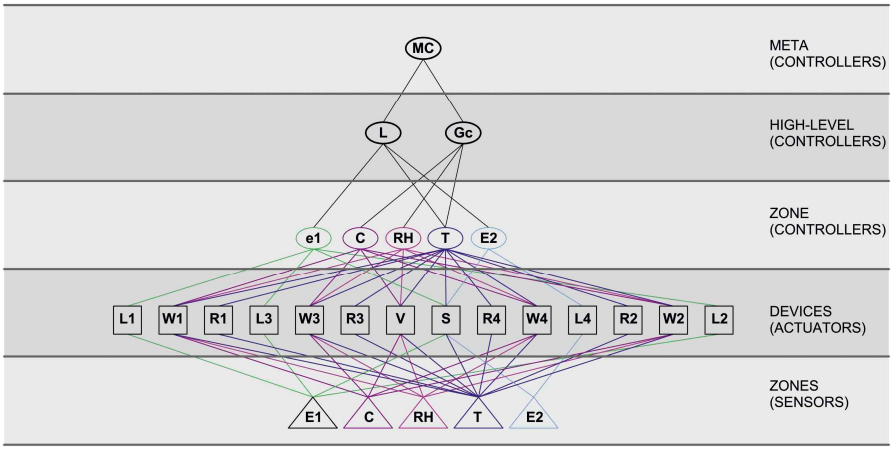
Lecture room space plan with multiple devices and associated control zones
Diffusers and shading zones



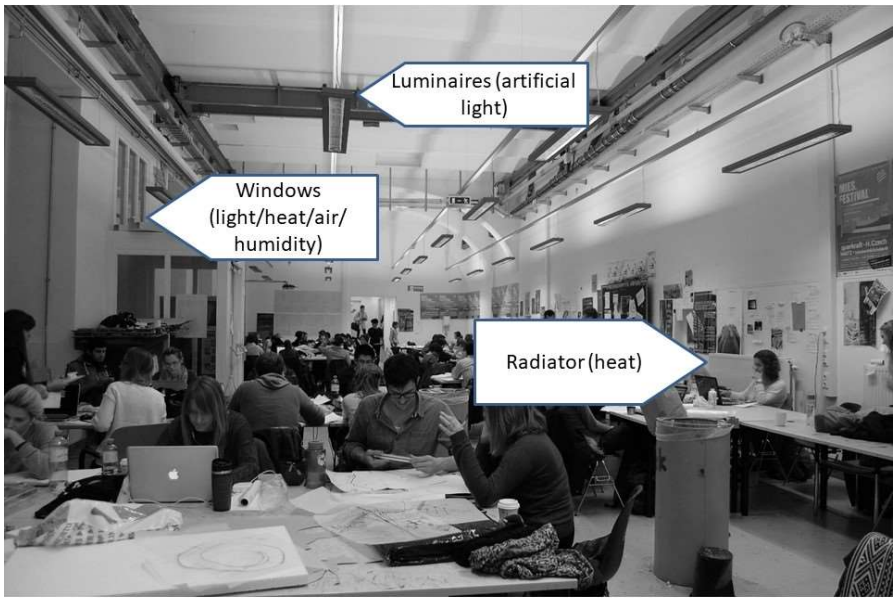
Lecture room space plan with multiple devices and associated control zones



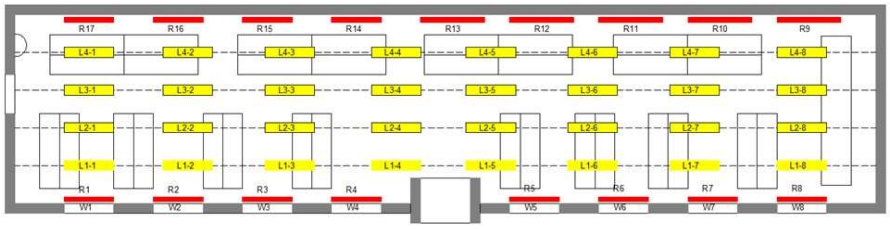
Distributed control logic schema



Project number 7: drafting room in a university building



Devices layout



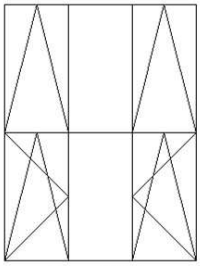
Actuators:

Radiators R1-R17: valve, smooth regulation (5 positions, *-4)

