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Smart field test: experience of users and technical aspects

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Abstract
Agent-based ‘smart’ systems for energy management in buildings show great promise for enhancing comfort of individual users, for saving energy and for enabling cost effective building management. The study is part of a larger project to design, implement and test an experimental smart system (called Smart) in a new office building at the ECN site near Petten, The Netherlands. The objective of this part was to investigate in a field test a prototype of Smart, with special attention for the user aspects.

In the study user comfort, perceived office temperatures and ventilation levels and the usage of comfort regulation systems were assessed before and after the introduction of Smart by means of questionnaires. For a more extended disclosure of these and other user aspects also interviews, group interviews, contextual interviews and participant observation were practised. The field test made clear that the Smart technology worked in principle and that the test users took a positive attitude toward the system. However, a comparison of the situation before and after the introduction of Smart taught that the type of building in which the system is implemented can have important consequences for the user assessment of novel comfort regulation systems such as Smart.

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SUMMARY

Agent technology based ‘smart’ systems for energy management in buildings show great promise for enhancing comfort of individual users, for saving energy and for enabling cost-effective building management. The present study is part of a larger project in which different aspects of the design and implementation of such a system (called Smart) in an office building were investigated. It reports about the user aspects of the implementation of Smart in a field test and its related technical aspects.

In the springtime of 2002, a prototype of Smart has been installed and tested in an open-plan office setting in a new building at the ECN site near Petten, The Netherlands. For the sake of the test, the office space was divided in five comfort zones in each of which temperature control was possible to a certain extent. During six weeks, a test population of about 25 office workers had access to Smart by an interface installed on their personal desktop computers. Through this interface, the test users were able to enter personal comfort preferences relating to perceived room temperature once per hour by means of a voting protocol. For each comfort zone, the individual votes were processed regularly by the Smart optimiser in which software agents represented the interests of individual users. The outcomes of optimising, in terms of optimal temperature settings per zone, steered the heating of the office space by setting the controls of dispersed heating units in the ceiling of the room.

The present study reports about aspects of comfort in the test situation as perceived by test users, and about the ways in which test users practised and assessed comfort regulation before and after the introduction of Smart. For investigating these aspects, questionnaires, personal interviews, group interviews, contextual interviews, and participant observation were used.

The main outcomes of the study are the following:
- The building manager expected most of Smart-like systems for optimising energy consumption against energy price by trading in liberalised energy markets. His expectations of Smart’s potential for comfort management and the saving of energy in buildings with high inherent energy efficiency were low.
- We found no Smart-related changes in the appreciation of comfort by office workers. The test users reported no perceptions of improved comfort after the introduction of Smart.
- Initial interest in Smart among test users dropped quickly, and over the complete test period Smart was used only modestly. During the test period of six weeks, 18 of the 23 test users voted 98 times.
- The test users turned to Smart only as a second best option for adjusting their comfort level. Most test users preferred alternative routes over Smart for comfort management, i.e. by adjusting ventilation or clothing.
- About 50% of the test users did not have a clear opinion on the usefulness of Smart. As far as opinions on the usefulness of Smart were expressed, these were mostly negative.

A number of Smart-independent conditions characteristic for the test situation seem to be responsible for these findings:
1. Smart was designed for usage in an individual environment, but it was applied in one large room in which all the users were located. Though this discrepancy was at least partly solved by establishing five comfort zones within the room, the comfort delivered could not be fine-tuned to individual preferences of users. Moreover, the equipment used to control the temperature within each zone (small heating units in the ceiling) was not designed for this purpose, and was not very effective.

2. Only during the test it became clear that, because of the high energy efficiency of the building, active heating was needed only during a short period in the early morning before the office workers arrived. During the rest of the day, the building was passively heating up by heat accumulation due to presence of people and operating appliances. There were no provisions for cooling that could be activated by using Smart. Thus, because of the inertia of the building, the practical possibilities to control comfort by Smart were very limited. Therefore, it is understandable that the test users perceived the effectiveness of Smart as low.
3. Test users could adjust comfort by means that were independent of the Smart system, i.e. by manually operating ventilation valves and by adjusting clothing. In the logic of users, these alternatives were to be preferred over using Smart because (i) they were perceived as being more effective than Smart, and (ii) they were already included in user routines before Smart arrived.

Consequently, Smart had to confront an adverse building logic. Its resulting lack of effectiveness then reinforced a user logic that turned users away from Smart. It is quite possible that, if a building with more favourable characteristics had been chosen as the test location, the Smart system would have been assessed more positively.

The field test revealed some shortcomings of the prototype used. Not all aspect of the Smart system, notably the use of the option for saving energy and some terms used by the Smart interface, were fully understood by the users. This incomprehensibility of some of its parts was shown to lead to decreasing the use of Smart and to negligence by test users of those options they did not understand. The scant information about the system given to the test users aggravated these shortcomings.

The physical measurements taught that the real temperatures in the building were considerably higher than the average temperature test users indicated as the preferred one. In this discrepancy looms an opportunity for the saving of energy in a new building that was estimated to be highly energy efficient. This outcome demonstrates that the delegation of energy efficiency to inherent building characteristics (large mass, high isolation value) may be undermined by use practice, i.e. by interaction processes between building managers and their clients resulting in temperatures going up.

The main recommendations derived from the study are:
1. Smart-like systems should be tested and applied in situations where they can make a difference. In the first place this implies that at the test site, all parameters needed to control comfort can be effectively manipulated and monitored by flexible equipment. Second, if Smart should be an obligatory passage point for users, *all* building provisions relevant for comfort management should be under the control of Smart and *only* accessible through Smart. A pop-up screen reminding users of occasions for voting can further support the enrolment of users. However, the logic of Smart should not overrule the demonstrated desire of users to keep control over their own comfort. On the other hand, this desire is expected to weaken as Smart better satisfies individual comfort preferences and succeeds in building trust among its users.
2. The spatial layout of the test site should be such that deliverance of individual comfort can be guaranteed. In an open office space these conditions are hard to realise. When we include also the previous recommendation, this implies that the design logic of the building has to converge with the design logic of the mode of climate control (cf. outcomes of WP 4.1).
3. Early user involvement in the design of the Smart field test is to be preferred, and test users must be better informed during the test. By early involvement of users, the designers of the Smart system can easier decide which options users are willing to trust to Smart and how the interface can best be designed. Careful communication with the users about the system at the introduction and during the test will also help to make it more transparent for users where needed, and thereby enhance its use and effectiveness.

Finally, users were asked opinions about possibilities to improve the functioning of the Smart system. The inclusion of additional options for comfort management in the Smart system, the use of a pop-up screen and the idea of grouping the users on the office floor according to their comfort preferences were assessed. The assessment of the first two options was ambiguous while the use of the last option was clearly rejected because of being incompatible with work relations. As the acceptance or rejection of such possible improvements is probably user dependent, this underlines the relevance of early user involvement and increased communication during the field test.

1 INTRODUCTION

Existing control systems for public and commercial buildings under-utilise new technical opportunities that emerge from computer networks which become increasingly fine-meshed. Especially in organising access to distributed generation and calculation capacity, the utilisation of existing potential is generally far from being optimal. At the same time, information that is or can be made available through networks- such as Internet and power lines- is seldom exploited fully to enhance the performance of such systems.

To improve this situation, a new generation of control systems is being developed for use in the operation of public, commercial and residential buildings. The general objective of the Smart-project is to formulate requirements for such new systems. The technology of these systems will be based on agent mediated communication over local networks, the Internet and power lines. Such novel control systems not only should improve the performance of the building, but should also offer opportunities to users (i.e. building operators as well as residents and workers) for linking comfort management with improving energy efficiency and the application of renewable energy. Along with energy saving, cost saving could be reached by automated selling and purchasing of energy through agent-mediated electronic marketplaces (Kamphuis et al., 2001).

One of the more specific goals of the Smart project is to gain experience about implementation of requirements for such a system in an experimental setting. Right from the start, aspects of use, such as user acceptance and embedding the system in a practice of use, were included in the development of system requirements to be explored in the field test. During the course of the Smart project, the user setting gained an even more prominent role in the design of the Smart system. Meant to improve comfort for individual users, the system however had to reckon with a collective of users in one large open-plan office floor at the test site, which introduced severe complications for its design. The present study reports about experience of test users with a prototype of the system, and assesses the results in relation with design constraints.

The Smart-project as a whole consists of a number of research and development activities divided over several work packages. For an elaborate project description and work-plan, we refer to the overall Smart project proposal (Projectplan, 2000). The present report is the final report of work package 4.2. The complete list of work packages can be found in Appendix A of this report.

2 APPROACH

For this work package, we applied the same general approach as for WP 4.1 (see ECN-C--02-008). Summarised briefly, this implies that we conceive systems (the building, its technical provisions including Smart and its users) to be ensembles or networks of actors interacting (i.e., acting and reacting) in the production of effects, which can be observed, measured and assessed to optimise the original design of the system. For the system to produce effects on the behaviour of its users, factors of most importance are:

- The strength and weaknesses of scripts, i.e. the extent to which specifics of the system guide intended as well as unintended forms of use.
- Overlaps and misfits between design logic and use logic, i.e. between interests, needs, values and conceptions of designers on the one hand (as inscribed in the hardware and software of the system) and of the users on the other.

In the test situation investigated, the material landscape in which the users navigated to optimise their comfort did not consist of the Smart system only. Users had also direct access to other equipment mediating comfort such as ventilation valves above the windows, which could be opened and closed manually, and thermostats for setting temperature. Thus users were able to manage their comfort via different routes through the provisions available to them. In fact, the Smart system had to compete with these alternatives to enrol users. Therefore, we did not only study the interactions of users with the Smart system *per se* but included in our study the interactions with other agents for comfort mediation.

Choices by users to take one or another route for comfort management may be influenced by the interaction of scripts (acting out the underlying design logic) of the different technical options offered on the one hand, and by use logic on the other. That is, the different options available may appeal in different ways to the logic of users in terms of desirability, comprehensibility etceteras. The logic which users -often tacitly- mobilise in making such choices is partly a historical product of the work situation itself, partly imported to that situation from other settings such as the home where also comfort management is taking place. On the other hand, comfort management at work may be governed by a different logic just because one is *not* at home, leading to different practices in terms of needs, values, assessments and actions. Taking user logic into account as a context of interpretation may thus make actions and reactions of users within the system more comprehensible, and may save the investigator from making de-contextualised interpretations of user behaviour that may be too individualistic and therefore less informative.

Designers may anticipate user logic and adapt the scripts of designs to achieve a better match between design logic and use logic. Greater congruence between both may ameliorate the implementation of new technology and prevent unintended forms of use. For such anticipation to be possible, forms of user representation have to be practised during design.

The context of the Smart field test was further complicated by the fact that the prototype of the system tested was implemented in a new building which already had a very high energy efficiency by design. That is, the saving of energy had been taken out of the hands (and minds) of the users and delegated to a large extent to actions of the building provisions itself in collaboration with the operators. This could imply that the design logic of the building made opportunities for the test users to save energy through the Smart system questionable, i.e. it might make the implementation of the energy saving option in Smart more difficult. One could say that, in this respect, the design logic of Smart was at odds with the design logic of the building (see the outcome of Smart WP 4.1, Jelsma, 2001). The fact that Smart, a tool for individual comfort management, had to prove itself in a shared environment -an open-plan office floor- added to this mismatch of logics. This mismatch had implications for the design of the Smart system as well as for the study of the user aspects (see below).

3 RESEARCH QUESTIONS

Taking into account the foregoing approach, the following questions were leading the study of the user aspects of the Smart test:

- How were users represented by designers, which assumptions did the designers make about the logic (preferences, views, attitudes, values) of users, and how were these translated into the design of the Smart system?
- How did interactions develop between the test users and the provisions for comfort management (Smart system and building provisions) in building 42-1? Did any new practice or routine develop, and how was it being shaped? How did the use of Smart relate to the use of other provisions for comfort management?
- Which forms of user logic underlie relevant user preferences, attitudes and actions?
- How did users assess the Smart system in terms of visibility, usefulness, transparency, trust?
- Were there any misfits between the logic of the system and the logic of the users than should be repaired in the next version of the Smart system?

4 PLAN, METHODS AND INSTRUMENTS

4.1 Plan

The study was carried out in two phases:

Phase 1: Preliminary investigation (February 2002)
This phase was carried out shortly before the Smart system was introduced and made available to test users. The objective of this part of the study was twofold. First, it aimed to obtain information that could be used during the next step of the investigation. The second purpose was to create a reference situation, i.e. to gain relevant information before the Smart system was made available to the test users, to be compared later with the data collected at the end of the test[1]. Comfort indicators checked with users were explored as an aspect of use logic, user assessment of the existing comfort was measured, as well as attitudes relating to energy saving in the office and expectations concerning the Smart system. Additionally, in this first stage, considerations about user representation have been developed and communicated with the designers of the Smart system. These helped to shape those parts of the system that would be in immediate contact with users. Finally, ideas were explored about possible motivations of users for saving energy in the office through the Smart system. These ideas were to be verified in the first phase.

Phase 2: User aspects of Smart field test (April 25-June 11, 2002)
Phase two was carried out during the field test. The objective of this part of the study was to produce data to answer the research questions, i.e.:

- To measure frequency and ways of use of the Smart system.
- To measure effects on the practice of comfort management by the test users and on comfort experience.
- To inquire on satisfaction of users with the system.
- To produce some insight in the underlying logic of the outcomes.

4.2 Survey of research methods and instruments

To tackle the research questions, different types of research methods or instruments were needed each of which was used to answer certain aspects of the research questions. In the sections below a survey of the research methods employed is presented. In this survey, it is explained which kind of data was collected by means of the methods described. The chapter ends with an overview of the research scheme describing the order in which the instruments were applied.

4.2.1 Questionnaires

Questionnaires are written lists of fixed sets of questions with pre-determined response options. Questionnaires can be used to collect data among a larger group of people. The data to be collected must be concrete and easy to define. Further, questionnaires lend themselves for measuring difference -such as difference in comfort perceptions- among respondents, and to calculate correlation between categories of answers if the group of respondents is large enough. Less focused data such as insights, ideas and considerations and especially the reasoning behind are hard to obtain by means of a questionnaire. In this study, questionnaires were used to collect and

[1] The alternative -working with a control group- was crossed out because the group of test users was too small to be split and the other floors in the new building were still empty at the time we planned the study.

to compare concrete data among users before and after the introduction of the Smart system. No correlation of data was practised because of the small group size.

4.2.2 Personal interviews

Personal interviews deliver qualitative data resulting from sessions in which an interviewer interrogates an interviewee. This technique is suitable to acquire detailed and unique data on individual perceptions, considerations and experiences but because of workload, only from a small group of persons. In our study, the personal interview was used to acquire information in only one case.

4.2.3 Group interviews

The group interviews we applied were a weak version of focus groups. Using focus groups is a qualitative research method based on discussions in small groups (seven to ten persons) initiated and led by a moderator to collect data on the topic in which the researcher is interested. Focus groups lend themselves particularly to explore a new topic, and to generate a rich understanding of participants' experiences and beliefs (see Morgan, 1997). An advantage of focus groups above personal interviews is that during the focus group participants can react to each other's opinions and experiences and so uncover valuable additional information. In this way it is possible, in a short time span, to disclose unexpected aspects of or reasoning behind user behaviour, and about shared or contested opinions. The focus group participants must be interested or involved with the subject of the focus group. It is advised to have different rounds per group until saturation of information occurs, and to run parallel groups in which homogeneity is sought in terms of sex, age, education, etceteras. In this investigation the latter conditions could not be fulfilled because of the small size and the limited availability of the user group. To save at least some of the advantages of a group approach -especially its explorative and discursive function-, we applied a weak form of focus groups in the second phase of the study. That is, we undertook a group interview with a small sample of the test users (seven persons) recruited via the questionnaire in the first phase.

4.2.4 Contextual interviews

A contextual interview is a combination between observation and an informal interview (Beyer and Holzblatt, 1998). In a contextual interview, a user of a system is interviewed as an expert on the use of the system. During the interview the user explains why and how he or she uses a certain technology or system. While the user uses the system or technology, the interviewer can interfere by asking question why the user acts the way that he does. By using contextual interviews, real time information on how systems are actually used can be obtained. Contextual interviews were used on a modest scale to obtain detailed data on an individual level about the daily use of the Smart system.

4.2.5 Participant observation

In participant observation, the observer becomes a member of the community he wants to observe. After some time the community will not notice the observer anymore so that he can observe the daily state of affairs without distorting it. Participant observation was used in the investigation to obtain background information for formulating the questionnaire and to obtain additional information on the actual behaviour of test users directed at comfort management.

4.2.6 Brainstorm session

Brainstorming was used as a technique to generate ideas about ways to save energy through Smart. One session was run for which a group of internal experts was recruited.

4.3 Research scheme

During the first phase (before the introduction of Smart) the following methods or instruments were applied:

- Participant observation of the users in building 42-1.
- Interview with one of the building managers.
- Brainstorm session with experts.
- Questionnaire addressing the test users in building 42-1.

During the second phase (after the introduction of Smart) the following methods or instruments were applied:

- Contextual interviews.
- Group interview.
- Questionnaire addressing the test-users of building 42-1.

5 TEST SITE AND TEST USERS

5.1 Test site

Smart was tested on the second floor of building 42-1, a new and innovative multi-purpose building on the ECN site. Designed as a showcase of sustainability, the building has leading edge energy technology well integrated in its architecture. For instance, to avoid mechanical cooling, the principle of summer night ventilation has been applied. This implies that the building mass -which is larger than usual to act as a buffer- is cooled after a hot sunny day by passive ventilation during the night. For this purpose, various ventilation shafts have been included in the building design. Cool night air enters the building through ventilation valves above the windows. These valves can also be used for additional ventilation during the day (the windows can not be opened).