Luminaires L1-1 – L4-8: switches, On-Off positions, one switch for each row

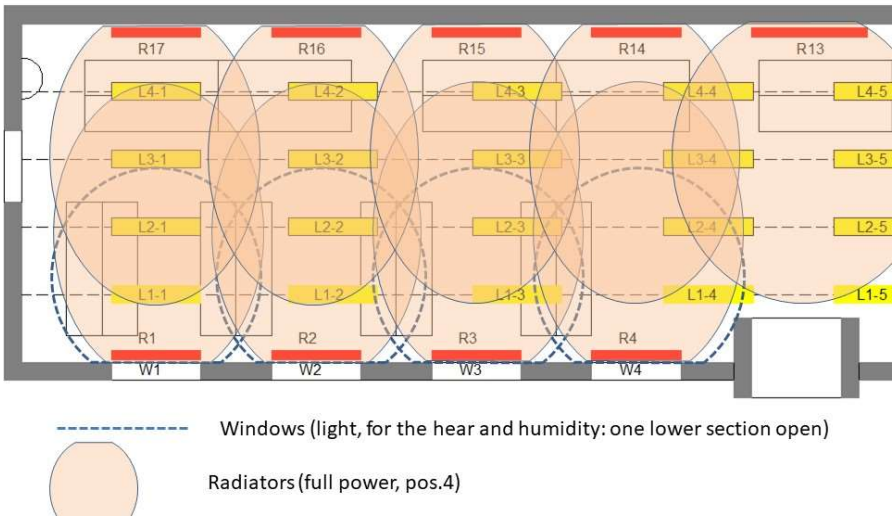
Windows W1-W8: >>>

1 position (tilt)



2 positions (tilt+open)

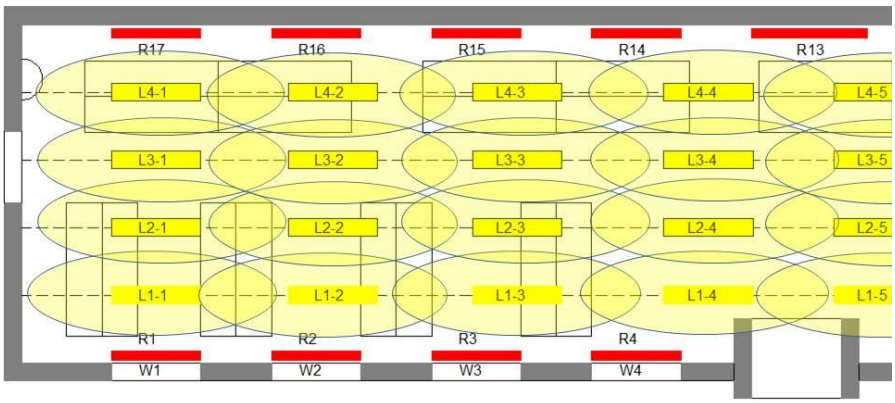
Control zones



Windows (light, for the hear and humidity: one lower section open)

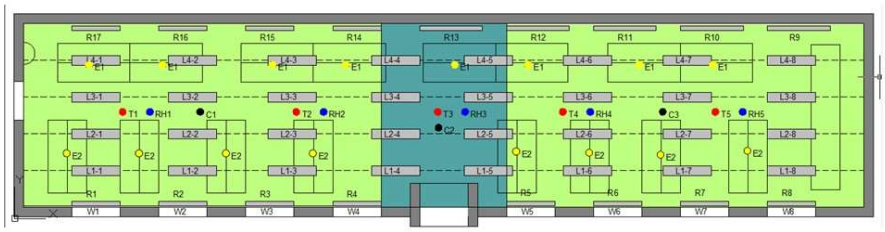
Radiators (full power, pos.4)

Control zones



Luminaires

Sensors



3 larger zones:
one entrance zone (blue)
2 working zones (green)

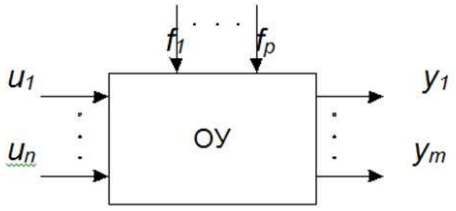
T1	T2	RH1	RH2	ZONE CONTROLLERS E1	E2

Method feedback

- Different scenarios are needed, containing assumptions on the actuators' positions
(the size of the control zones and the number of sensors may vary)

- Sensors as zone representatives: one sensor for each device zone? Or functional zone?

General approach to the control systems in metallurgy



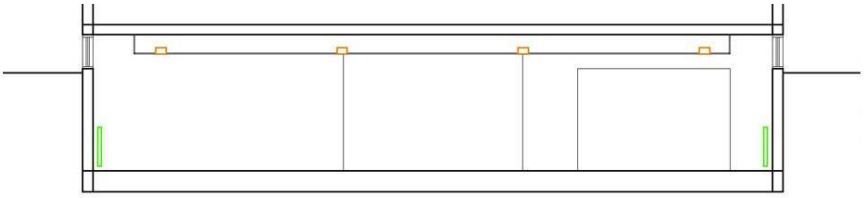
Term	Definition	Building science application
CO (OY) Control object	Technical process or device from the control point of view	Room within the building
un, control actions	Actions that are performed to control the object	Changing the temperature, opening the windows, etc
fn, noise actions	Actions that influence the object but can not be controlled	Weather conditions outside the building
yn, output variables	Output parameters resulted from the control actions	Indoor temperature, indoor illuminance, etc.

Project number 13: ladys' gym

Generating schema
with devices and zones

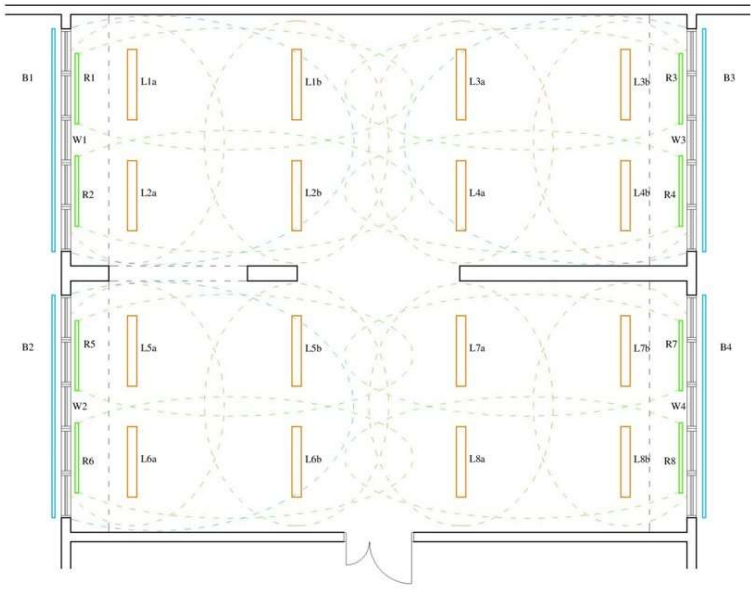
Information about the room

- Lady's Gym – Adolf Schäf Heim (Home for students)
- In the basement
- Consists of two identical open rooms
- Room area: 141.77 m2
- Room hight: 264 cm
- Windows on oposite walls
- Windows hight: 66 cm
- Blinds in form of a non-transparent sticker on all the windows
- 8 radiators