Blowing in air, which is being heated on cold days, centrally ventilates the building in the daytime. Due to the fact that the building is very well isolated, the central heating in building 42 is only in operation a few hours a day during autumn, winter and springtime**.** The temperature of the air blown into the building is set according to the Fanger regime [2]. Electric convection heaters in the ceiling can heat up the air further locally in places that are too cold (close to windows and corridors). The building operators set the temperature of the blown-in air as well as the local heaters' temperature. By setting a room thermostat, workers on the office floor can adjust the temperature per block of 8 ceiling heaters within the range set by the operators (plus or minus three degrees). They also have the possibility to open the valves above the windows to increase the ventilation level within the building (for a more extended description of the design of the building and its provisions, see WP 4.1 final report, Jelsma 2001).

During the fall of 2001 building 42-1 came into use. About thirty employees of the Shared Service Centre, the central administration unit of ECN, started their work on the first floor. The floor was laid out as an open-plan office space, with clusters of desks separated by low fences. The Smart system was introduced about six months later (in April 2002) when the office workers were well accustomed to the building and its provisions.

The Smart system was briefly introduced to the unit's employees by an e-mail announcing the preliminary investigation. In this e-mail the employees were invited to join as test users and to collaborate in the test. Handing out the questionnaire for the first phase was used as an occasion for further explanation of the system and its test. About two months later, a next e-mail announced the actual introduction of Smart indicating how the employees could log in on the Smart screen by using their desktop computers. This screen supplied the interface by which test users could interact with Smart, mainly to enter comfort preferences (see below). Only at the end of the test it appeared that a few employees had not been able to get access to Smart. However, the large majority of them (about 25 persons) used the system and participated in different parts of the investigation.

It is important to emphasise here that Smart was offered to test users as an additional, electronic option for handling comfort in their work environment. The mechanical provisions already pre-

[2] Fanger, a Danish researcher, developed a complicated formula relating empirically derived parameters of perceived thermal comfort in buildings such as air temperature, humidity, draft and clothing of test persons. From this widely used formula average settings for comfort management in buildings are derived (Fanger, 1970). The standard temperature and ventilation settings are chosen such that no more than 10% of all users will complain about the comfort they perceive. This 10% level - called predicted mean value, PMV- is a standard value laid down in the ISO standard EN 7730 (Fanger, 1996). The optimal comfort level is reached if only 5% of all users of a building complain about perceived comfort.

sent -such as the thermostat and the ventilation valves- remained available to them during the test.

5.2 Test users

The group of test users participating in the study (about 25 persons) consisted of employees of ECN's administration department. The distribution of sex in this group was about equal, whereas most members were above the age of fifty (for detailed information, see Appendix B Part B.3). Computer literacy was supposed to be high because of the kind of office work the test users practised; this was fully computer based.

6 USER REPRESENTATION IN DESIGN

Representing users directly in the design process was undermined by the fact that, in the early stage of this process, the users were still unknown. For a long time, it remained unclear which department would move into the new building in which Smart was to be installed. Nevertheless, designing Smart needed an image of its future user to be made explicit and to be fed back into design decisions. Especially the open-plan character of the office room was an issue of concern in this respect. Below we report the deliberations of the design team about user representation and the related design decisions made.

6.1 User heterogeneity

The use context of the Smart-test differs from systems developed for in-home comfort management systems such as early applications of COMFY (Boertjes et al., 2000). Within the home the roles of user and manager/operator coincide. In an office building, these roles are separated. Therefore, the Smart system had to deal with two types of users:

- Building managers operating the building management system.
- End-users instructing the building system through Smart. Within the class of end-users, further heterogeneity is to be expected. A relevant discrepancy that may appear is a difference in interest for experimenting with the system. Gender effects could occur here.

The distribution of authority and competence between both user types had to be inscribed in the software of the Smart system, so it needed attention to be given in the design process. The distribution inscribed had to reckon with the authorities, responsibilities and interests of both user groups. In principle, by using Smart, end-users can influence (i) aspects of comfort such as temperature, humidity and ventilation, (ii) energy used for this comfort to be supplied, and (iii) the share of 'green' energy in the total energy consumption by managing the solar energy generated by the roof covering the hall of the building. However, the design team decided that building managers should control all cost and energy trading aspects of the building management. Saving costs by trading energy should not be a burden of the end-user in the office. The Smart system was rather to be integrated in the existing management logic of building operators, i.e. setting bounds to the preferences that end-users are able to enter into the system. Further, the technical design characteristics (the 'scripts') of the building introduced further constraints on the conditions users were able to influence (see Jelsma, 2001). Consequently, the authority of Smart users was restricted to management of thermal comfort within the limits set by the building operators, and to saving energy in the supplying of this comfort. Since energy efficiency is an aspect of sustainability that users might want to promote, but also one of cost saving for the employer, the team's general opinion was that saving energy should be an option that users could choose to use or to neglect. Further it was clear that end users should have only competence to control comfort in the primary rooms, i.e. where they do their daily work. Secondary rooms such as corridors and hall were to stay under the exclusive authority of the building managers.

A second aspect of use was the challenge to find solutions for serving *individuals* within the constraints of the present script of the building, i.e. in an environment of *shared* technical equipment for creating comfort in an open-plan office environment. The technical solution sought was to define five thermal or comfort zones in which the temperature could be regulated more or less by bringing the settings of the ceiling heat convection units in each zone under the control of Smart. In the kind of hybrid environment present, three options for representation of end-users in the design of the system were distinguished:

1. *As a group* in a climate zone. After negotiations the group enters its preferences into the system. That is, negotiations about preferences are delegated to the group.

2. *As individuals*. Individuals enter their preferences into the system, which then calculates and implements an averaged solution. In this case, negotiation between individual preferences is delegated to the system and is invisible to the users.
3. *As individuals in a group*, i.e. a combination of option 1 and 2. End-users are conceived as individual group members who must be enabled by Smart to consider the choice made by other group members in making their own, and so influence the outcomes of the choice process in terms of thermal comfort acquired. This requires the system to make the choice process transparent to the group members.

After appraising the merits of all options the design team came to the following conclusion. Option 1 waters down the goal of Smart too much. Moreover, negotiation within the group may lead to conflicts. Option 2 keeps the suggestion of individual comfort management alive for end-users, but in reality the preferences entered individually are thrown into an electronic melting pot hidden to the users. This may undermine the confidence of users in the system. Therefore, from a user perspective, option 3 is to be preferred, but probably was the most complicated option to realise technically.

Inspired by a pilot study with a similar system (the DUCOZT system, see Oseland et al., 1997), the team decided to realise option 3 by developing an individual voting system for Smart. The voting system implied that every user in a thermal zone could enter his vote (warmer/colder) within a voting period (e.g. one hour) while seeing the aggregated voting of other users at the moment of voting. A user interface materialising this idea would look like this (cf. Oseland et al.):

Previous requests in your zone:	
warmer	63%
no change	13%
cooler	25%
time to next vote:	15 mins
current time	10.15

6.2 Control, trust and access

Further user aspects relate to control, trust and access. Users should put trust in the system, and have a feel to be in control of the system where needed. The following minimum requirements for the design of the system and its interface were thought to apply.

- *Transparency*: the system should make clear to users which actions they have to perform to achieve the outcomes they desire. The user must be able to check the system over time on the effects of an instruction entered and to compare these with the comfort perceived, in order to be able to formulate the next instruction. This means that the system must have forms of feedback toward users. The most important feedback is the perception of a comfort change after voting for such a change. For some functions, feed-forward may be considered too, that is, whether the system should inform the user beforehand on the effects of instructions entered, e.g. in the case of voting (showing before voting what others have voted already) and of saving energy. On the other hand, the system should not bother users with information they do not want, and it should not be a burden by interfering with normal office work too much.
- *Reliability*: to inspire confidence of users, the system should give reliable information, and not conceal information that users think to be important. For that reason, option 2 of user representation (see above) was found to be problematic. Further, the system should never interfere with normal office work as carried out on the computer under Windows. If users suspect it to do so, they will abandon the system.

- *Equality and access*: all end-users should have equal chances to manipulate the system for controlling comfort and saving energy. This means that the interaction with the system through the user interface should be as simple as possible, otherwise differences in competence to handle computers might introduce unwelcome heterogeneity between users in realising benefits through the system.

6.3 Communication with end-users

The formats and forms in which information is communicated by the system to its users were thought to be very important. Information contains a script, i.e. the layout of the information exerts specific forces on the actions of users. Relevant guidelines in this respect were considered to be as follows:

- *Avoid settings entered by users from force of habit or decency*: it is (perceived) comfort that is at stake. To break routines (e.g. routines of setting thermostats as being done at home), interface settings to be made by users should preferably not refer to familiar values such as degrees Celsius. It is better to present choices in differential terms (more/less or +/-). In asking users for comfort preferences it might even be better to refer to direct perceptions of feeling comfortable (see interface box below):

How would you like to feel?	
Warmer	[ ]
No change	[ ]
Cooler	[ ]

- *Report status and trends*: information about what the system is about to realise (i.e. trend) might be of higher value to users than only information about the condition(s) at a certain moment (i.e., status), since conditions change quicker than trends last. That is, information on status is obsolete the next moment, whereas information on trends is not. An example of giving combined information on status and trend is shown below (cf. Oseland et al., 1997):

Current temperature in your zone is:	[19ºC]
Your zone is now:	[↑ warming]

- *Set clear and motivating targets*. This could be helpful in supporting end-users to save energy (cf. McCalley and Midden, 1998).

6.4 Enrolling end-users

The first thing the Smart system must achieve is recruiting users. The force of the system to enrol users can be dosed by varying the openness of its script:

1. *Open script*: users have to activate the system themselves.
2. *Half-open script*: the system offers it service to users automatically (for instance, with regular intervals the Smart interface pops up) but users may switch it off unused.
3. *Closed script*: the Smart interface pop-up screen will only disappear after the user has entered preferences[3].

[3] A pilot study with the smart DUCOZT system revealed that a majority of the end-users (69%) preferred option 2 (Oseland et al., 1997).

6.5 Energy efficiency

To generate ideas about the design question how Smart could promote the saving of energy by changing behaviour of users, a brainstorm session with internal experts was held. The discussion at this meeting revealed the following opportunities and constraints for an energy saving feature to be effective:

- Considerable saving of energy is delegated to the building itself, i.e. the building is energy efficient by design (see Jelsma, 2001). This implies that its users have little opportunity for saving energy, which may undermine efforts to do so.
- In a utility environment, the saving of energy does not reward users but the employer. Users loose nothing by neglecting energy efficiency.
- Experience in the home environment demonstrates that support for extra behavioural effort to save energy is low; only 10% of residents are motivated to do so.
- Energy is only a small share of the costs faced by the employer. Due to productivity loss, dissatisfaction about comfort is a much more costly risk of increasing energy efficiency.
- Giving feedback, i.e. confronting users with long-term developments in energy consumption generally increases awareness, which generates incentives for saving energy by changing behaviour. This appeared from a campaign targeted at Dutch households (in Dutch: ‘Zuinig stoken, zuinig aan’). Goal setting may help consumers to maintain incentives over a longer period. Here again the question arose whether the results found within households apply in a work environment.

Part of the experts’ low expectations about energy saving potential in the office stemmed from the realisation that comfort levels were already tuned to user needs by the Fanger criteria on which the building’s central comfort management is based. Complaints by office workers more or less forced a further fine-tuning of the system to user needs. During the session, the building manager present indicated that, for an operator, the easiest way to satisfy complaints about cold is to raise the building temperature. Those who are getting too warm open the window. In this way, an optimum comfort is realised which users will not give up easily, he thought. However, this practice leads to an average temperature in ECN buildings close to 23 degrees C, a temperature considerably higher than most workers were expected to have at home. The experts agreed that in this temperature difference a considerable potential for saving energy is looming, since a 1-degree decrease in room temperature implies a 10% saving of energy consumption. Behavioural change supported by Smart could support an ECN-wide policy setting targets for bringing down office temperature. Smart could help in giving feedback to users about their contribution in catching these targets, the experts argued. This approach could be successful only if the employees could be convinced to participate, and such participation would be voluntary. The latter condition is difficult to realise in an open-plan office setting. It was decided that the participants in the Smart-test would be consulted about such an initiative.

7 RESULTS OF THE PRELIMINARY INVESTIGATION

Various research instruments were used to gain information on the situation in building 42 before Smart was introduced (see Section 4.4). The information obtained can be divided into information on the following subjects:

- Interview with building operator.
- Perceived comfort.
- Use of options comfort regulation building 42.
- Expectations and opinions on Smart.
- Attitude and conditions on energy saving.

7.1 Interview with building operator

One of the members of the department of ECN Building Operation & Management (FAC) was interviewed. Explaining the functioning of the current climate provisions and management in building 42-1 took a large part of the interview (the data from this part have been taken up in Section 5). Asked about his expectations about Smart, the building operator described the regulatory possibilities of Smart as limited. Since control of ventilation (which is related with humidity control) falls outside Smart's range of action, temperature remains as the sole comfort parameter users can influence through Smart. On the other hand, Smart could enhance user satisfaction by giving users an improved feeling of control that might decrease complaints. Though performance of the climate system and changes in settings are continuously registered by the building management system, the operator emphasised that building 42-1 is new and lacks a historical record of stored data. This might hamper evaluation of the performance of Smart where comparisons to be made require a reference, as in measuring changes in energy efficiency. According to the operator, supporting the opportunity to optimise energy consumption against energy price by trading on a liberalised energy market is the greatest promise of smart climate systems for buildings.

7.2 Comfort assessment and control

Comfort as perceived by future test users before the introduction of Smart was assessed by a questionnaire (see Appendix B).

First, we asked respondents to rank their perception of thermal comfort on the work floor. On average, perceived thermal comfort was marked as 6,9 on a ten-point scale (10 indicates perfect comfort). Air quality was marked as 2,9 on a scale from 1-5 (on which 5 means 'fresh'). Second, we requested respondents to rank determinants of comfort perception in order to be able to appraise possible dissatisfaction with Smart later on during the field test. Such dissatisfaction might appear to be related to one or more high-ranking parameters that were not under the control of Smart. In addition, this measurement yielded a check on how comfort was appreciated by the future test users in relation to the parameters derived from the Fanger doctrine, which was the theoretical ground on which comfort management in the test building was based. If Fanger is right, comfort in the building was expected to be perceived as satisfactory. If so, this would constrain the possibilities of Smart to improve comfort.

Respondents ranked ambient air temperature (i.e., whether the air feels comfortable or not) and draft as the most important comfort determinants by far. Besides being probed about determinants of comfort assessment as such, respondents were asked which aspects of comfort they wanted to have influence on. Besides ambient air temperature and ventilation, respondents mentioned lighting (artificial light as well incoming sunlight) as important factors they should be able to control. Air temperature preferred by respondents ranged between 19.9 plus or minus 0.8 degrees. Answers to questions about comfort perception over time revealed that appreciation of air temperature and ventilation decreased during the day. Proceeding from morning into afternoon, the number of respondents perceiving the building's climate as too hot increased (see Figure 7.1).

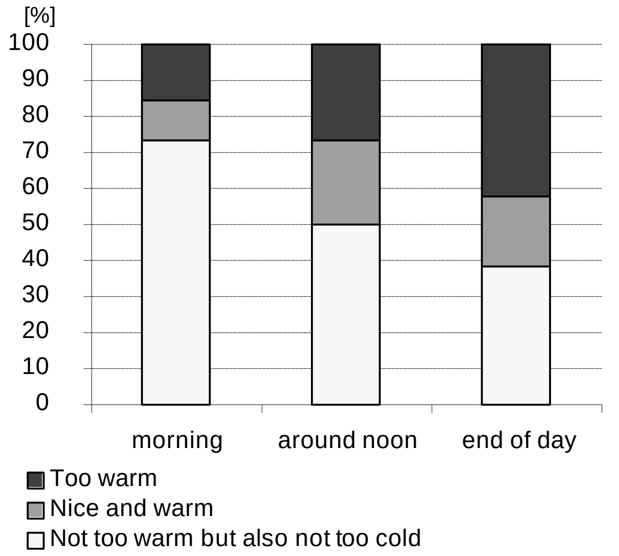

Figure 7.1 *Assessment of thermal comfort during the day*

With respect to ventilation a similar but weaker trend was observed, i.e. decreasing comfort during the day (see Figure 7.2 below).

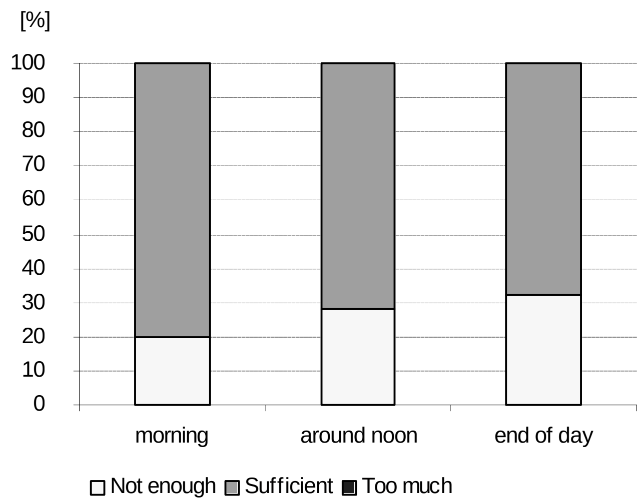

Figure 7.2 *Assessment of ventilation during the day*

7.3 Use of options for comfort regulation

Independent of Smart, users of building 42 can regulate their comfort by setting a room thermostat and opening and closing of the ventilation valves (see above). Various items in the questionnaire addressed the question of how often these regulation possibilities were used in practice. It appeared that the thermostat was only occasionally set by 12% of the respondents. In setting the thermostat no consultation of colleagues beforehand of afterwards took place according to 76% of the respondents. Two kinds of reasons not to use the thermostat could be distinguished. The one reason was ignorance; about half of the users did not know the thermostat existed. The other half deemed adjusting the temperature unnecessary or did not take time to set the thermostat.