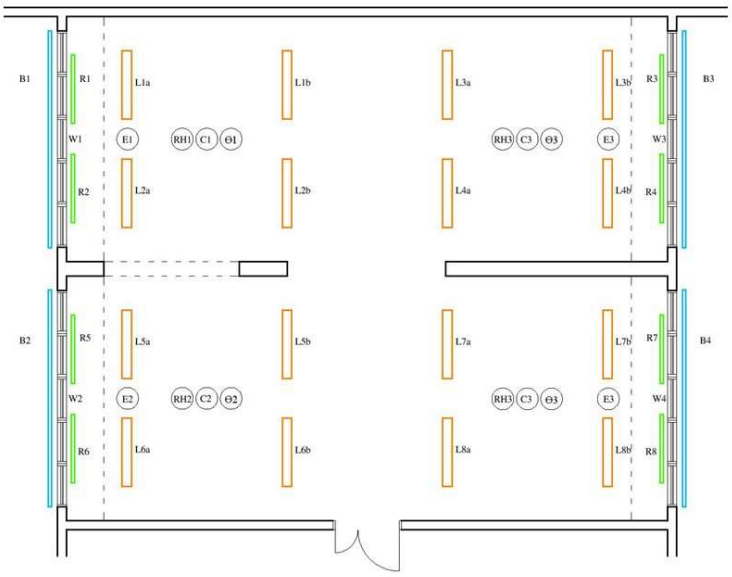


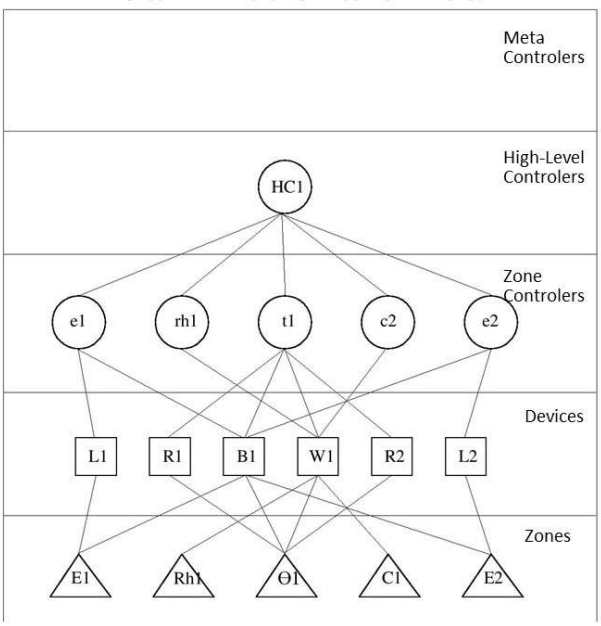



Plan with multiple devices and associated controle zones



Plan with sensors



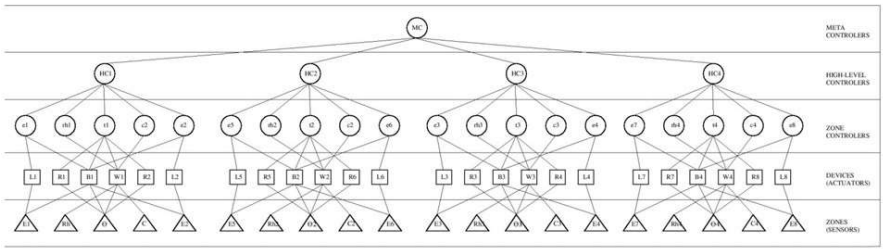


Shema generation one part

- Devices and sensors devided in 4 groups
- Each group has one wall with windows, blind, two radiators and a set of 2 fluoroscent lights.
- **6 devices and 5 sensors**

Schema generation with devices and sensors

- **24 devices and 20 sensors**
- Devices and sensors devided in 4 groups
- Each group has one wall with windows, blind, two radiators and a set of 2 fluoroscent lights.



Comments

The proposed solution:

- The proposed solution has overal 24 devices and 20 sensors
- 16 fluoroscent lamps are grupated so that each two work in pair and as one device – the system has 8 devices only for the lightening

Weaknesses:

Such a high number of light devices is maybe not necesery for such a small event room.

Possible other solution:

- As the Gym room has two identical rooms, without any doors inbetween, the solution could be given only with 2 divaces for the lights – one for each room.

8.8. Questionnaire students

Questions	Answers
1. What is your educational background?	21 architect, 4 engineer
If others or you have a second, please specify	Building Science and Technology building science Civil Engineering urban planning Constructing Architecture and Management
2. Have you learned in your education something about building systems?	9 Yes, 10 a bit, 6 no
3. Have you had experience in design of buildings technology systems?	4 Yes, 8 a bit, 13 no
4. If you are an architect, have you in your professional work communicated to the building service engineers?	4 Yes, 5 a bit, 12 no
5. If the answer to the above question is yes or a bit, how would you judge the engineers competent and open for suggestions?	8 open for suggestions of the architects, 2 not interested in understanding the intentions of the architects, 0 others
If others, please explain:	-
6. If you are an engineer, do you find architects	2 ... are able to understand technical issues and can change the designs if necessary, 2 ... are not aware of the technical issues and don't care about environmental performance, 0 others
7. Do you think architects should know more about building systems?	22 Yes, 3 a bit, 0 no
8. Does the proposal method make the understanding of the rule of technical systems in buildings easier?	2 yes very much, 15 yes, 4 a little bit, 4 not so much, 0 not at all
9. Does the purpose method helps identify problems in the design of technical systems in buildings?	2 yes very much, 13 yes, 10 a little bit, 0 not so much, 0 not at all
10. Does the purpose method helps to save energy in the building?	4 yes very much, 14 yes, 5 a little bit, 2 not so much, 0 not at all
11. Was it clear and easy to apply the method to the room you selected?	0 yes very much, 12 yes, 9 a little bit, 4 not so much, 0 not at all
12. Can you give us examples of problems you faced?	See table question 12 and 16

13. Has the method the potential to improve the communication between architects and building service engineers?	1 yes very much, 12 yes, 11 a little bit, 1 not so much, 0 not at all
14. What kinds of problems in the selected rooms did you identify by using the method? (multiple answers possible)	13 The room did not have sufficient sensors, 9 It is not clear which parts of the room are controlled by which device, 9 There is not enough personal control possibility in the room, 3 others
If others, please provide examples:	- There are too many control points for an automated control system to be efficient. At best the sensor results can be only informative. - Hard to identify control zone , hard to place sensors
15. Most of you had selected smaller rooms. Do you think the method could be also applied to larger and more complex rooms?	3 yes very much, 15 yes, 6 a little bit, 1 not so much, 0 not at all
16. What problems do you expect in using the method for larger rooms?	See table question 12 and 16
17. In order to apply the method to the room you had selected, how much time was approximately necessary?	1 less than 1 hour, 15 1-3 hours, 9 3-5 hours, 0 more than 5 hours
If more than 5 hours, how long?	-
18. What were the main problems in using the method? Please describe a few examples:	See table question 18 and 19
19. Do you have any specific suggestions for the improvement of the method? Please provide them:	See table question 18 and 19

Question 12 and 16

	12. Can you give us examples of problems you faced?	16. What problems do you expect in using the method for larger rooms?
1		It it might not be clear which parts of the room are controlled by which device.
2	Was not so easy, when some people are sensors and controllers at the same time (teachers).	The Scheme will be very big and it will be very hard to keep the overview of all the parts. Also when their are many devices of the same kind the line connections will become to long and it can get unclear how things are connected.
3		No Problems, just a bigger structure tree and maybe more interconnections between terminals and controls, etc. besides, we chose a big room.
4	Selected rooms have a large window.this window is opening or closing by one door which is located in the left corner. my problem was how could manage right corner of the room with the area near the window!	One of the difficulties could be start from opening or closing doors and windows.How to evaluate for example, C ,T or RH in large rooms!
5	The space had not enough sensor and some place had not enough device. and big area of window without blind	the problems include to the number of sensor or the number of device and control each of them in large room.
6		For the larger rooms with the higher amount of devices, connection between zones, devices and controllers can be to complicated and unclear.
7	It was easy after the more detailed explanation with the examples from the student presentations. It was hard to define the required number of sensors, but it was easy to show the existing situation afterwards.	the problem of scaling, it also takes a lot of time to arrange the elements together with the lines in the right way. It would be much easier if some application will be used for this, similar to this http://latentflip.com/hacks/violin/

8		The schema gets quite complicated as the no. of controllers and sensors increase.
9		If you have a complex building, with a lot of devices, it could be hard to group them and apply the method. On the other hand, in my opinion, if the method is applied successfully, it is more helpful for controlling larger rooms' systems.
10		The person who will use the method will need to simplify the effect of devices in the room, and seperate zones in a way that is not to complicated to understand.
11	Problems placing human in scheme, with devices that are operated only by occupants Problems defining lighting sensors depending on daylight, and integrating existing motion sensors in the scheme	lots of sensors, scheme can get to complicated
12		it might be too complex to model a big project manually.
13	First tried to apply the method for the whole floor of analyzed building, however- it was very complicated then and almost impossible to define it properly on one schema.	See 12. Confusing in larger areas, too many relationships.
14	If I had to do the same thing for a building (not for a room) it would be much more complicated (I have tried that but I have failed).	It is getting much more complicated (I have tried doing that but without any success).
15	It was a bit confusing to define Meta-controller in a room. When the amount of sensors is higher that usual for a small room, schema might get very complicated.	The schema will get much more complicated and connections between the devices and controllers as well. Apart from that, to my mind, the method should function well for bigger rooms as well.
16		A more complex system at a certun point can become inefficient.

17	It was hard to identify the control zones.	Having too many zone controllers which have the need of High level Controllers
18		I expect that it will be more complicated to use this method in larger rooms. If there are a lot of sensors scheme can become confusing.
19	room had a couple working places so at the beginning it wasn't so clear where to put our light sensors	Scheme for distributed control logic can get confusing if the analyzed space is too complex
20		In biggest spaces the system becomes more complex, the meta controller can be overloaded by different inputs and it couldn't work fast. Also, the system ignores other devices of secondary importance.
21	It was difficult to define the number of high level controllers at the first phase	I think that there would be too much information and it would be difficult to have a readable graphic
22		The schema will become a little bit more complicated
23	-When you have control devices in different shape and power and not uniformly distributed in the space , its hard to arrange distinct control zones and thus hard to place sensors in right place where you can retrieve a reliable information to transfer to the controllers.	-more devices ==> more complex controle zones ==.> more sensors ==> more complexe information to zone controllers ==>more nodes and more control rules -Simulation-based control strategy==>larger number of possibility ==>more complexe calculation might let to less reliable results
24		In larger spaces the amount of sensors will be increased and hence connections between them should be carefully controlled in order to keep the system simple and effective in using

25	I was not sure about the real technologies in the building, so my project was more or less an estimation of how the building systems could work and they could be connected among each other.	- right estimation of the number of sesnors - roght distribution of sensors - great number of devices/systems - complicated and chaotic diagramm