About a third of the respondents (8) reported that they operated the ventilation valves regularly. About half of the respondents indicated that consultation about opening or closing took place beforehand, while about a third of the respondents indicated that no consultation took place. Seven people indicated that temperature control was dependent on time. Especially after a cold night the temperature was judged to be too low, and too high during the afternoon.

An individual possibility to improve one's comfort level is adjustment of clothing to the environmental temperature (Fanger's clothing factor). Whether the office workers practised this option was explored by asking which kind of clothing they normally wore at work compared with clothing worn at home. A majority (77%) of the respondents indicated they wore the same clothes at work as they did at home. However, some respondents did adjust clothing in relation with their work situation. Two people wore thinner clothes at work than they did at home and four people took off part of their clothing (e.g. a jacket or cardigan) during the day. This outcome corresponds with the outcomes presented above indicating that the temperature on the floor was generally perceived as high (Section 7.2).

7.4 Interest in Smart

In the questionnaire we took up one question to test the interest of the future test users in having a stake in their own comfort management by operating Smart. We could not exclude the possibility that office workers would see such management as a burden preferably to be delegated to others (building operators and systems). The basic attitude on this matter was positive though opinions of most users were conditional, i.e. dependent on how the system would function (see Figure 7.3).

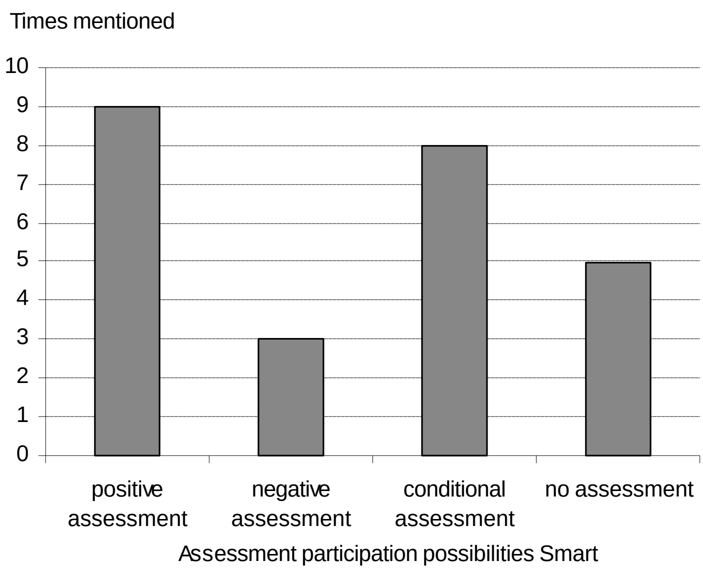

Figure 7.3 *Assessment user interest in Smart*

7.5 Attitude on energy saving

To complement the expert meeting (see Section 6.5) we probed test users' attitude on their willingness to save energy in the office. In order to prevent predictable answers as much as possible we asked users' response to statements on the topic. Per item users were asked to indicate

which one of pairs of contradicting statements were true (see Appendix B). The statements offered were either directed towards the user's attitude to the saving of energy as such or toward the conditions under which users were willing to do so. In the following paragraphs the responses to these questions are given.
With respect to users' willingness to save energy, it became clear that:

- Most users found it appropriate that the responsibility to save energy is allocated to the users (92% in favour).
- About a fifth of the respondents were inclined to allow a decrease in their comfort level in order to save energy.
- Almost three quarters of the respondents considered a pre-set energy saving goal as an interesting challenge.
- About a third of the respondents were willing to adjust their clothing to enable energy to be saved.
- Most users were willing to join discussions with colleagues in order to save energy (85% in favour).

Concerning the conditions under which the users of building 42 were willing to save energy the following data were collected:

- Users wanted to be in control of the comfort being handed in for saving energy (88% in favour).
- Energy saving had to be voluntary (73% in favour).
- Feedback was appreciated. 46% of the users was interested in saving energy only if feedback was given about the quantity of energy saved.
- A reward for saving energy was not deemed necessary. Only 8% of the respondents answered to be interested in energy saving only if they would receive a reward [4].

7.5.1 Temperature preferred by users and temperature as measured by Building Operation & Maintenance

In the questionnaire users were asked to enter the temperature they preferred to have in building 42. The preferred temperature mentioned was 19,9 degrees Celsius (standard deviation 0,8 degrees). This temperature was compared with the temperature measurements carried out by Building Operation & Maintenance (FAC). In Figure 7.4 below the temperature curve recorded during weekdays in January 2002 is given [5].

[4] It is possible that some of the people answering 'No' to this question did so because they deemed a positive answer not to be socially correct.

[5] The curve is based on the average of temperatures measured by the sensors in the office room at about 1.5 meters above floor level (communication with building operator).

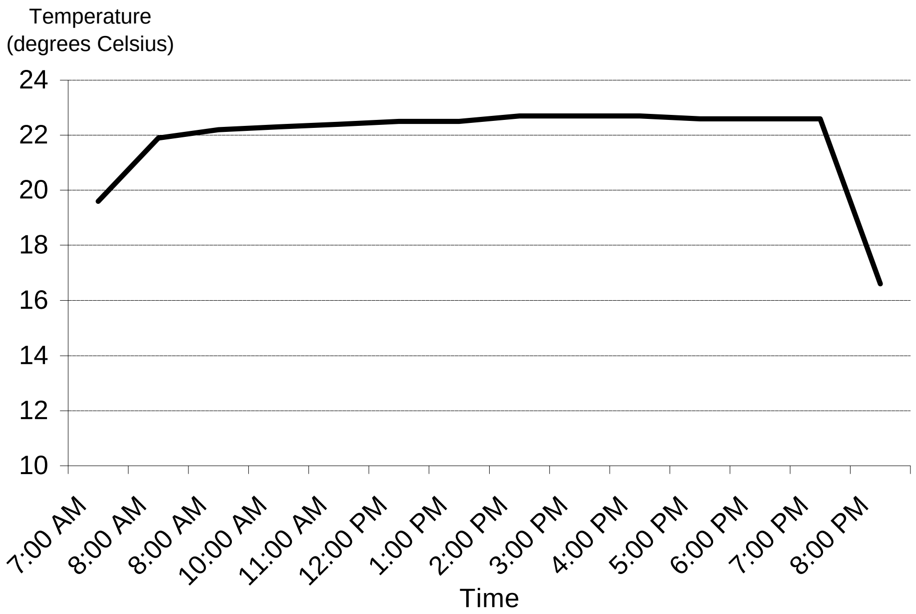

Figure 7.4 *Average daily temperature at the test site for weekdays in January 2002*

The average temperature during working hours (9 AM to 5 PM) amounted to 22,5 degrees Celsius, a value considerably higher than the preferred average as indicated by test users in the questionnaire. During a discussion about this outcome in the design team, the FAC representative accounted for the curve by explaining that in practice the building, because of its high energy efficiency, is actively heated up only during a few hours in the early morning. Shortly before arrival of the workers (around 8.30 a.m.) the central heating is switched off. The building then continues to rise in temperature slowly by the presence of people, switched-on appliances (computers, electric light) and sunlight.

7.6 Main findings and conclusions

Although the preliminary investigation was undertaken to acquire a reference for the future field test, it yielded some salient findings which are worth to be summarised:

- The perceived overall comfort in the building before introduction of Smart was assessed as satisfactory on average (ranked as almost 7 on a ten-point scale). Ambient air quality, however, was appreciated considerably lower (ranked as 2.9 on a five-point scale).
- Respondents' ranking of comfort determinants for the building's climate is consistent with those used in Fanger's doctrine. Lighting ranked high as an additional comfort indicator. Most probably this had to do with the new building's lack of blinds. Participant observation on the office floor during two summer days made clear that sunlight was an important comfort issue especially for workers sitting near windows, which they blinded using sheets of paper and ECN flags (some time after conclusion of the investigation sun blinds were installed).
- The ambient air temperature respondents indicate as the preferred one (19 ± 0.8 degree Celsius) differs considerably from the measured temperature on the office floor (22.5 degree, showing a slight increase during the day). This difference is consistent with (i) respondents' reported perception of the building's climate being rather too hot than too cold, (ii) this perception becoming stronger during the day, and (iii) the fact that about a quarter of the respondents wore less clothes than at home.

- Respondents communicated that they prefered to control their own comfort. Again control of lighting was a salient parameter here. Respondents had poor knowledge about provisions for comfort management already present (the thermostats) or used them only modestly (the ventilation valves).
- The attitude of the future test users with respect to Smart was found to be rather positive, though mixed with a certain reservation concerning its effectiveness.
- Respondents' attitude towards voluntary saving of energy in the office was positive on the condition that such a mission would not lead to decreasing comfort, e.g. compelling workers to wear more clothes.

On the basis of this findings, we conclude that Smart faced a challenge to prove itself at the test site chosen. Comfort parameters perceived as important such as ventilation and light fell outside its control. The only parameter it could hope to influence, ambient temperature, appeared to be subordinated to the inertia of a building with a high mass meant to save energy on its own.

8 RESULTS OF THE SMART FIELD TEST

According to the original plan, the field test was scheduled to take place during the winter of 2001/2002. However, due to design problems (see Jelsma 2001), only in the spring of 2002 a prototype of the Smart system became available to be installed at the test site. The field test proper lasted from April 25th until June 11th. A disadvantage of the test being shifted to a warmer season was a diminished need to operate the space heaters, the Smart system utilised for managing thermal comfort. Moreover, a higher outside temperature might induce discrepancies in comfort perception compared to the winter season in which the preliminary investigation had been carried out. Such discrepancies might affect the referential value of the preliminary investigation. For instance, increased sunshine in the daytime might heat up the building and lower comfort, although this effect was counteracted by sunblinds, which had been installed meanwhile. The comparability of the reference situation and the test situation might also be affected by a temporary failure of the ventilation valves during the test; i.e., the valves could not be opened. However, this inconvenience lasted only about a week.

8.1 Introduction of the field test

In order to participate in the Smart test each employee had to reply to an email send by Building Operations and Maintenance. When they did so, participants received the address of the web page on which the Smart interface could be found. By means of this interface (see below) individual test users could enter their thermal comfort preferences into the system. Users could do so only once during a certain time period. This time lasted for about one hour and was called a voting period. Individual comfort preferences entered into the system were represented by software agents, which negotiated -on the basis of an algorithm- for each voting period the preferred temperature to be set within each thermal zone (for technical details see Chapter 10).

Only at the end of the test it appeared that a few workers at the test site had not succeeded to get access to the Smart system (about 5 of the 22 respondents of the second questionnaire). Some of these people had not received the initial email while others who did reply to the email still had no access to Smart. One employee was located by the Smart system in the wrong thermal zone. Consequently, about 18 workers could participate in the Smart test as initially intended.

8.2 User interface

The user interface of the Smart system is shown in Figure 8.1 below. It functioned as a dialogue box for communication between the user and the Smart system. At the user side preferences could be entered into the Smart system. From the system’s side, the interface supplied the user with information about voting and comfort trends in the zone of interest.

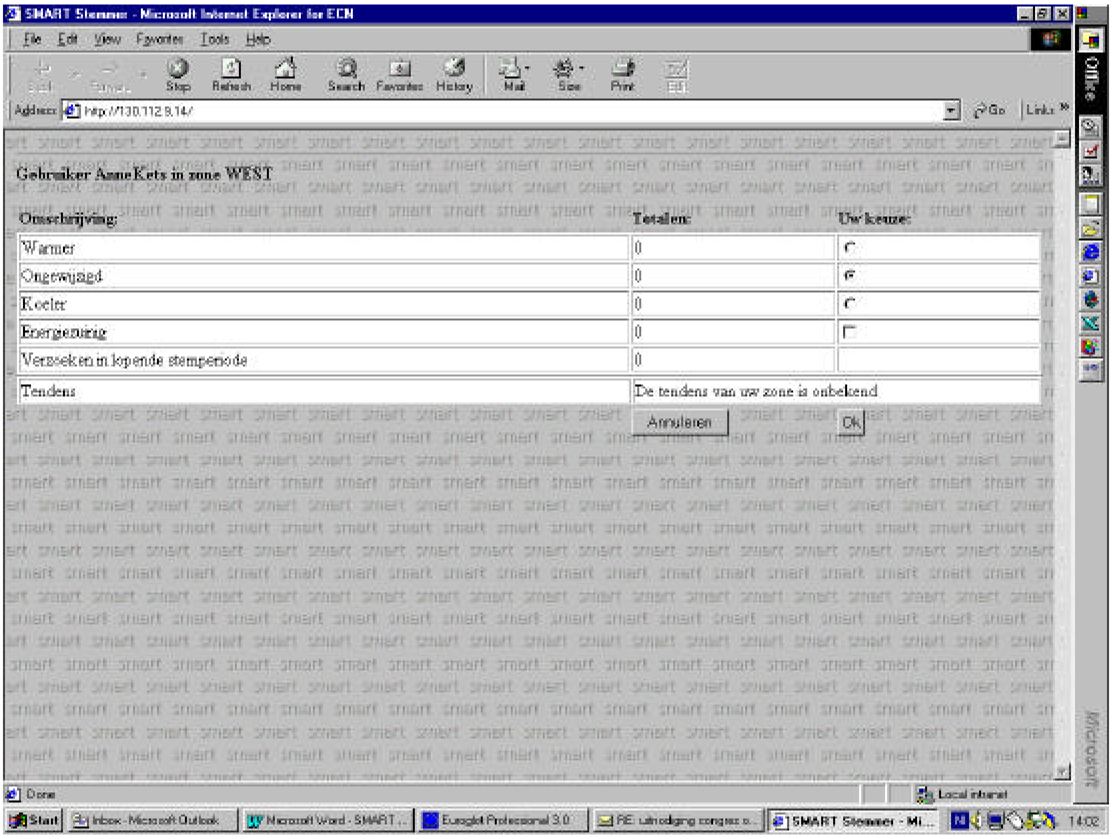
Figure 8.1 *Smart user interface*

The user could enter the following preferences into the system:

- Thermal comfort. Three options were offered to the user, indicated by 'warmer', 'unchanged' and 'cooler' ('warmer', 'ongewijzigd' and 'koeler' respectively in Figure 8.1).
- Energy efficiency. The user could urge the Smart system to save energy in realising the preferred comfort by ticking the box 'energy efficient' ('energiezuinig' in Figure 8.1).

The Smart system informed the user about the number of votes entered during the current voting period within his zone, and displayed whether these votes promoted an unchanged, increasing or decreasing temperature. The number behind 'requests during the current voting period' ('verzoeken in de lopende stemperiode', see Figure 8.1) indicated the total of votes entered during the current voting period. By the box behind 'tendency' ('tendens') the user was informed whether, as a result of voting, the temperature in the zone was rising or decreasing. If the tendency was unknown this was also communicated ('de tendens van uw zone is onbekend', see Figure 8.1).

8.3 Results of the field test

A group interview, a brief contextual interview with two test users and a questionnaire measured the results of the field test. In addition, Building Operations and Maintenance supplied results of measurements of physical parameters made during the test, whereas Smart logged actions of users such as voting behaviour. 22 persons filled in the questionnaire. As some of the respondents unfortunately had no access to Smart (see above) not all questions were answered by all respondents. This has been accounted for in processing responses. An overview of all responses to the questionnaire (i.e., responses given or left open) by test users can be found in appendix C. In the following sections, the results of the Smart field test are described regarding the following aspects:

- Perceived comfort.
- Use of different options for comfort management.
- Saving energy by Smart.
- Comprehensibility of Smart.
- Possible improvements of Smart.
- Overall assessment of Smart.

8.3.1 Comfort assessment

To assess comfort at the test site as perceived by test users, the questions used in the questionnaire were the same as those used for this purpose in the preliminary investigation. That is, on the one hand respondents were asked first to mark overall thermal comfort, ventilation and air quality perceived during the complete test period on a ten-point scale. Second, an assessment of the temperature and ventilation during various times of the day was requested.

Overall thermal comfort level was marked as 6,5 on a ten-point scale, while ambient air quality was marked as 2,6 on a five-point scale. From the second question it appeared that the assessment of thermal comfort at the test site changed during the day. By the majority of users, the temperature in the morning was indicated as being not too warm but also not too cold. At the end of the day the opinions on thermal comfort had changed considerably: about half of the test users assessed the temperature as 'too warm' (see Figure 8.2).