Question 18 and 19

	18. What were the main problems in using the method? Please describe a few examples:	19. Do you have any specific suggestions for the improvement of the method? Please provide them:
1	Prioritising devices in overlapping influence areas.	
2	Overview can get lost by bigger structures.	Maybe make the influence of devices and controllers visible. For example a blind will just have 10% influence on the temperature zone (passive heat gain) and a heater 90%. When both is connected with a line they are displayed like equal. Maybe to show over colors or thicker lines.
3	Analysing which actuators belong to which zones etc. For our room most of the terminals were controlled by the professor using the room, except the ventilation system. He complained that in summer the HVAC is regulating the temperature too and it is often too cold, and changing this is not possible. We were told, that calling the control room (which is in a different building) does not give an immediate solution. -> this problem can be generalized to any room having mixed controlled systems. further problems can occure if automized systems do not operate in the user's interest eg.: the automized systems create discomfort for the occupant.	
4	In my opinion the main problem is with the control device.Automatically if they work together, how to should open the window to complete the C or RH If have enough temperature. Or if it is working manually who should care about to manage them.	

5	dose not cover any source of heat and light. the lake of lighting in some part of place.	
6	No problems.	
7	defining the zone controllers and placing the sensors	improving the interface :)
8	As mentioned the schema gets quite complicated. But I think dividing the rooms virtually into different sections can help solve that situation	
9	In my case, firstly I named all devices one by one. At the end, I had really complicated scheme even it was no meaning to named them separately. Then, I decided to group similar devices (for instance two windows on the north wall are named as 'window 1'). In thay way, I simplified the scheme.	
10	- Defining zones as there were no sensors - Getting information abouts controls, escpecially for central operated systems	
11	understanding the existing sensors, what influence what, how to make scheme for existing sensors with devices that are operated by occupants only, how to make new scheme with suggested sensors, but still leave people as actuators for some devices, how to decided what is a high level controller with scheme that has people in it	
12	if the room or zone becomes bigger and more complex. the scheme will look really complicating.	
13	see 12.	na.

14	My problem was that I tried with much larger room and since I didn't have any experience with the method I made some mistakes. I have changed it and it was all fine. At the presentation when I had to present it I have made the presentation much more complicated than I had to make it and since I was not presenting from my laptop something went wrong. After that I have fixed it and I hope it is fine now.	
15	One of the problems was placing the sensors themselves, as in the first version they were placed furniture-oriented. Though, as location of furniture is a changing factor, location of sensors has been changed to room-oriented.	As a suggestion, a row of zone controllers might be eliminated, as they resemble the same content and sequence of connections, as zones (sensors).
16	There are too many control points for an automated control system to be efficient. At best the sensor results can be only informative.	
17	Figuring out when do you need zone controllers and when High Level Controllers	Not at the moment
18	Selected room had small area, but a lot of devices, so it was simplified. (two windows on one wall were represented as one...) Zones were overlapping so the plan was not clear.	
19	Because room dimensions were too small but to many of devices in it we were little confused where to put sensors (the best position) Correlation between dimensions of analyzing room and number of devices can cause overlapping influences of devices - how much those information are reliable	

	because of simplification of assumed impact zones of devices...	
20	The problem was to define how many high level controllers were necessary in the room.	
21	The first problem was that at first, in a room without any sensor, it has been difficult to identify the needed sensor. Then it has been difficult to decide how many high level controllers were needed.	I think that, if this method wants to be adaptable also to big buildings, there should be a clear formulation concerning how to deal with the complexity of information that a bigger building can bring.
22	I had some problems about defining the high level controllers	As we discussed in class, it could be considered useless the last level: zones (sensors)
23	-defining the importance and influance of devices in zones controlers -Device placement to get real information specially in complexe rooms - Theoretically the method can be used easely	
24	Problems were connected with defining certain energy saving measures that could be applied after sensors installation.	
25	to understand which devices are controlled by mechanical controller, which are controlled by human or by both of them and how to depict them correctly.	

8.9. Notes on the working process of the students

The interim result and the final presentation show, which tasks were carried out correctly by the participants and which tasks the students had problems with.

	Feedback	**Results**	**Task 1: Select and document (plan/section/images) and acutal space/room**
1	Reworking on: -zone plan: zones, missing zones for ventilation, -sensor plan: there is no sensor plan for the choosen room in the presentation, -schema for distributed control logic: there is no schema for the choosen room in the presentation, -comments about strenghts and weakness of the METHOD.	see feedback and tasks	OK
2	Reworking on: -zone plan: unclear illustration (lots of colours) - it`s not so clear (it would be clearer if you make first plan with devices - so you already did, second plan with devices and zones and third plan with devices, zones and sensors), -schema for distributed control logic.	good reworked presentation; schema with too many devices make it unclear	OK
3	Reworking on: -zone plan: there are lots of zones - it would be possible to combine the zones which are toghether controllable (e.g. if a few lights have the same switch), -sensor plan: there is no sensor plan for the choosen room in the presentation (it is very useful if the first plan is with devices, second plan with devices and zones and third plan with	good reworked presentation with good illustration of device, zones and sensor plans! schema unclear	OK

	devices, zones and suggested sensors), -schema for distributed control logic, -comments about strenghts and weakness of the METHOD.		
4	Reworking on: -sensor plan: there are too many sensors; sensors and zones don`t match. it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic, -comments about strenghts and weakness of the METHOD.	see feedback and tasks	OK
5	Reworking on: -schema for distributed control logic	see feedback and tasks	OK
6	Reworking on: -zone plan: it`s not clear why the shading and the diffusors have the same zone, -sensor plan: the position of the sensors are not clear, there could be more lighting sensors, -schema for distributed control logic	clear plans with zones and devices	OK
7	Reworking on: -zone plan: not clear - it would be clearer if you combine the zones which are toghether controllable (e.g. if a few lights have the same switch), -sensor plan: the position of the sensors are not clear (it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors), -schema for distributed control logic	see feedback and tasks	OK
8	Reworking on: -zone plan: window-, shadowing- and radiation zones are missing, -device-, sensor- and zone plan: it is very useful if the first plan is with devices, second plan with	plans with devices, zones and sensors are clear, schema is not	OK

	devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic, -comments about strenghts and weakness of the METHOD.	clear/not finished	
9	Reworking on: -zone and sensor plan: sensors should not be orientated on the flexible furniture, -schema for distributed control logic, -comments about strenghts and weakness of the METHOD.	see feedback and tasks	OK
10	Reworking on: -sensor plan: positions of the sensors are unclear, there are too much temperature sensors for that small room, -schema for distributed control logic.	plans with devices, zones and sensors are clear, schema is not clear/doesn`t work	OK
11	Reworking on: -sensor plan: the choosen position of the lighting sensor is unclear, -schema for distributed control logic.	see feedback and tasks	OK
12	Reworking on: -sensor plan: the choosen position of the lighting sensor is unclear, - devices-, sensor- and zone plan: it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic: is not finished.	see feedback and tasks	OK
13	Reworking on: -schema for distributed control logic: blinds have no connection in the schema because they are not flexible, -comments about strenghts and weakness of the METHOD.	see feedback and tasks	OK

14	Reworking on: -description of the room: unclear description - it is not clear if anything is automated by now, -schema for distributed control logic: is not finished.	see feedback and tasks	OK but too less description, it`s not clear if anything is automated by now
15	Reworking on: -zone plan: is missing, - devices-, sensor- and zone plan: it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic.	good reworked presentation but it could be a better depiction of the plan with devices, zones and sensors and the schema. HC level of the schema doesn`t work.	OK
16	Reworking on: - devices-, sensor- and zone plan: it is not so clear! it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic, - comments about strenghts and weakness of the METHOD.	good reworked presentation with good illustration of device, zones and sensor plans! Positions of E and HC level unclear. Missing comments about the method.	OK

17	Reworking on: - devices-, sensor- and zone plan: it is not so clear! sensors should not be orientated on the flexible furniture. it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic.	see feedback and tasks	OK
18	Reworking on: - devices-, sensor- and zone plan: it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic.	very clear plan with devices, zones and sensors; see feedback and tasks	OK
19	Reworking on: - sensor plan: if there are no devices to navigate in a room, it is not necessary to put sensors in it (e.g. a room without a radiator doesn`t need a temperature sensor), -schema for distributed control logic, -comments about strenghts and weakness of the METHOD.	see feedback	OK
20	Reworking on: - devices-, sensor- and zone plan: it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic.	good reworked presentation with a little mistake at the HC level	OK

21	Reworking on: -description of the room: is missing, - devices-, sensor- and zone plan: it is very useful if the first plan is with devices, second plan with devices and zones and third plan with devices, zones and suggested sensors, -schema for distributed control logic, - comments about strenghts and weakness of the METHOD.	see feedback and tasks	missing