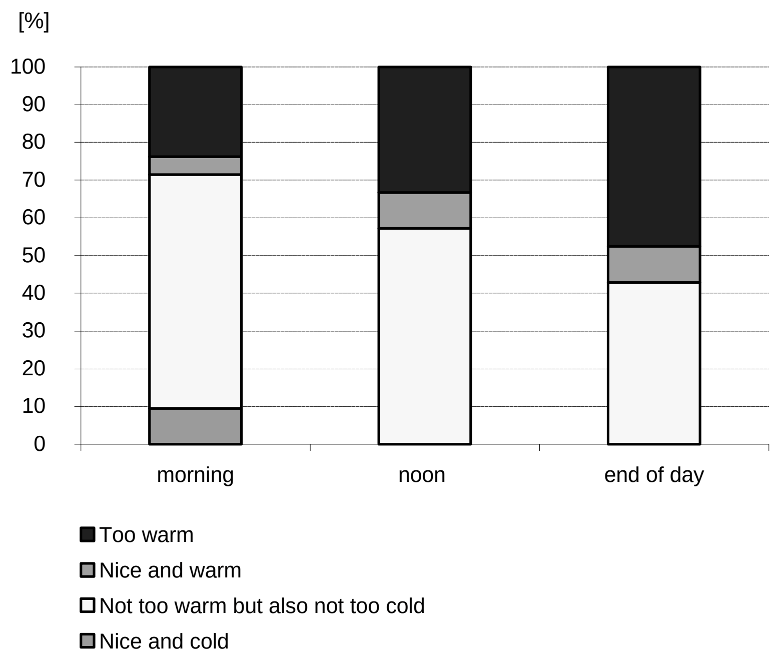

Figure 8.2 *Assessment of thermal comfort during the day*

Respondents' assessment of ventilation exhibited a similar trend. The majority assessed the ventilation level as sufficient during the morning but in the course of the day satisfaction decreased. An overview of the assessment of the ventilation level during the day is given in Figure 8.3.

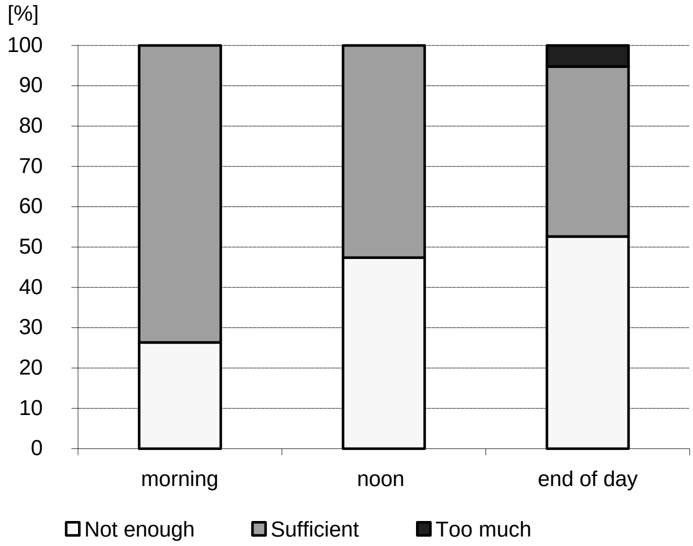

Figure 8.3 *Assessment of ventilation level during the day*

When asked to compare comfort levels before and after the introduction of Smart, most respondents (94%) indicated not to have noticed any change in comfort level since Smart had been introduced.

8.3.2 Use of options for comfort regulation

During the field test, the test users could regulate their comfort level by means of the Smart system and by opening and closing the ventilation valves (personal communication with building operator). Further they could set the room thermostats (though it is unclear whether these were functioning during the Smart field test). Finally, test users could regulate their level of thermal comfort by adjusting their clothing. How and how often the various regulation possibilities were actually used was measured by means of various questions in the second questionnaire. First we checked how frequently the various regulation possibilities were used during the Smart field test. Secondly we asked questions about the preferences of users regulating their comfort level.

It appeared that most respondents made little use Smart for regulating their comfort level[6]. When they did use Smart they mostly used it individually, that is, according to the majority of respondents (64%) no consultation of colleagues in their thermal zone took place[7]. In Figure 8.4 it is depicted how often the respondents made use of Smart. Respondents who skipped the question are included in the figure.

[6] For precise data about voting behaviour, see the table in Chapter 10.
[7] This percentage leaves room for the conjecture that a considerable part of the test users did consult colleagues before voting. At least, during the group interview consultation was said to be common practice.

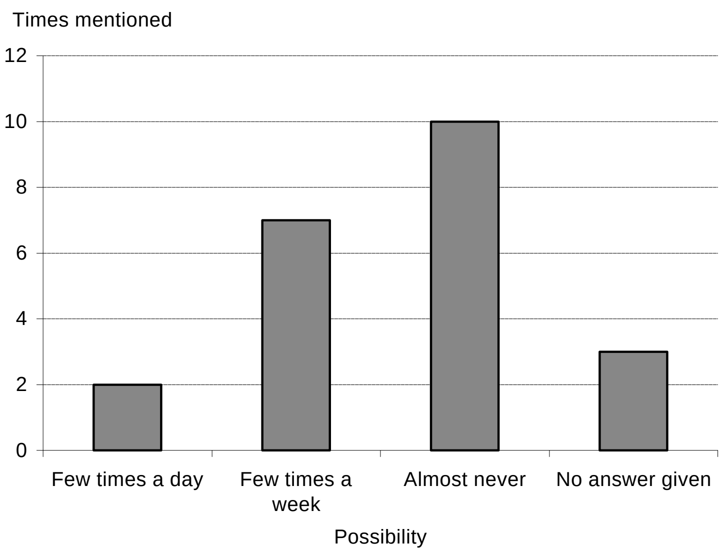

Figure 8.4 *Use of Smart*

We identified the following reasons to be the most important for test users in not using Smart in actions of comfort management. Test users either did not think of Smart in the moment they undertook an action directed at adjusting thermal comfort (40% of the respondents) or they expected other options they could apply for this purpose to be more effective than Smart (33% of the respondents). Almost half of the respondents who did use Smart to regulate thermal comfort did not notice any effect of such action. Almost all respondents indicated that they used the ventilation valves about as often as they did before Smart was introduced.

During the group interview test users made clear that, in most cases, Smart was not the first option they seized for to adjust thermal comfort. In order to validate this observation for the larger group of test users, questions on preferences for different routes of comfort management were included in the questionnaire. Route preferences were measured as the regulatory option used first to adjust thermal comfort. That is, test users were asked what they did first if they wanted to adjust thermal comfort in two situations, i.e. when they perceived the climate in the office as too hot or as too cold. The answers given are plotted in Figure 8.5.

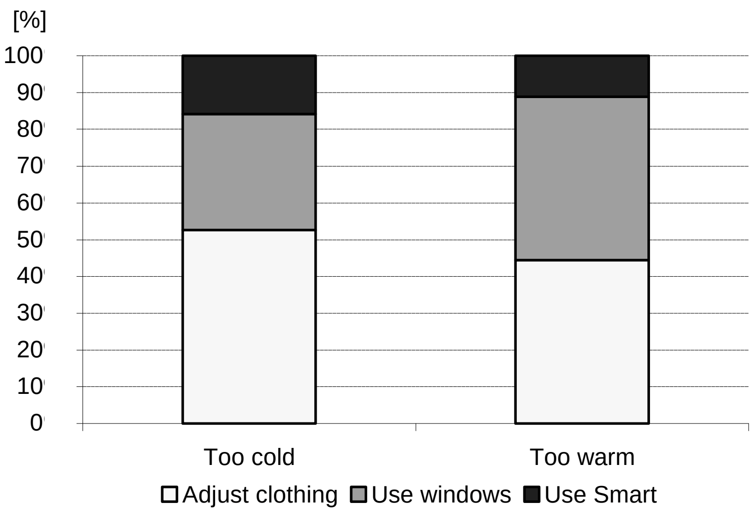

Figure 8.5 *Actions taken first for adjusting thermal comfort*

The results indicate that most respondents, when feeling uncomfortable, first adjusted their clothing before they took action to adjust the temperature by manipulating the ventilation valves or turning to the Smart system. These priorities are confirmed by answers to a question on the route preferences being followed in the situation in which the ventilation valves could not be operated [8]. Even in this situation, only 21% of the users indicated that Smart was the first option chosen for managing comfort. When inquired about reasons for neglecting Smart in the first instance, a considerable part of the respondents answered that they deemed the other options more effective, whereas they also attributed considerable influence to routines already established before the introduction of Smart (see Figure 8.6).

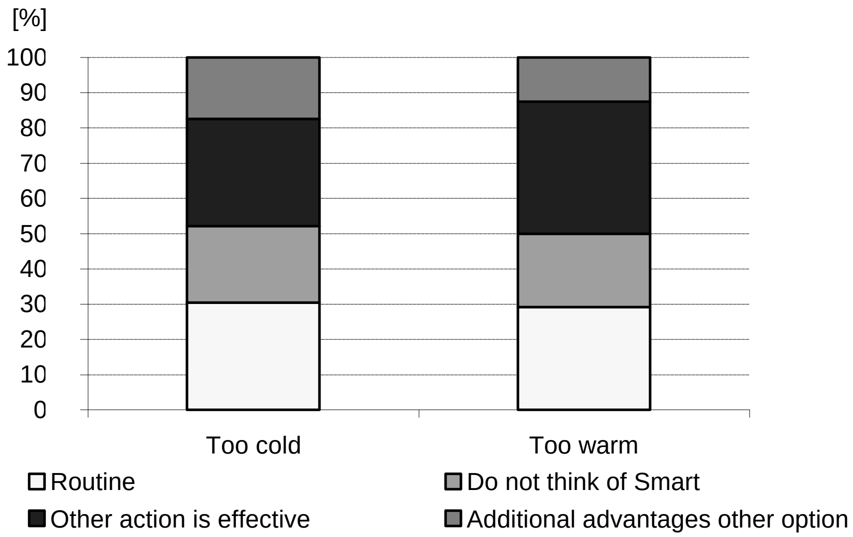

Figure 8.6 *Reasons given by test users for not using Smart*

The results as depicted in Figure 8.5 seem to indicate that the first action users take to improve the comfort situation, especially when they perceive the climate as being too hot, is opening the ventilation valves.

8.3.3 Saving of energy

By means of the questionnaire, the following aspects of saving energy through Smart were investigated:

- Use of the energy saving option in the interface.
- Test users' need for information about the energy saved.

While entering their comfort preferences by the Smart screen the test users could indicate that energy should be saved by ticking the box 'energy efficient'. The group interview made clear that not any of the interviewees ever used this option. This outcome was affirmed by answers in the second questionnaire: more than 80% of the users did not tick the option 'energy efficient' while entering their comfort preferences. A possible reason of this behaviour is given in Section 8.3.4 below.

Questions probing the need among test users for more information on energy saving through Smart either in general or more directed towards the effects of their own energy saving behaviour (i.e., by ticking the box) confirmed the results gained by the first questionnaire (preliminary investigation). By means of this first questionnaire 46% of the users made clear they were only interested in saving energy when feedback was given on the amount of energy saved. In the second questionnaire about 50% of the users indicated that they would appreciate to receive

[8] Within the test period, the ventilation valves did not work during about a week because of a failure in the electric controls (see above).

general information on the possibilities to save energy through Smart or on comfort decreasing effects of their own energy saving behaviour.

8.3.4 Comprehensibility of Smart

Comprehensibility as tested by contextual interviews
About a month after the introduction of Smart two contextual interviews were carried out with test users X and Y.

Observation made clear that X had made a shortcut to the Smart screen in his office bar[9]. While promoting his preference for improved comfort by correctly entering a vote through the Smart screen, he neglected the box 'energy efficient'. He explained this by saying that he did not know what the effect of this action would be on the comfort level he was voting for. Further he indicated that information given in the box 'requests in the current period' was unclear to him too. What was 'current period' supposed to mean (an hour, a day, a week?), and who could have done the requests (X, others within the comfort zone, everybody on the floor?). By co-ordinating his voting behaviour with that of his neighbour he had found out that, in any case, persons within the same zone could make 'requests in a current period'. Further he had observed that after voting the OK-button disappeared, and that voting was impossible for the next hour. He added that he preferred to have a reference for this own voting behaviour, in terms of the real room temperature. Displaying the current temperature in the Smart screen would urge him, he thought, to check whether the ventilation valves needed opening or closure, or make him aware of a cold he might have caught.

Y had never used Smart up to the moment of the interview. This did not imply that she was indifferent about comfort, to the contrary. She used to be active in setting the room thermostats and handling the ventilation valves, in which she involved colleagues by consulting them. Y was rather dissatisfied with the comfort situation in the office, and she regularly called the building operators to complain about it. After reading the introductory mail she successfully installed the Smart screen. Her first impression of the screen was favourable. Her first vote was a vote for 'unchanged'. After entering this vote correctly the figure in the box 'requests in the current period' changed from 0 to 1. This change she misinterpreted as someone else having entered a preference different from hers. Like X, Y neglected the box 'energy efficient', which she explained by referring to the clothes she wore. Y regretted the fact that Smart offered no opportunities to communicate complaints about the current comfort situation directly to the building managers.

Comprehensibility as tested by the group interview and the questionnaire
The group interview confirmed that not all aspects of Smart were completely clear to the test users. For this reason the comprehensibility of the Smart interface and the following aspects of the functioning of Smart and the possible effects thereof were assessed through the questionnaire.

The interface and its concepts.
The interface was assessed as user friendly by most of the respondents (14 of the 16 respondents who answered the question). However, some of the concepts used in the interface appeared to be unclear to parts of the test population. Table 8.1 shows the shares of the test population who understood the concepts concerned. Respondents who did not answer the question were not included in the calculation.

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[9] As we found out, about half of the test users did this, despite the fact that this was not recommended in the introductory mail. The presence of short cuts indicated that at least those users who made them had the intention to use Smart.

Table 8.1 *Percentage of respondents that completely understood the concepts used in the Smart interface*

Concept	Measured percentage of people indicating that they completely understood the concept used [%]
Segment	94
Warmer	94
Unaltered	89
Colder	94
Energy saving	50
Requests in the present voting period	78
Tendency	56
Annul	89
OK	94

The table demonstrates that especially the meaning of the concepts ‘energy efficient’, ‘requests in the present voting period’ and ‘tendency’ were unclear to at least some of the inhabitants of building 42, while further indicating that ‘energy efficient’ caused the largest trouble to be understood by far.

Functioning of Smart.
The group interview showed further that test users were puzzled not only about the way the option ‘energy efficiency’ might work, but also were wondering what happened when several users within the same segment enter different comfort preferences into Smart within a certain voting period. By taking up questions in the questionnaire we checked both observations. Thus respondents were asked first whether they understood what happened when they ticked the box ‘energy efficient’. A large majority of the respondents (76%) gave a negative answer to this question. Second, the question was asked whether it was clear to respondents what happened when more than one person voted during a certain voting period in a certain sector. 27% of the respondents who answered this question indicated to be quite sure about what happened when more votes were entered into the Smart system. The share of the test population stating either to be unsure or to have no idea about what happened under this circumstance was 38% and 33% respectively.

Effects of incomprehensibilities.
Anticipating aspects of Smart that might be unclear to the users we incorporated in the questionnaire questions about possible effects of this incomprehensibility. When asked how they reacted to such incomprehensibilities, most respondents answered that they did not use the options that they did not understand (69%). The fact that about half the users did not understand the option ‘energy efficient’ may thus account for the fact that this option was almost never used. A further question inquired test users about the effects of ignorance about the way Smart processes votes of users entered during a voting period within a particular thermal zone. The results are depicted in Figure 8.7. In most cases, lack of transparency was said to lead to a decrease in the use of Smart. From this figure and the possible effects mentioned above it can be concluded that a knowledge gap on the actual functioning of a technology may lead to unwanted effects.

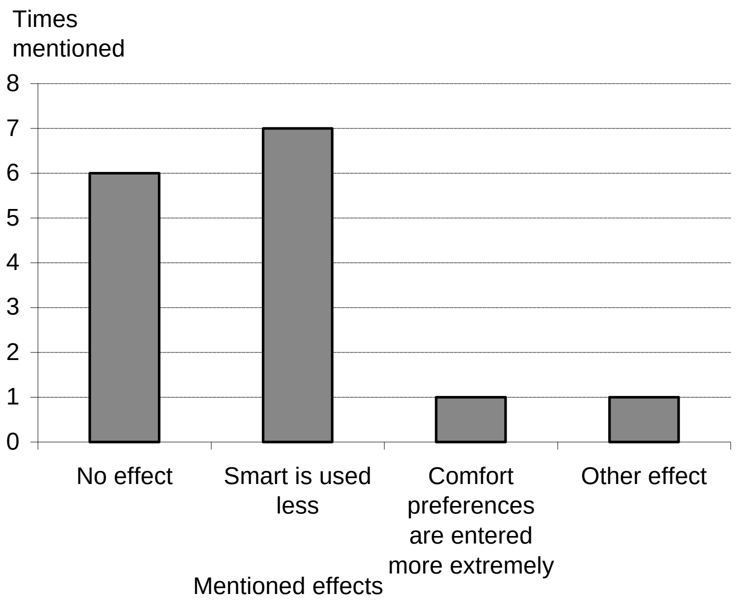

Figure 8.7 *Effects as presupposed by test users to occur in situations in which several users within one segment enter comfort preferences into the Smart system within the same voting period*

8.3.5 Possible improvements of the Smart system

In this section opinions of respondents about possible improvements of the Smart system are reported. These opinions are derived from the group interview as well as from answers to the questionnaire. The group interview indicated that negligence of Smart by users mainly had to do with (i) options for comfort management existing beside Smart, (ii) the invisibility of Smart and (iii) the influence votes by others were supposed to have on the comfort change (i.e., the effect of voting was unclear). The following opinions on improvements of Smart that might counteract these weaknesses were derived from the group interview and the questionnaire.