	Task 2: Document with identify devices/terminals and respective terminals (marks/symbols on plan)	Task 3: Specify your best estimate of the spatial influence zone associated with each device/terminal (show on the plan)	Task 4: Generate the scheme for distributed control logic
1	OK	missing zones for ventilation; no sensor plan for the choosen room	no schema for the choosen room
2	OK	OK	too many separated devices make the schema unclear. Problems with HC level
3	OK	OK but problems with a fex sensors (windows, blinds)	Problems with HC level
4	OK	zones and sensors don`t match.	Problems with HC level
5	OK	OK	Problems with HC level
6	OK	OK	OK
7	OK	OK but too much sensors	not clear
8	OK	OK	Problems with HC level
9	OK	OK but too much sensors	In the schema the connection between E1 and R is too much -> problems with HC level
10	OK	OK	schema unclear
11	OK	OK but sensor position of E not clear	Problems with HC level
12	OK	OK but sensor position of E not clear	HC level missing
13	OK	OK	Problems with HC level
14	OK	OK	no so clear
15	OK	OK but sensor position of E2 not clear	Problems with HC level
16	OK	OK but sensor positions of E not clear	Ok but little mistake (no connection between t & Vo)
17	OK	OK but lighting sensors orientate on the flexible furniture	Problems with HC level

18	OK	OK	Problems with HC level
19	OK	OK but zones and sensors don`t match - too much sensors	Problems with HC level
20	OK	OK	OK - little mistake at HC level
21	OK	OK	doesn`t work

8.10. **Curriculum Vitae**

DI Birgit Rader

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Date of Birth:	22.06.1987
Nationality:	Austria

Professional Background

2019 – ongoing	Owner of the real estate company *Rader Immobilien*, Villach, Austria
2019 – ongoing	Trainer at *Wifi* for homestaging courses, Klagenfurt, Austria
2018	Managing director of the real estate company *Immostage*, Villach, Austria
2016 – ongoing	Owner of the company *Homestaging Expert*, Villach, Austria
2013	Architect in *Hausverstand.Com*, Vienna, Austria
2010	Charitable project: planning and building a school, South Africa
2009 – 2010	Architect in *Auratect*, Spittal/Drau, Austria
2008 – 2009	Architect in *st:art architecture&design*, Klagenfurt, Austria

Educational Background

2013 – 2019	PHD, TU Wien, Vienna, Austria Topic: Approaches and tools toward integrated design of buildings and their environmental control systems
2018	Training as real estate agent, real estate manager and real estate developer
2005 – 2012:	Master of Architecture, TU Graz, Austria Master thesis: Städebauliches Konzept zur Steigerung der Lebensqualität in der Stadt Spittal an der Drau
2005:	Highschool graduation, Bundesoberstufenreal-gymnasium Spittal an der Drau, Austria

Computer Skills

Operating system	MS-Office
Image processing	Photoshop, Adobe ImageReady CS, Adobe InDesign
CAD	Autocad, Revit, Archicad, Artlantis, SketchUp, 3dsMax, V-Ray, DIALux
Simulation	EnergyPlus, MatLab, Archiphysik

Languages

German, English

Publications:

Rader B. & Mahdavi A. 2016. Bridging the gap between systems controls and architectural design. Applied Mechanics and Materials. Special Volume: Energy Saving ad Environmentally Friendly Technologies – Concepts on Sustainable Buildings (2016) 824; pp. 821 – 828.

Rader B. & Mahdavi A. 2016. Supporting integrated approaches to the design of buildings and their technical systems. Clima 2016 - 12th REHVA World Congress, Aalborg, Denmark; 22. - 25. May 2016, ISBN: 87-91606-26-8; Paper-Nr. 182.

Mahdavi A. & **Rader B.** 2016. Integrated buildings and systems design: approaches, tools and actors. Proceedings of the ECPPM 2016 eWork and eBusiness in Architecture, Engineering and Construction, Limassol, Cyprus; 07-09 September 2016, Christodoulou & Scherer – Balkema. ISBN: 9781138032804; pp. 57 - 64.

Rader B. & Mahdavi A. & U. Pont 2015. Bridging the gap between systems controls and architectural design. 10th International Conference Buildings & Environment 2015, Bratislava, Slovakia, 15. - 16. October 2015.

Mahdavi A. & Schuß M. & **Rader B**. 2015. A Multi-Zonal Schema for Systematic Compartmentalisation of Building Systems Control Logic. www.ticon.org – Journal of Information Technology in Construction, 20 (2015), Special Issue; pp. 121 – 131.

Mahdavi A. & **Rader B.** 2014. Testing a method for the generation of the systems control schemes for buildings. Proceedings of the 2nd ICAUD International Conference in Architecture and Urban Design Epoka University, Tirana, Albania, 08-10 May 2014.

Rader B. & Mahdavi A. 2014. Usability assessment of a generative building control logic distribution scheme. Proceedings of the 10th European Conference on Product and Process Modelling (ECPPM2014). Taylor & Francies – Balkema. ISBN: 978-1-138-02710-7; pp. 609 – 613.

Rader B. 2012. Städtebauliches Konzept zur Steigerung der Lebensqualität in der Stadt Spittal an der Drau. Master Thesis.