Test users participating in the group interview hailed changing the system such that Smart instead of the users would control the ventilation valves as an improvement. The questionnaire did not confirm this outcome, however. A majority of the respondents (52%) agreed with the current situation, i.e. the users should continue to operate the valves. In their opinion, Smart should only regulate the ambient air temperature. 31% of the respondents disagreed and found that the small windows could best be operated by Smart. In that case, the Smart system should decide when to open or close the valves in order to reach the preferred comfort level.

To increase the visibility of Smart, we tested opinions on installing a pop-up screen for Smart. About half of the respondents indicated that they preferred this solution. As preferred by most, such a screen should appear repeatedly during the day and should disappear by clicking it away, i.e. instead of disappearing only if a vote had been entered.

On the office floor, the employees' desks were clustered according to the kind of work activities they perform. In one of the items of the questionnaire it was proposed to cluster workers according to comfort preferences as recorded by Smart. In that case, a more optimal comfort could be realised because the bandwidth within which Smart calculates compromises between individual preferences entered would be smaller. Most respondents (78%) resisted this idea strongly, explaining that office work would suffer too much from such re-allocation.

8.3.6 Overall assessment of Smart

At the end of the questionnaire, respondents were asked to make a final assessment of the usefulness of Smart. The outcome is shown in Figure 8.8. The high amount of respondents (50%) that apparently felt to be unable to make any assessment in this respect (‘no opinion’) is remarkable.

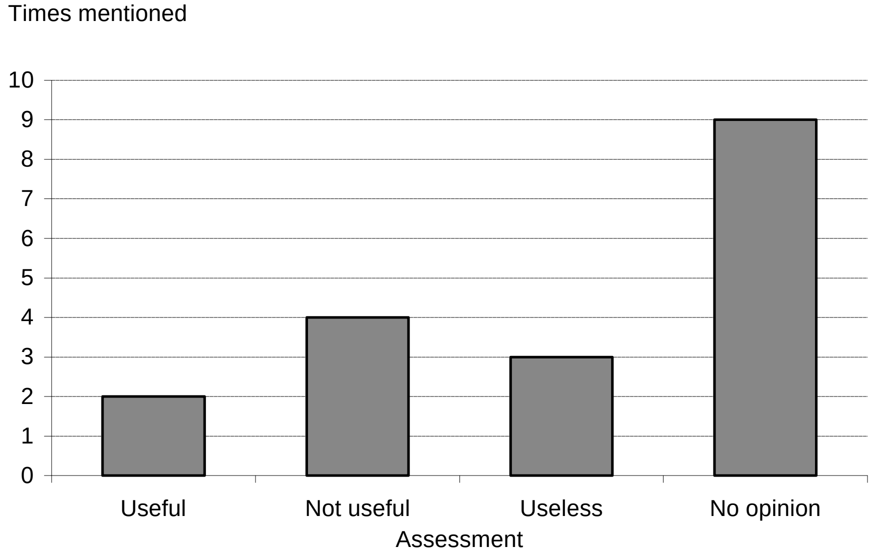

Figure 8.8 *Assessment of the usefulness of Smart*

9 COMPARISON OF THE TWO MEASUREMENTS

In this chapter the outcomes of the preliminary investigation are compared with those of the Smart field test. Apart from additional discrepancies reported in Chapter 8, the only difference between the two situations was the opportunity for users to use Smart during the field test. The comparison includes the following aspects:

- Comfort assessment.
- Attitude with respect to saving energy and the actual use of the energy saving option of Smart.
- Expectations and opinions on Smart and the appreciation of the Smart system.

9.1 Comfort assessment

In the preliminary investigation as well as at the end of the Smart field test, the test users were asked to assess certain aspects of comfort in the office (thermal comfort, ventilation, ambient air quality) as they perceived it. For comparative reasons, the questions used to this end were the same in both questionnaires.

The assessment of thermal comfort and ventilation appeared to be almost equal in both situations. Only the ventilation level at the end of the day was valued somewhat lower during the field test than in the measurement carried out in February [10]. Markings by users of the thermal comfort and the ambient air quality in both measurements did not differ much either. In Table 9.1 the figures are compared; in this table also the standard deviation (sd) is included.

Table 9.1 *Comparisons with respect to thermal comfort and ambient air quality*

	Preliminary investigation	Smart field test
Mark thermal comfort (scale 1-10 where 10 is perfect)	6,9 (sd = 0,9)	6,5 (sd= 1,2)
Mark air quality (scale 1-5 where 5 is fresh)	2,9 (sd= 0,9)	2,6 (sd= 0,8)

If the standard deviation is not taken into account, a weak trend towards a decrease in ambient air quality and thermal comfort can be discerned. However, the differences between the two measurements fall entirely within the standard deviation if this is taken into account. So it can be concluded that no significant change in the assessment of thermal comfort or ambient air quality between the two situations occurred. This outcome is confirmed by the responses given to a straightforward question in the second questionnaire inquiring users whether they had perceived any change in comfort level after the introduction of Smart. Most respondents (94%) reported that they had not perceived any difference. Somewhat earlier the group interview had shown the same negative outcome. However, in the case of the group interview the participants held strong opinions that this negative outcome did not prove that any comfort improvement realised by Smart was lacking. There might have been an undetected improvement, they thought. They judged it most probable that they would observe any deficiency in comfort while improvements stood a high chance to remain unnoticed.

9.2 Saving energy: attitude of users and use of the energy saving option

The first questionnaire revealed a positive attitude towards saving energy in the office. On the condition that responsibility for saving energy was left to the users, a considerable percentage of users were willing to adapt their behaviour in order to save energy.

[10] Most probably, this difference points to the temporary failure of the ventilation valves (see preceding chapter).

From the group interview and the second questionnaire a different picture arose. Before adjusting the temperature by means of Smart or the thermostat, most users acted environmentally friendly by first adjusting their clothing or closing the ventilation valves before adjusting the temperature. However, when users decided to adjust the temperature by means of Smart they neglected the option ‘energy efficient’ almost completely. This non-use can at least partly be explained by the incomprehensibility of this option as revealed by the questionnaire, see Paragraph 8.3.4.

9.3 Expectations and opinions on Smart and the assessment of the Smart system

The attitude towards the Smart system as measured in the first questionnaire was compared with the assessment of the effects and the usefulness of Smart as measured in the second questionnaire. The initial attitude towards the Smart system was predominantly positive, although quite a few people made conditional statements. The assessment of the actual usefulness of Smart as tested in the second questionnaire was far less positive. As indicated in Paragraph 8.3.6 most users did not have an opinion on the usefulness of Smart while most users who had an opinion judged Smart to be useless. This assessment is in line with the lack of any perceived effect brought about by Smart.

10 TECHNICAL ASPECTS AND PHYSICAL MEASUREMENTS

10.1 Technical aspects

10.1.1 Connection of Smart to the existing building management system

SEBOS[11] has a number of views on managing the building, which are based on a physical description of the relevant climate dynamics within the building it manages. These views enable the SEBOS-optimiser to calculate effects of management actions (in terms of realised comfort) on the provisions that have an influence on the thermal parameters. In the physical description not only local controllers, but also centrally controlled parts of the installation are taken into account. SEBOS further models the user in terms of position in the building and voting behaviour. For obtaining data pertaining to the real comfort parameters and for giving out setpoints to parts of the comfort installation, connections had to be made to the existing building management system (BMS). The connection scheme is depicted in Figure 10.1. The existing building management system was a Sauter EY-2400 system, which consists of a central computer with local, dedicated control units. These control units receive their setpoints either from local settings on switch panels, partly accessible by the user, or from the central system. The building management system has a supervisory role and also helps in data-acquisition for evaluating purposes.

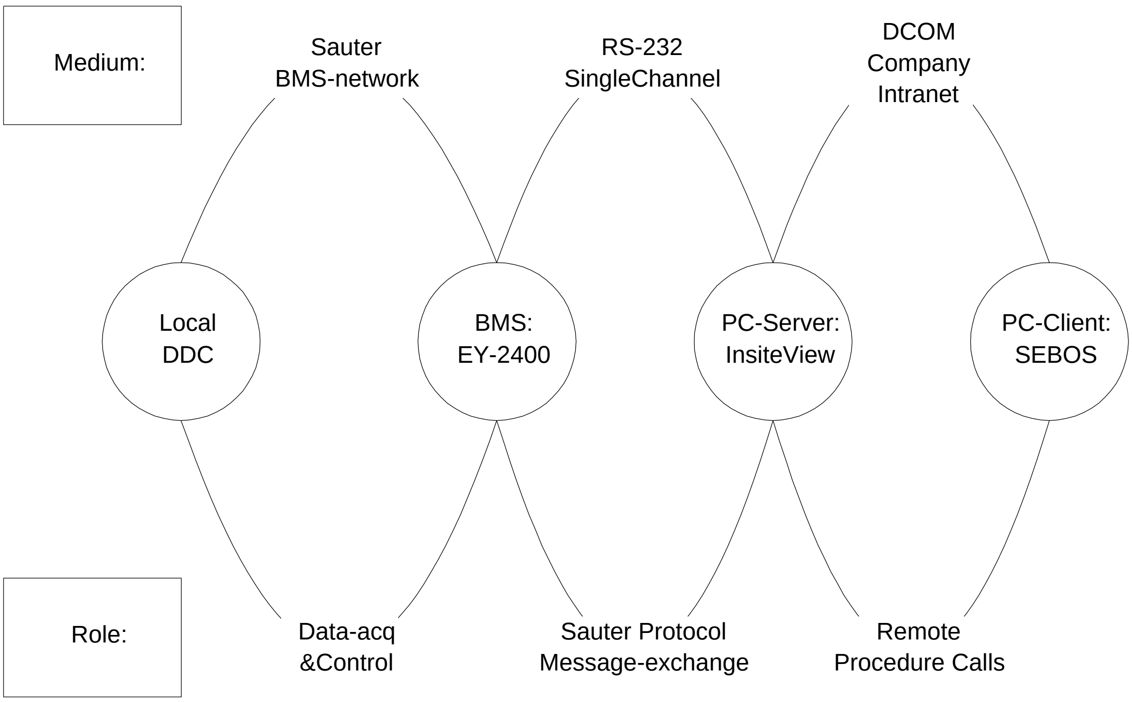

Figure 10.1 *Data-transfer from DDC to SEBOS*

Another important task is the diagnosis of system malfunctions and planning and surveillance of repair actions. A Sauter system internally uses proprietary physical and software connections to transfer data between the central BMS and the substations/local controllers. Its communication scheme has severe bandwidth limitations. Only changes of data exceeding a certain magnitude given rise to data traffic. This scheme hinders flexible data-collection as compared to polling and broadcast techniques with predefined frequencies; especially during tuning the building

[11] SEBOS is the software supporting Smart functions, i.e. feeding the building management system (BMS) with internet data (such as weather and price forecasts) and providing communication between users and the BMS.

management system and in the process of calibration of sensors this leads to heavy data traffic. Furthermore, the building operator diminishes the accuracy of data collection in order to avoid data-transfer problems.

For remote access to the data a communication channel of Sauter EY-2400 was used by means of an RS-232 connection. Using this connection scheme, the InsiteView building management system[12] was connected with a modem for remote access or a null-modem. The Sauter system has a protocol language consisting of commands and predefined answer formats for retrieving data and setting values (Geveke,1994). Central in this is the definition of a 'protocol' or macro, which aggregates a number of sensors and actuators belonging to part of the installation. In the current setting, a protocol was defined to handle all data in the office space that were considered to be relevant for the field test. Signals per climate zone included the measured temperature (output only) and the setpoints (input and output). Given the amount of data to be transfered, a data collection frequency of once per 15 minutes was the maximum achievable. Within the software of the InsiteView-server a driver was written implementing a set of 'protocol'-inquiries. The InsiteView server was directly connected to the internal local area network using central Internet-technology.

To get access from the InsiteView server to the SMART software, an interface based on Microsoft COM was written. In COM, remote procedure calls can be made after a marshalling procedure for function arguments and returned values has been performed. In this way, InsiteView function calls and data-structures, available from Delphi-ObjectPascal, were made transparent through the network and available to the Java-code from the SEBOS-shell. The mechanism is described in (Kamphuis, 2002). Thus, the real-time data needed per segment could be obtained, combined with the other information, and the setpoint values could be set from the SEBOS-shell according to the strategy calculation.

10.1.2 Measurements and control settings.

The existing building management system provided us with the measured temperature of the five internal climate zones, the outside temperature and wind velocity. A number of parameters in the central installation, necessary for the air and heat flow calculation into the segments was measured as well. Furthermore, the setpoints of the controllers of the local ceiling heating units were measured. These were under control of SMART in the field test period; they were modifiable by the user in other periods by setting wall thermostats. For the field test the number of local controllers was increased from two to five in order to reflect the segmentation of the office floor. Apart from the field test period, some data were collected in the winter period to get some insight in the building management operational strategy. In the SEBOS-model the local controller for the ceiling heat convection unit and the central air treatment box was modelled as depicted in Figure 10.2. Centrally heated air, partly exchanged with the outside, is mixed with ambient convected ambient air in a heating unit, that obtains it's heat from the centrally heated water.

[12] InsiteView is a more advanced system for building management than the one currently in use at the test site at ECN (indicated as BMS). InstiteView is developed and appplied by the technical partner in the Smart project (Kropman BV). Studying opportunities for future extensions of systems such as InsiteView by smart systems as developed and tested here was a major objective of the Smart project.

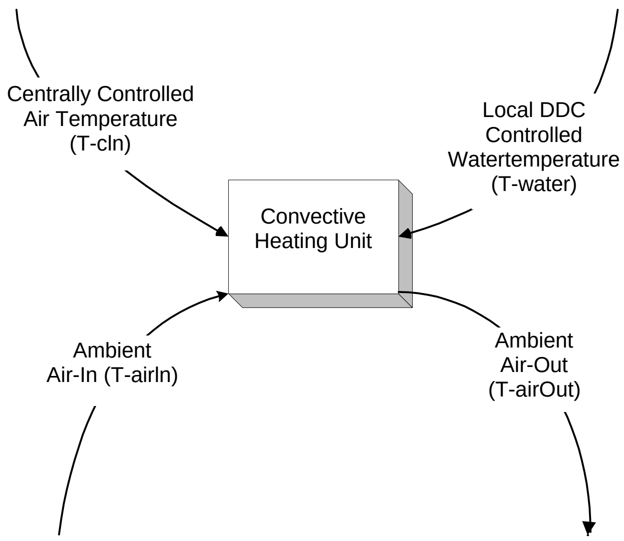

Figure 10.2 *Convective heater model*

SEBOS expresses the control strategy by administering a dose of heat to a segment for every period in the simulation. From the model, a setpoint had to be generated for the PID-controller of the ceiling unit given the measured central heating water-temperature and the temperature of the pre-heated air. This was realised for one part by mapping the heat flow to a temperature difference and for another part by using the predicted model temperature.

10.1.3 Comfort index calculation as a function of time over the day

User comfort votes were collected using a WEB-browser interface. The preferences were stored in the vote-file format as described in (Kamphuis/Warmer,2002). Each user had a votefile maintained by the InsiteView WEBServer. This votefile retained for every user the vote-direction and the voting time. The SEBOS-shell has access to the votefiles and to a user table, in which information about which user resides in what building segment is contained. During each SEBOS-run all vote-files of all users are processed. Votes are valid if they are within the vote's latency period. During the experiment this period was defined to be a week. A vote for the temperature to go up or down is mapped to the desired decrease or increase in comfort level in the Fanger model by a temperature shift in the Fanger index (Fanger,1994) calculation. By the voting procedure, a time-dependent modulation of the comfort level as defined by the building manager is obtained. The building manager is then able to set the modulated comfort level defined in this way as the new comfort level after the votes' latency period. In this way, the involvement of the user in management of comfort is expected to decrease in time; that is, after a while, the new (adapted) comfort level set matches the level as preferred by the user. The latter comfort level is used for calculating the strategy for comfort aspect controllers during the next optimisation cycles. The trend as determined during the field experiment is depicted in Figure 10.3.

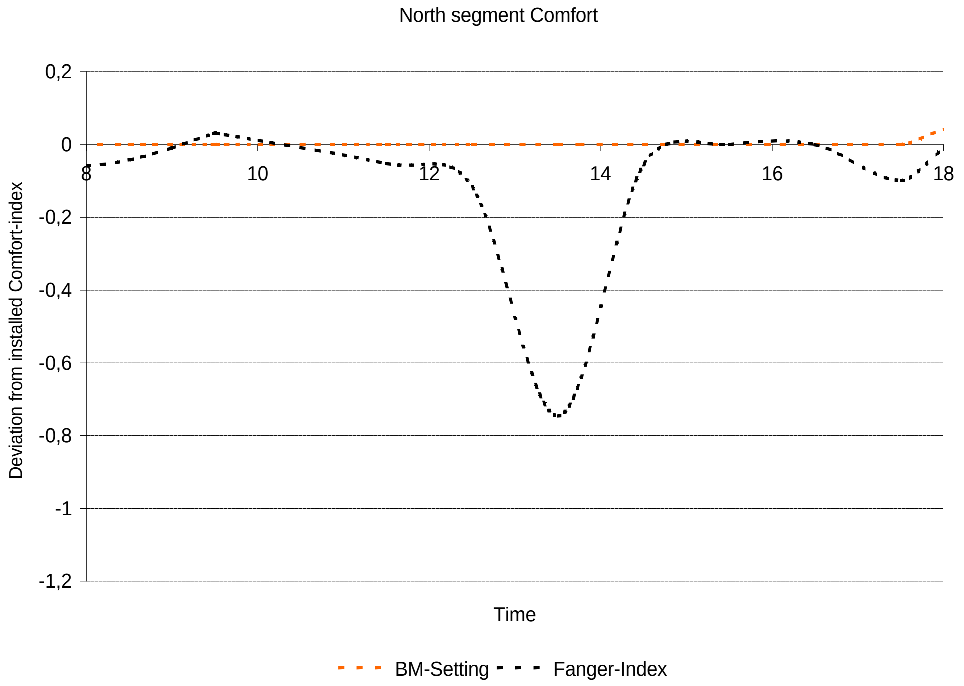

Figure 10.3 *Modulation of the Fanger index as derived from the votes issued over time*

The figure shows that the largest comfort deviation occurs at around 1.30 p.m. Users then perceive the ambient air temperature as higher than desired. In the early morning the opposite is true, i.e. the ambient air temperature is perceived as slightly too low.

10.2 Measurements during the field experiment

10.2.1 Temperatures and settings

Temperatures as measured during the winter period (November 2001- March 2003) in the north segment are depicted in Figure 10.4.

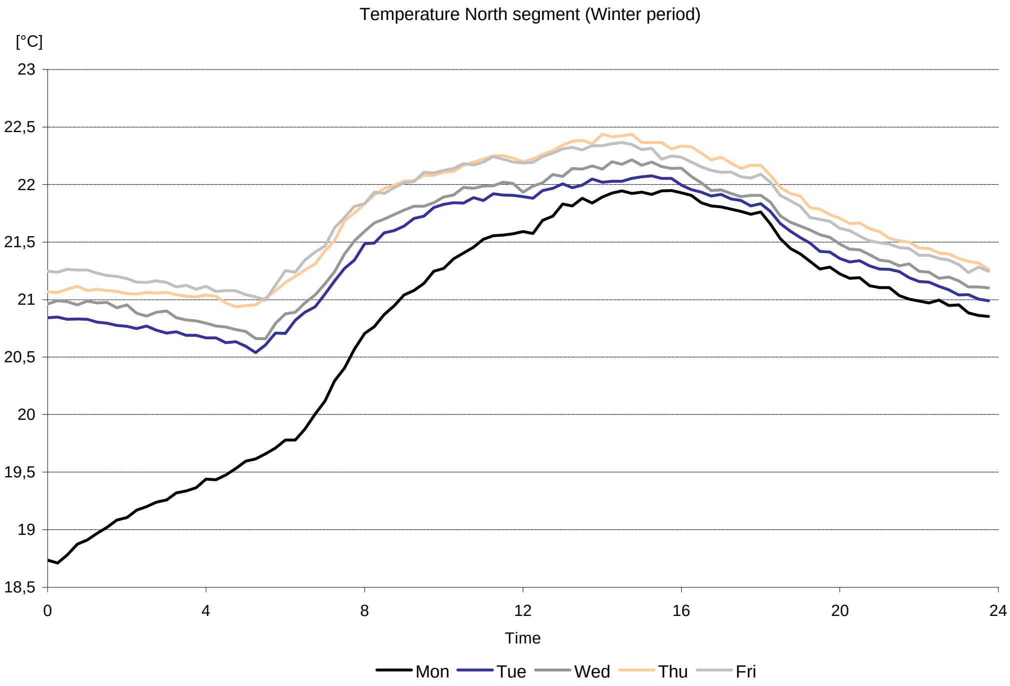

Figure 10.4 *Temperature north segment*

The temperature curves indicate that the large heat capacity of the building leads to a very slow pace of reaching a maximum temperature of 22 degree Celsius on Monday (lowest curve). On all workdays this maximum temperature (over 22 degree Celsius) is reached only in the afternoon.

Temperature set-points for the controllers of the local heating units in the ceiling are shown in Figure 10.5. These setpoints are the result of the building manager's baselevel settings and of possible adjustments by users setting wall thermostats in the office room. The figure clearly demonstrates the current heating regime and how the building reacts to it. Early in the morning the setpoint is increased by the BMS to preheat the climate zones. Just as shown by Figure 10.4, the building achieves the maximum temperature only after a period of 10 hours. This is further shown in Figure 10.6, where the setpoints and realised temperatures are shown for a whole week. It can be seen, that the building manager, in order to reach a acceptable temperature on Monday morning, starts warming short after midnight. The other days, warming is started at 5:30.

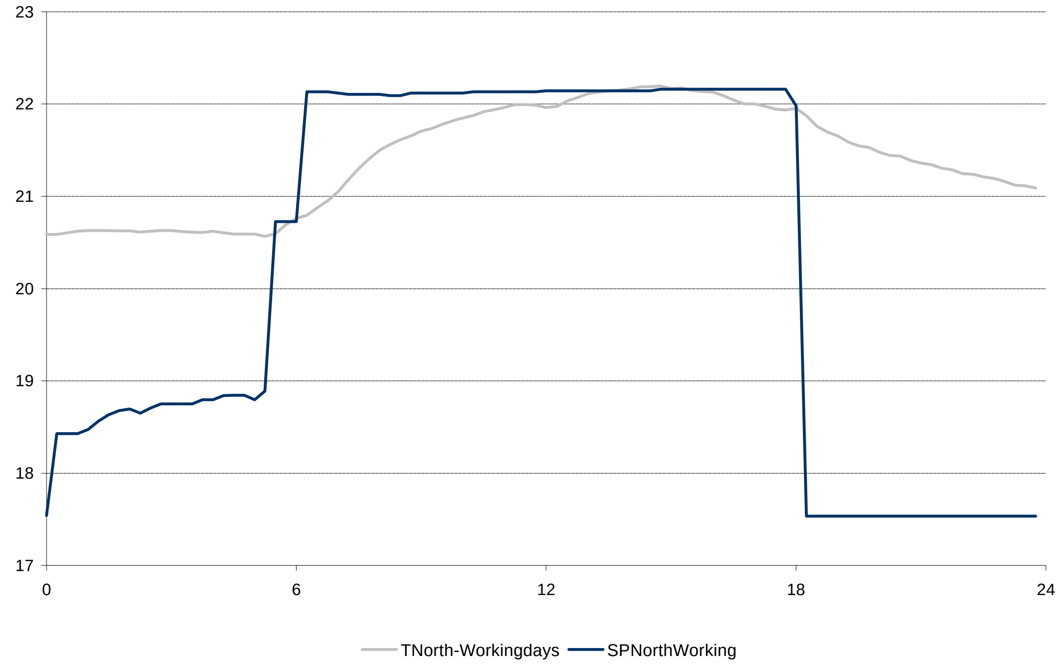

Figure 10.5 *Local controller setpoints on working days; north segment (winter period)*

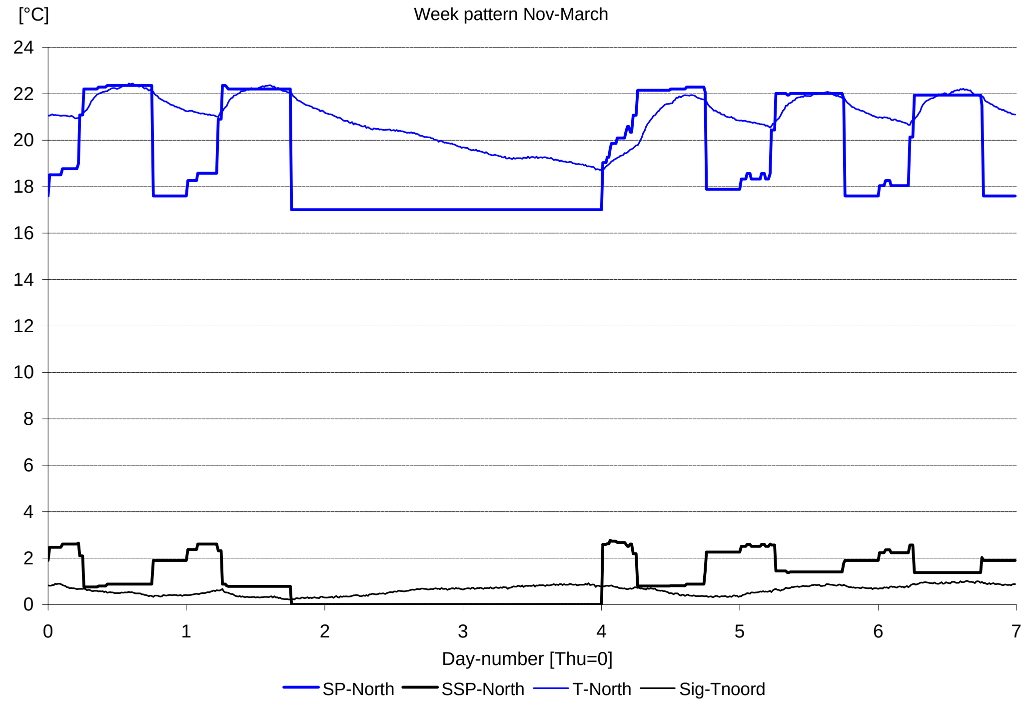

Figure 10.6 *Setpoints and temperature for north-segment. The lower lines indicate the sigma of averaging*

Figure 10.6 shows the impact of actions of users on comfort by setting the wall thermostats to be very limited. It is hardly possible for users to have any impact on the momentous comfort level through setting the room thermostats. Reacting to a low temperature comfort situation early in the morning by increasing the setpoint only leads to a further overheated temperature comfort situation in the afternoon. In Figure 10.7 and figure 10.8 the comfort actuator parameters TWater and TcIn, which determine the heat dosing mechanism (see Figure 10.2) of a climate zone, are shown. The decrease at 6:00 and increase at 18:00 hour correspond to the switch on/off points of the central ventilation system, which is only operational during working hours.

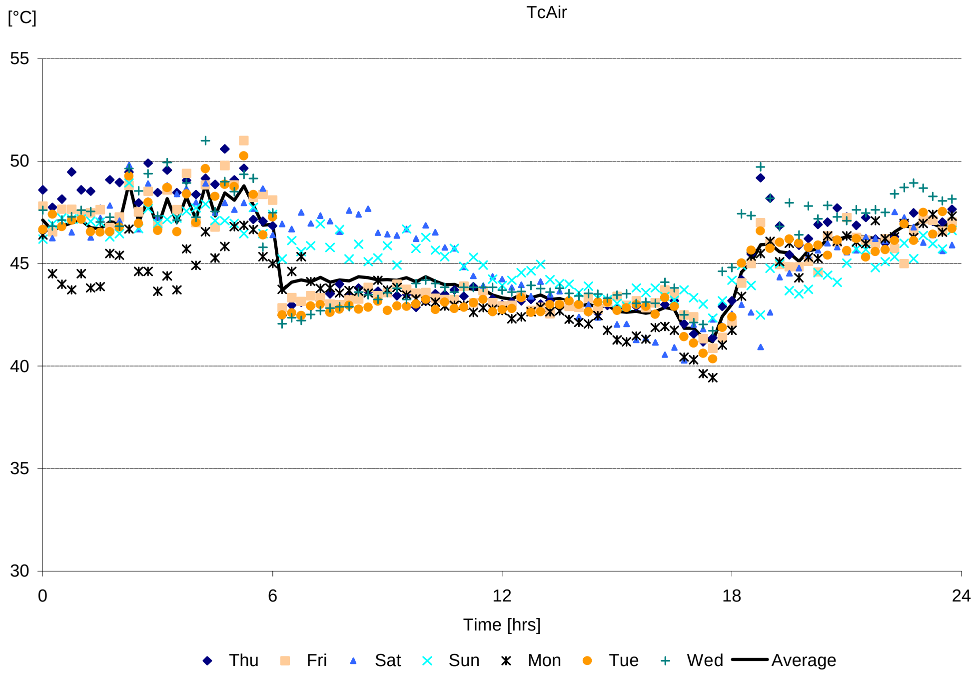

Figure 10.7 *Average central heating water temperature winter period*

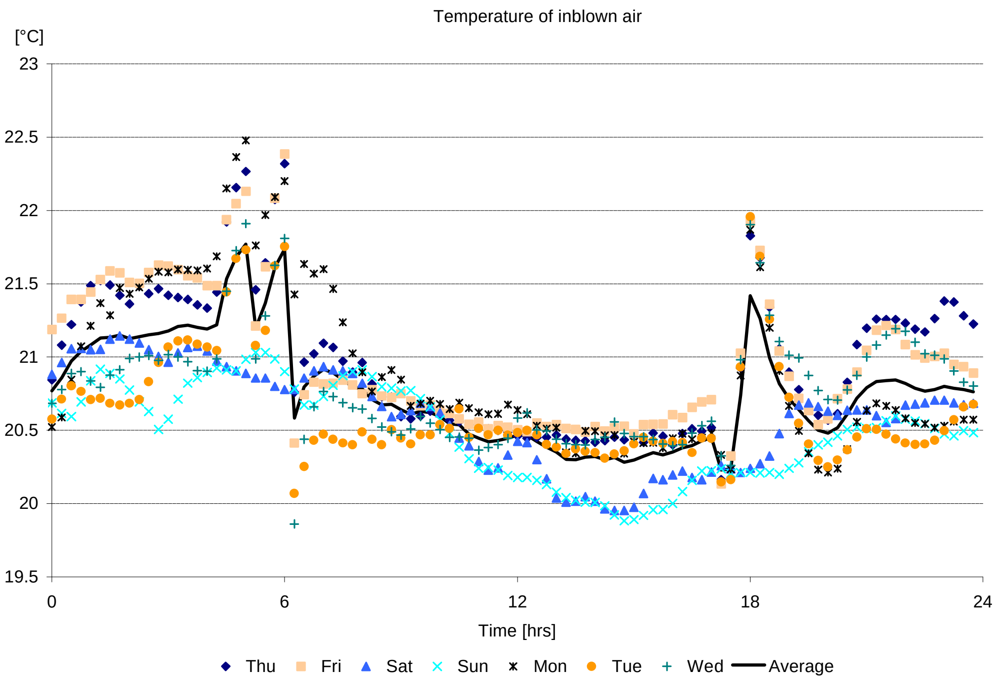

Figure 10.8 *Temperature of in-blown air*

Increasing the water temperature of the central heating and switching on the ventilation system later in order to preheat the climate zones with accumulated air from the mechanical ventilation would be possible steps to increase the possibilities for more instantaneous comfort control. In addition, the temperature of the air blown in could be decreased during the afternoon. An extended Smart system in combination with a leading edge BMS can optimise these parameters in a more sophisticated way than is possible with the current configuration.

10.2.2 Voting behaviour

The voting behaviour of the population in the different climate zones is shown in the following table.

Table 10.1 *Distribution of votes per climate zone during the test period*

Segment	Possible Voters	Actual Voters	Votes	Too Warm	Equal	Too Cold
West	2	2	2	0	1	1
Oost	7	5	18	13	1	4
North-West	2	2	10	3	2	5
North-East	5	2	5	3	0	2
North	7	7	63	38	10	15

The trend in the votes collected is depicted in Figure 10.9. The dashed lines denote the voting behaviour for individual days. Most votes, especially in the afternoon hours, indicate that the user's perception is 'too warm'. The Monday-pattern only indicated a strong tendency in the voting behaviour toward an increase in temperature in the morning. The afternoon-peak in votes for 'colder' appears to be delayed on Monday.

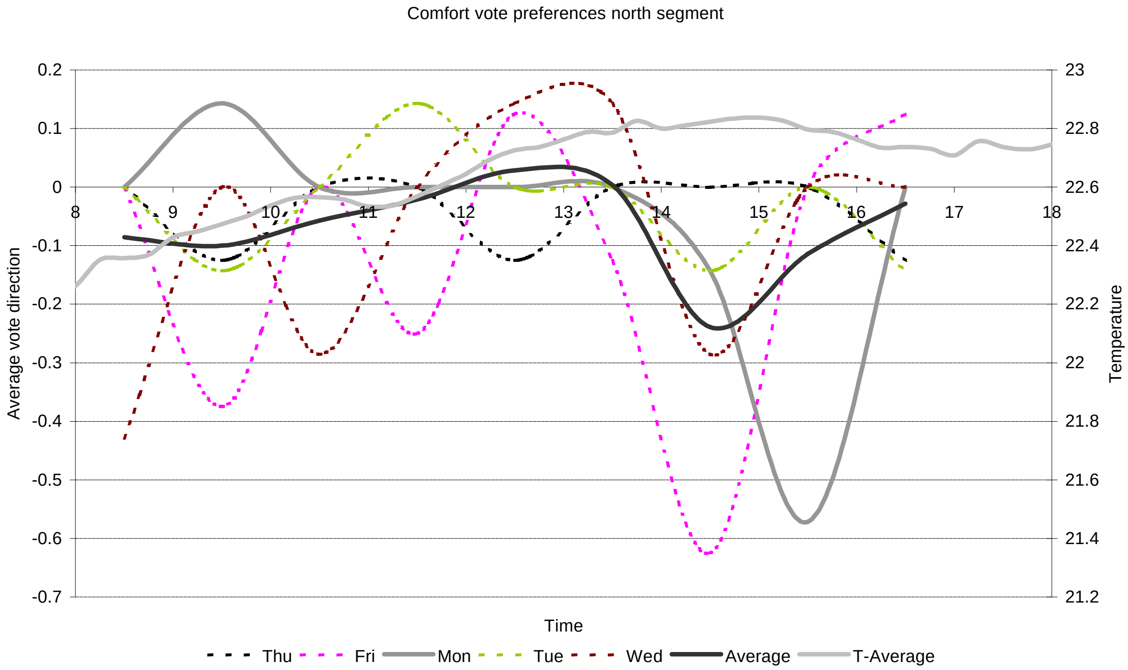

Figure 10.9 *Voting behaviour north segment and average temperature*

For the east segment, with fewer voters, a comparable trend can be observed (see Figure 10.10). The Monday pattern, with its characteristic morning 'too cold' peak and its shift of the 'too warm' peak in the afternoon can be seen as well. The overall voting behaviour is consistent with the responses of users to the questionnaires, i.e. the ambient air temperature in the afternoon is perceived as too high.

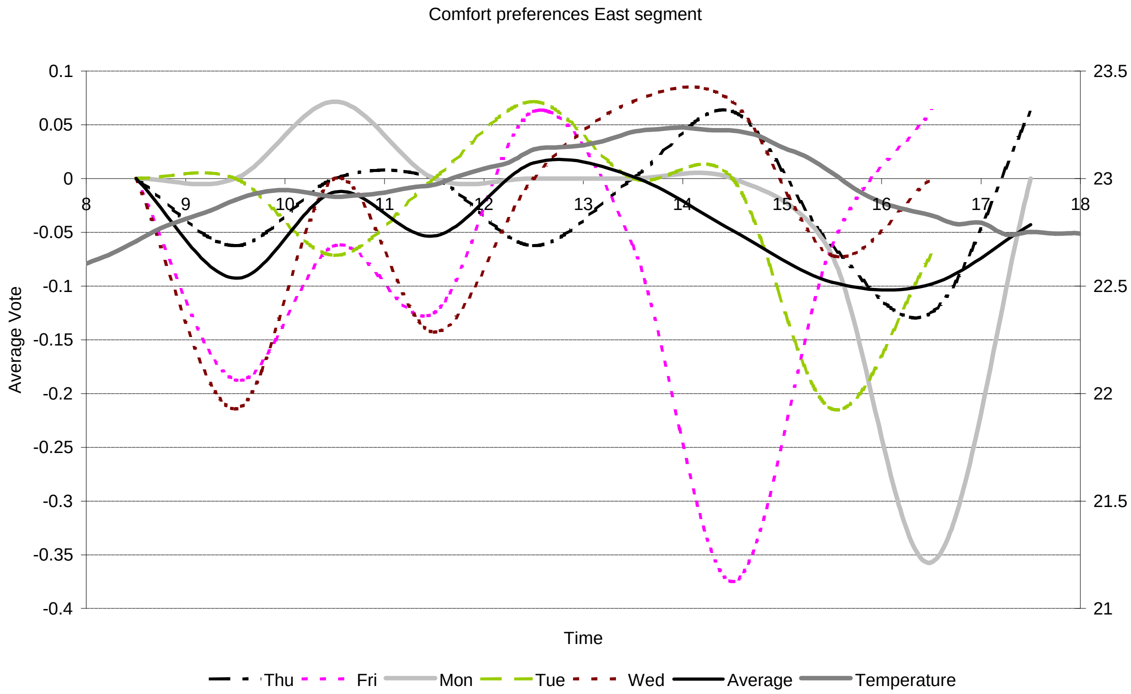

Figure 10.10 *East segment comfort votes and average temperature*

Conclusions

From the material presented we draw the following conclusions.

In the present test environment, neither the building and installation architecture nor the SMART-design appear to offer the building users good opportunities to influence thermal comfort in their climate zone. The intrinsic inertia of the building due to its physical parameters and comfort provisions hinders fast feedback on user control actions. Further, we expect SMART to deliver a better performance if the time horizon over which the comfort level is optimised, on the basis of data on the building physics and environmental parameters, is extended beyond the limit 24 hours which was practised in the present field test.

From the temperature measurements it follows that there is energy saving potential looming in the difference between the preferred temperature as indicated by users in the questionnaire compared to the real office temperature. The difference amounts to approximately 2 degrees, which could result in a saving of up to 20% in heating cost.

Our measurements seem to support the expert group conclusion that building managers tend to react to complaints about temperatures in a building being too low by adjusting the building's heating-curve upwardly. In Fanger terms, the voting procedure suggests that if the building is managed -using a Smart system- towards the target at the other side of the bell-shaped distribution as presented in Figure 10.11, the percentage of people dissatisfied remains unchanged. This is especially true in view of the voting behaviour during the day and maintaining a satisfactory comfort level within a scope of a day. We expect that lowering the heating curve of the building will deliver better comfort during the whole day, but especially during the afternoon hours.

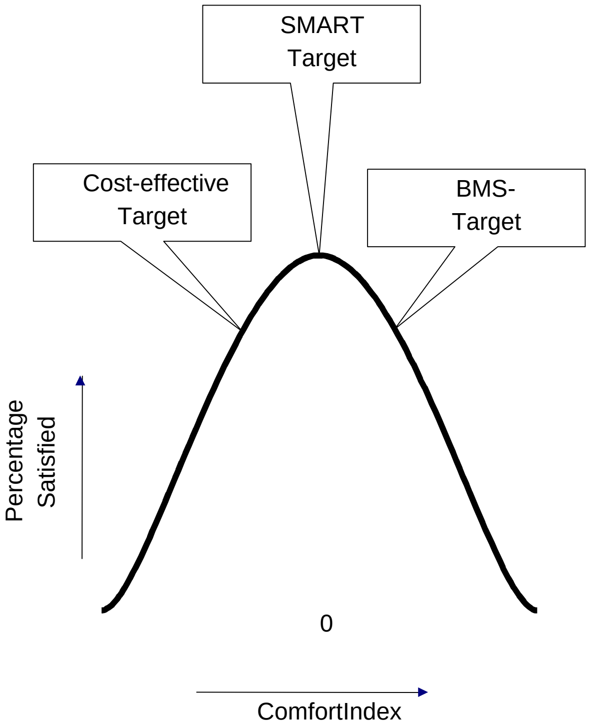

Figure 10.11 *Managing to an optimal percentage of users satisfied*

The data presented above confirm the findings of the design phase study. Involving users in the management of their comfort requires a short feedback cycle; i.e., users should see systems to react to their preferences within a short time. This should be reflected in the response of comfort aspect controllers.

The voting procedure as applied here, which is also used in other cases (Oseland, 1997), yields consistent results with respect to the comfort perceptions in different climate zones. The trends in the perceptions measured in this way also coincide with overall trend as measured by the questionnaires (see Chapter 8). Even day-type specific trends are reproducible.

11 CONCLUSIONS AND RECOMMENDATIONS

We investigated the use of possibilities for comfort management and compared the comfort situation as perceived by test users before and after the introduction of a prototype of the Smart system in an office building. In addition, behaviour of the building and of the test users during the field test was mapped by physical measurements. From the main findings of this investigation we draw the following conclusions:

- Smart use by the test population was rather limited. In all, 18 out of the 23 test users who had access to Smart voted 98 times during the 1,5-month test period. Mainly for this reason, we did not see any specific routines of Smart use developing. Rather, test users preferred sticking to old routines of opening ventilation valves and adjusting clothing to remedy decreases in perceived comfort. We estimate the fact that Smart had to compete with other options for comfort management deemed more effective by users, and the relative invisibility of Smart (no pop-up screen was used) to be important reasons for the failure of Smart to become an obligatory passage point for comfort management by users.
- The current central heating regime in combination with the building's great mass resulted in decreasing comfort during the day. Both the physical measurements, the votes entered and the comfort perceptions reported point in the same direction, i.e. the office space became too hot in the afternoon. This situation was not improved by installing Smart. Participants in the test did not perceive any change in comfort after Smart had been installed. Neither did they detect any relation between voting (entering preferences into the system) and the comfort level they perceived. That is, there was no Smart-related perception of improved comfort by test users who faced a concrete comfort deficiency in their office environment.
- At the end of the field test, about 50% of the respondents did not have an opinion on the usefulness of Smart. As far as opinions on the usefulness of Smart were expressed, these were mostly negative. Most probably, this low appreciation of Smart results from its perceived (and real) lack of effectiveness. Nevertheless, from the beginning of the test the general attitude among test users concerning Smart was positive, presumably because Smart was seen as giving users a voice in comfort management (see also next point).
- Test users made clear that they wanted to be in control of their own comfort. The fact that Smart invited them to vote for thermal comfort was welcomed as an improvement compared to the existing situation. In the same vain, a majority of users wanted to keep control over ventilation by operating the valves instead of delegating this function to Smart. We see users' attitude toward saving energy as a further confirmation of this preference for control. Users were willing to save energy in the office, only on the condition that they could decide on any related decrease in comfort.
- Smart did not meet the demand of transparency for users in all respects. Especially the way in which Smart processed preferences entered by different voters and reacted to ticking the option 'energy efficient' were unclear. This led to almost complete neglecting of the option for saving energy. A better explanation beforehand could have made a difference.
- Linking physical measurements and discussions with experts to data gathered from users, we conclude that ambient air temperatures to which employees had become accustomed were considerably higher than the ones they indicated to prefer by means of the questionnaire. This practice of maintaining high office temperature seems to have a history of building operators raising the ambient air temperature in reaction to repeated complaints by office workers who feel too cold, while others who then start feeling too warm open windows to realise the preferred comfort of their own. In this way all workers are more or less satisfied, but at high costs. Just in this situation a well operating Smart system could bring improvement by supplying individual comfort, and thus safe cost and energy.

In sum, the outcomes of the field test confirm those of the study on the design stage of Smart (WP 4.1, Jelsma, 2001). The limited functioning of Smart as demonstrated in this report has not much to do with the Smart system as such, but results mainly from clashing design logics. The building in which Smart was tested had its own logic of handling comfort and saving energy that was at odds with the principles of Smart. Nevertheless, the field test proved that the technology of smart systems for comfort management in office buildings works in principle, and holds, if properly implemented, a promise for considerable energy savings. In contrast to initial low expectations of experts about opportunities for further improving the inherent energy efficiency of the building in which the Smart test was carried out, the test showed that in the demonstrated discrepancy between real and preferred temperatures a considerable potential for lowering energy consumption is looming. If included in building design from the beginning, Smart systems can help reaping this fruit by realising a more sophisticated building management over day and night on the basis of a larger data set than was available in this limited field experiment.

For further experiments the following recommendations apply.

Smart can best be applied in a building with individual or almost individual compartments. This way the future users of Smart can adapt their comfort level individually as originally intended by the designers of the Smart system.

If possible the users should be involved earlier in the design of the Smart field test and better be informed during the test. Early involvement of users can help designers of Smart in making more informed decisions about the division of control options between Smart and the user. From a functional perspective, it seems most desirable to bring all building provisions for comfort management under the authority of Smart. However, the present study confirms earlier ones in showing that such total delegation may violate the user's preference for exerting control over his own comfort. User involvement in design may also deliver a user interface with optimal clarity. The transparency the system should have is a topic that should be discussed with users. Early communication with users may lessen or prevent negative effects of certain possibly incomprehensible aspects of the system as showed up too late in the present field test. Such preventive measures should be complemented with a careful introduction of the system to the user.
To enhance the visibility of the Smart system, the use of a pop-up screen should be considered. In this as well as in another field test (see Oseland et al., 1997) test users were found to be in favour of such a reminder.

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APPENDIX A WORK PACKAGES

List of work packages of the Smart project:

WP 1 Multi-agent frame work
WP 1.1 Agent rolls and utility functions
WP 1.2 Defining agent platform, optimising strategy and tasks
WP 1.3 Evaluation of electronic market mechanisms
WP 1.4 Final report multi-agent technology

WP 2 Model studies and scenarios
WP 2.1 Energy and comfort scenario analyses
WP 2.2 Evaluation of comfort strategies and of concepts for building operation

WP 3 Design of software application and field test
WP 3.1 Mapping the local context
WP 3.2 Interface design
WP 3.3 Development of multi-agent software application
WP 3.4 Management and monitoring of field test

WP 4 Study and evaluation of design and use
WP 4.1 Comparing Smart-logic with design logic of test building
WP 4.2 User aspects of Smart[13].

[13] This final report concerns WP 4.2.

APPENDIX B FIRST QUESTIONNAIRE

In this appendix the questionnaire presented to the users of building 42 is presented. The questionnaire was originally drafted in Dutch.

First the questionnaire is presented. After the questionnaire the answers given to the questions in the questionnaire are presented.

B.1 First questionnaire: Questions

The first questionnaire consisted of two parts. The first part was anonymous and was meant to obtain information on among other things comfort perceptions, regulation possibilities and attitudes in relation to energy saving measures. Users were asked to fill in their name and some personal questions in the second part of the questionnaire (this part was separated from the first part of the questionnaire). The answers given in this second part were used for formulation of the group that was asked to participate in the group interview after the introduction of Smart. The outcome of group interviews is strongly dependent on the composition of the group interviewed according to among others (Morgan and Krueger, 1997).

B.1.1 Questionnaire Part 1

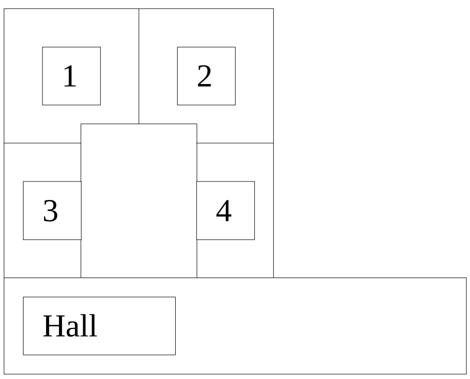
Personal information

1) How old are you?
[ ] 18-25
[ ] 25-35
[ ] 35-50
[ ] 50+

2) What is your gender?
[ ] male
[ ] female

3) In the next picture the office you work in is sketched. Can you give an indication of the place where you work in this office?

I work in part… of the office



4) How would you mark your *present* comfort situation? (You can use marks from 1 and 10 where 1 stands for awful and 10 for perfect).
…….

5) Which aspects would you consider if you have to indicate if you find your working place comfortable?
[ ] my perception of the temperature of the air in the building
[ ] the heat or cold radiated by the radiators or windows in the building
[ ] the freshness of the air in the building (fresh as an opposite of musty or stale)
[ ] the moistness or dryness of the air in the building
[ ] if I have cold feet or not
[ ] if I have cold hands or not
[ ] if I have to perspire or not
[ ] if I feel drafts or not
[ ] other aspects of the inner climate viz.…..

6) Which aspect of the aspects mentioned below that you feel is the most important aspect to consider if you have to indicate if you work in a comfortable environment?
[ ] my perception of the temperature of the air in the building
[ ] the heat or cold radiated by the radiators or windows in the building
[ ] the freshness of the air in the building (fresh as an opposite of musty or stale)
[ ] the moistness or dryness of the air in the building
[ ] if I have cold feet or not
[ ] if I have cold hands or not
[ ] if I have to perspire or not
[ ] if I feel drafts or not
[ ] other aspects of the inner climate viz.…..

7) Which working temperature would you like to have in building 42?
[ ] about 16 degrees Celsius or colder
[ ] about 17 degrees Celsius
[ ] about 18 degrees Celsius
[ ] about 19 degrees Celsius
[ ] about 20 degrees Celsius
[ ] about 21 degrees Celsius
[ ] about 22 degrees Celsius
[ ] about 23 degrees Celsius
[ ] about 24 degrees Celsius or warmer
[ ] I don’t know

8) Which comfort aspects of your working environment would you like to regulate?
[ ] temperature (by means of a thermostat)
[ ] ventilation (by means of opening or closing windows)
[ ] heat originating from sunshine (by means of blinds)
[ ] light originating from sunshine (by means of blinds)
[ ] light (switching on or off of artificial lights)
[ ] other aspect of comfort viz…………………….

Inner climate building 42

9) What do you normally think of the temperature on the floor you work on? Can you please tick the appropriate box below (for the situation on an average working day in this season).

Table B.1 *Possible assessments temperature*

Situation	Too cold	Nice and cool	Not too warm but also not too cold	Nice and warm	Too warm
When I enter the building in the morning I normally consider the temperature as…					
Round noon I normally consider the temperature as…					
At the end of the day I normally consider the temperature as…					

10) How are you normally clothed when you're working?
[ ] The clothes I wear at work are warmer than the clothes I wear at home
[ ] I wear the same clothes to work as I do at home
[ ] The clothes I wear at work are thinner than the clothes I wear at home
[ ] I often take off some of my clothes (cardigan, vest etc) when I'm at work

11) What do you normally think of the ventilation level on the floor you work on? Can you please tick the appropriate box below (for the situation on an average working day in this season).

Table B.2 *Possible assessments ventilation level*

	Not enough	Sufficient	Too much, it is almost like drafting
When I enter the building in the morning I normally consider the ventilation as…			
Round noon I normally consider the ventilation as…			
At the end of the day I normally consider the ventilation as…			

12) Can you mark the air quality on your floor in building 42? You can use marks between 1 to 5 where 1 stands for mushy and 5 for fresh.
………

Possibilities to influence the inner climate in building 42

13) Do you make use of the thermostat in building 42 to adapt the temperature settings?
[ ] yes, quite often
[ ] yes, sometimes
[ ] no, almost never

14) What happens when someone does use the thermostat to change the temperature settings?
[ ] No consultation takes place
[ ] before the temperature settings are adapted consultation takes place
[ ] Consultation takes place after the temperature settings are changed. The consultation process ultimately leads to a compromise

15) If you never do so, why don’t you adapt the temperature settings by means of the thermostat?
[ ] I don’t find it is necessary/ I don’t have time to care about the temperature settings
[ ] I didn’t know it was possible
[ ] Because of the necessary consultation processes
[ ] When I adapt the temperature setting, the setting is often altered by someone else within a short period of time. Setting the temperature is thus not very useful

16) Do you open or close the small windows to regulate the level of ventilation on the office floor?
[ ] Yes, quite often
[ ] Yes, sometimes
[ ] No, almost never

17) What happens when someone opens or closes the windows?
[ ] No consultation takes place
[ ] Before the windows are opened or closed consultation takes place
[ ] Consultation takes place after the windows are opened or closed are changed. The consultation process ultimately leads to a compromise

18) If you never do so, why don’t you adapt the ventilation level in the room by means of the small windows?
[ ] I don’t find it is necessary/ I don’t have time to care about the ventilation level
[ ] Unknown possibility
[ ] Because of the necessary consultation processes
[ ] When I open or close the windows, the windows are often closed or opened again by someone else. It is thus not very useful to adapt the ventilation level by means of the small windows.

19) Are there periods of time when it is not possible to regulate the temperature on the office floor sufficiently? If applicable, please detail your answer (which time of the day, which kind of weather, is it too cold or too warm etc?)
…………………………………………………..
…………………………………………………..

Smart

20) How do you judge the facts that Smart makes participation in the setting of comfort levels possible?
[ ] I like the idea because……………………………………………………………………
…………………………………………………………………………………………………
[ ] For me this isn’t necessary because……………………………………………………..
…………………………………………………………………………………………………
[ ] It depends on…………………………………………………………………………….
………………………………………………………………………………………………..
[ ] I don’t know

Energy savings

21) The following proposition on the area of energy savings is the most appropriate for me (please tick one).
[ ] Energy saving doesn’t concern employees. The responsibility for energy savings lies with ECN.
[ ] Energy savings by employees is appropriate for ECN

22) The following proposition on the area of energy savings is the most appropriate for me (please tick one).

[ ] I want to determine myself how much comfort I surrender in order to save energy

[ ] The amount of comfort surrendered in order to save energy may be determined by building operation

23) Can you indicate if you agree with the following statements (please circle the right answer)?

Energy savings at work have to be voluntary I agree/ I don't agree

Energy savings at work may have to mean that my comfort is decreased I agree/ I don't agree

I'm only interested in saving energy if I get feedback on the amount of energy I save I agree/ I don't agree

I consider achieving a pre-set energy saving goal as an interesting challenge I agree/ I don't agree

I'm only interested in energy savings if I get rewarded for my efforts (e.g. extra leave or a surprise present) I agree/ I don't agree

I'm willing to wear warmer clothes at my work such that the central heating can be turned down and energy is saved I agree/ I don't agree

I may be willing to join discussions with colleagues in order to save more energy as a group I agree/ I don't agree

B.2 Questionnaire Part 2

Explanation: In order to be able to choose participants to be invited for the group interview, possible participants have to be characterised. The following questions are meant to make this characterisation possible.

1) We would like to have an impression of you on certain areas. Can you indicate if the following prepositions apply?

Table B.3 *Possible characterisations*

Preposition	This applies to me	This doesn't apply to me	This sometimes applies to me
I'm technically interested generally speaking.			
I'm interested in computer possibilities generally speaking.			
I like to use and explore new computer programs once in a while.			
I'm able to do my work with the computer, but for the rest I'm not very good with computers.			

2) Can you indicate which of the possibilities below does best apply to you?

[ ] I'm normally not the one who is the first to wants to change the temperature within the room. The temperature settings are thus not very important for me at most of the times.

[ ] I think I like the same temperature as most of the people in my environment. Most people would agree with the temperature settings I would like to apply.

[ ] I m always one of the first to be cold or warm in a certain environment. Therefore I would like to have a temperature setting of the system that is close to my temperature preferences.

[ ] I would like to work at different temperatures than most people in my environment.

3) Did you ever complain to FAC (building operation and maintenance) about the inner climate of your working environment?
[ ] No.
[ ] yes, I did once.
[ ] Yes, I did complain to FAC more than once.
[ ] I don't know what FAC is.

4) What did you complain about (please specify)?
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

5) What is your name? ……………………………………………………..

6) What is your gender?
[ ] male
[ ] female

7) Are you possibly interested in participating in a group interview (this group interview will probably take place in *May/ June* and will take about one hour)?
[ ] yes, I would like that.
[ ] I don't know, maybe I'm interested, maybe not.
[ ] no, I'm not interested.

8) When have you planned to go on holidays this year?
……………………………………………………….

9) Are there specific days or periods during the day that you're not at work?
If so, please specify…………………………………………………………………………
……………………………………………………………………………………………

B.3 First questionnaire: Answers

The questionnaire was answered by 26 persons. Only the answers to questions to the first part of the questionnaire will be given.

Personal information
Question 1

Table B.4 *First questionnaire, answer question 1*

Age	Times mentioned
18-25	0
25-35	5
35-50	6
50+	15

Question 2

Table B.5 *First questionnaire, answer question 2*

Gender	Times mentioned
Male	15
Female	11

Question 3

Table B.6 *First questionnaire, answer question 3*

Working place	Times mentioned
Part 1	8
Part 2	9
Part 3	3
Part 4	6

Question 4
The mark given was 6,9 with a standard deviation of 0,9 (scale 1-10).

Question 5

Table B.7 *First questionnaire, answer question 5*

Comfort aspect	Times mentioned (max 26)
Temperature perception	25
Heat or cold radiated	2
Freshness of air	17
Moistness or dryness	18
Cold feet	8
Cold hands	10
Perspiring	11
Draft	20
Other aspects	7

The other aspects mentioned were:
- Light (mentioned 4 times)
- Not enough oxygen
- Dust
- The smell of the air

Question 6

Table B.8 *First questionnaire, answer question 6*

Comfort aspect considered most important	Times mentioned (max 26)
Temperature perception	10
Heat or cold radiated	0
Freshness of air	1
Moistness or dryness	0
Cold feet	0
Cold hands	1
Perspiring	0
Draft	4
Other aspects	0

Question 7
The average preferred working temperature is 19,9 degrees Celsius with a standard deviation of 0,8 degree.

Question 8

Table B.1 *First questionnaire, answer question 8*

Comfort aspect	Times mentioned
Temperature	18
ventilation	18
Heat from the sun	14
Sun light	18
Artificial light	21
Other aspects	1

The other aspect mentioned was the possibility to direct light to individual working places.

Question 9
In the following table it is indicated how often the various temperature assessments were made.

Table B.10 *First questionnaire, answer question 9*

	Too cold	Nice and cool	Not too warm but also not too cold	Nice and warm	Too warm
Temperature in the morning	0	0	19	3	4
Temperature round noon	0	0	13	6	7
Temperature at the end of the day	0	0	10	5	11

Question 10

Table B.11 *First questionnaire, answer question 10*

Possibility	Times mentioned
Thicker clothing at work than at home	0
Same clothing at work as at home	20
Thinner clothing at work than at home	2
Part of clothing taken off during the day	4

Question 11
In the following table it is indicated how often the various ventilation assessments were made.

Table B.12 *First questionnaire, answer question 11*

	Not enough	Sufficient	Too much, it is almost like drafting
Ventilation in the morning	5	20	0
Ventilation around noon	7	18	0
Ventilation at the end of the day	8	17	0

Question 12
The mark given was 2,9 with a standard deviation of 0,9 (scale 1-5).

Question 13

Table B.13 *First questionnaire, answer question 13*

Frequency setting temperature by means of the thermostat	Times mentioned
Quite often	0
Sometimes	3
Almost never	23

Question 14

Table B.14 *First questionnaire, answer question 14*

Consultation related to temperature setting	Times mentioned
No consultation	20
Consultation before the temperature is set	5
Consultation after the temperature is set	1

Question 15

Table B.15 *First questionnaire, answer question 15*

Reasons not to adapt the temperature setting	Times mentioned
Not necessary/ no time	10
Unknown possibility	10
Because of the consultation process	2
The temperature will be set by someone else shortly afterwards	1

Question 16

Table B.16 *First questionnaire, answer question 16*

Frequency opening or closing the small windows to regulate the ventilation level	Times mentioned
Quite often	0
Sometimes	9
Almost never	17

Question 17

Table B.17 *First questionnaire, answer question 17*

Consultation related to opening and closing the windows	Times mentioned
No consultation	9
Consultation before the temperature is set	14
Consultation after the temperature is set	3

Question 18

Table B.18 *First questionnaire, answer question 18*

Reasons not to open or close the small windows	Times mentioned
Not necessary/ no time	10
Unknown possibility	3
Because of the consultation process	3
The temperature will be set by someone else shortly afterwards	3

Question 19
Periods of time when it is not possible to regulate the office temperature sufficiently.
The following time periods were mentioned:

- Monday mornings after a cold weekend.
- Summer days with temperatures exceeding 25 degrees Celsius.
- Afternoons.
- The whole day (because other people have different temperature preferences).
- Mornings on cold winter days.

- The whole day when the wind is strong (additional information: from someone who is sitting next to the door).
- Between 12 and 15 in the afternoon (too hot and not enough ventilation).

Question 20

Table B.19 *First questionnaire, answer question 20*

Assessment of the idea that Smart enables participation in comfort management	Times mentioned
Positive assessment	9
Negative assessment	3
Conditional assessment	8
No assessment	5

Question 21

Table B.20 *First questionnaire, answer question 21*

Most appropriate preposition	Times mentioned
Energy saving doesn't concern employees	2
Energy saving by employees is appropriate	24

Question 22

Table B.21 *First questionnaire, answer question 22*

Most appropriate preposition	Times mentioned
Comfort to be surrendered is to be determined by me	23
Comfort to be surrendered may be determined by the building operators	3

Question 23

Table B.22 *First questionnaire, answer question 23*

Preposition	Percentage that agreed with the preposition
Energy saving has to be voluntary	73
Energy saving at work may decrease my comfort	19
I'm only interested in energy savings when I get feedback	46
I consider achieving a pre-set energy saving goal as an interesting challenge	69
I'm only interested in energy savings when I get rewarded	8
I'm willing to wear warmer clothes such that the central heating can be turned down	35
I'm willing to join discussions with colleagues in order to save more energy as a group	85

APPENDIX C SECOND QUESTIONNAIRE

In this appendix the second questionnaire presented to the users of building 42 is presented. The questionnaire was originally drafted in Dutch.

First the questionnaire is presented. After the questionnaire the answers given to the questions in the questionnaire are presented.

C.1 Second questionnaire: Questions

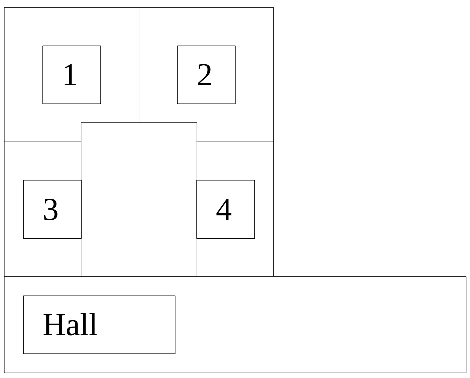
Personal information

1) How old are you?
[ ] 18-25
[ ] 25-35
[ ] 35-50
[ ] 50+

2) What is your gender?
[ ] Male
[ ] Female

3) In the next picture the office you work in is sketched. Can you give an indication of the place where you work in this office?

I work in part… of the office



4) Did you take part in the group interview on Smart?
[ ] yes
[ ] no

5) How would you mark your comfort situation *during the last six weeks*? (You can use marks from 1 and 10 where 1 stands for awful and 10 for perfect).
…….

Inner climate building 42

6) What do you normally think of the temperature on the floor you work on? Can you please tick the appropriate box below for the situation after the introduction of Smart.

Table C.1 *Possible assessments temperature within building 42*

Situation	Too cold	Nice and cool	Not too warm but also not too cold	Nice and warm	Too warm
When I enter the building in the morning I normally consider the temperature as…					
Round noon I normally consider the temperature as…					
At the end of the day I normally consider the temperature as…					

7) What do you normally think of the ventilation level on the floor you work on? Please tick the appropriate box below for the situation after the introduction of Smart.

Table C.2 *Possible assessments ventilation level within building 42*

	Not enough	Sufficient	Too much, it is almost like drafting
When I enter the building in the morning I normally consider the ventilation as…			
Round noon I normally consider the ventilation as…			
At the end of the day I normally consider the ventilation as…			

8) Can you mark the air quality on your floor in building 42? You can use marks between 1 to 5 where 1 stands for mushy and 5 for fresh.

………

Temperature and comfort setting

9) When you are cold, which action do you perform first?
[ ] I pull on an extra cardigan or vest
[ ] I close the windows when they are open
[ ] I regulate the temperature by means of the thermostat or Smart (skip the next question)

10) If you don't initially use Smart to increase office temperatures, what is the reason for this?
[ ] The actions I take are routine for me.
[ ] I don't think of Smart when I'm too cold
[ ] The actions I take have a positive effect. I have the idea that the effect that Smart has is less than the effect of the actions I take
[ ] Changing my clothing or opening windows also have other positive effects like…………….

11) When you are too warm, which action do you perform first?
[ ] I pull out a cardigan or vest
[ ] I open the windows when they are closed
[ ] I regulate the temperature by means of the thermostat or Smart (skip the next question)

12) If you don’t initially use Smart to decrease office temperatures, what is the reason for this?
[ ] The actions I take are routine for me.
[ ] I don’t think of Smart when I’m too hot
[ ] The actions I take have a positive effect. I have the idea that the effect that Smart has is less than the effect of the actions I take
[ ] Changing my clothing or closing windows also have other positive effects like…………….

13) Some time ago I wasn’t possible to open or close the small windows by hand. The office temperature became quite high during this period. What did you do to decrease the temperature during this period?
[ ] I didn’t do anything, because I quite liked the higher temperature
[ ] I didn’t do anything, because I wasn’t interested enough to perform actions to decrease this temperature
[ ] I adjusted my clothing after which I did use Smart to change my temperature settings after all
[ ] I did use Smart to change the temperature setting after which I adjusted my clothing to the higher temperature after all
[ ] Before I tried to regulate my comfort by the methods described above I first phoned the building operator to ask him to open the windows

Use of Smart

14) Do you have Smart as short cut or link on your computer?
[ ] yes
[ ] no

15) When you don’t have linked Smart to your computer, what’s the reason for this?
[ ] I’m not interested in Smart
[ ] I wouldn’t know how to link Smart
[ ] Another reason viz……………….

16) Do you use Smart to regulate your comfort/ temperature level at work?
[ ] Yes, a few times a day
[ ] Yes, a few times during the week
[ ] No, almost never

17) When you regulate the temperature by means of Smart, do you notice the effect of your actions?
[ ] Actually I don’t use Smart very often, so there are no effects to be noticed
[ ] Although I use Smart I don’t notice effects of my actions
[ ] After regulating the temperature by means of Smart, my complaints gradually lessen
[ ] Regulating the temperature by means of Smart clearly has a positive effect

18) If someone regulates the temperature by means of Smart, how does it happen?
[ ] Without consultation (skip the next question)
[ ] With consultation beforehand

19) What do you think is the reason for these consultations?
[ ] To verify that someone is not the only one that feels uncomfortable
[ ] To ascertain that others are not disadvantaged by the desired temperature setting
[ ] To persuade others to enter the same temperature settings into their computer
[ ] Other reasons viz…………………………………

20) When you almost never use Smart to regulate your temperature settings, what's the reason?
[ ] Not necessary/ no time
[ ] I didn't know it was possible
[ ] I don't think of mart at the moment want to regulate my comfort settings
[ ] Because of the necessary consultation process
[ ] Because of my expectation that voting by Smart has effect on my comfort level
[ ] Other reason, viz…………………………………….

21) Do you close or open of the small windows more or less often since the introduction of Smart?
[ ] Yes, I open or close the windows more often since Smart is introduced
[ ] No
[ ] Yes, I open or close the windows less often since Smart is introduced

22) Are there periods of time when it is not possible to regulate the temperature on the office floor sufficiently? If applicable, please detail your answer (which time of the day, which kind of weather, is it too cold or too warm etc?).
…………………………………………………..
…………………………………………………..

Regulation possibilities
23) How would you like the idea of Smart manifesting itself by means of a pop-up screen?
[ ] Convenient, this way I don't forget to vote
[ ] Convenient but I want to be the one to decide how often the screen appears on my computer
[ ] Inconvenient, it will braek my concentration
[ ] Inconvenient because………………………………………

24) How often would you like the pop-up screen to appear?
[ ] Never
[ ] Once a week
[ ] Once a day
[ ] Repeatedly during the day (e.g. in the early morning and after the lunch)
[ ] Every time I start up my computer

25) When would you like the screen to disappear?
[ ] Independent of voting behaviour
[ ] Dependent of voting behaviour, with other words you have to vote to make the screen disappear

26) If you would have to choose how would you like to use Smart?
[ ] I would like to evoke the Smart page myself
[ ] Would like Smart to appear as a pop-up screen
[ ] I don't care how Smart can be used

Regulation possibilities (2)
On this moment Smart can only be used to regulate the temperature in your sector of the office. Which aspects of the inner climate would you like to be regulated by Smart?
[ ] I would like Smart to regulate the temperature, I want to be able to open or close the small windows myself
[ ] I would like Smart to regulate the temperature and the small windows. I would like that people can tell Smart if they want the windows to be opened or closed so that Smart can decide to open or close these windows
[ ] I would like Smart to regulate the temperature and the small windows. I would like people to be able to enter temperature settings into Smart so that Smart can decide to open or close the windows in order to reach the preferred temperature.

28) What is the reason you chose one of the possibilities while answering the last question?
……………………………………………………………………………………………………
…………………………………………………………………………………………………….

Entering your preferences into the Smart screen. Below a picture of the Smart screen is shown.

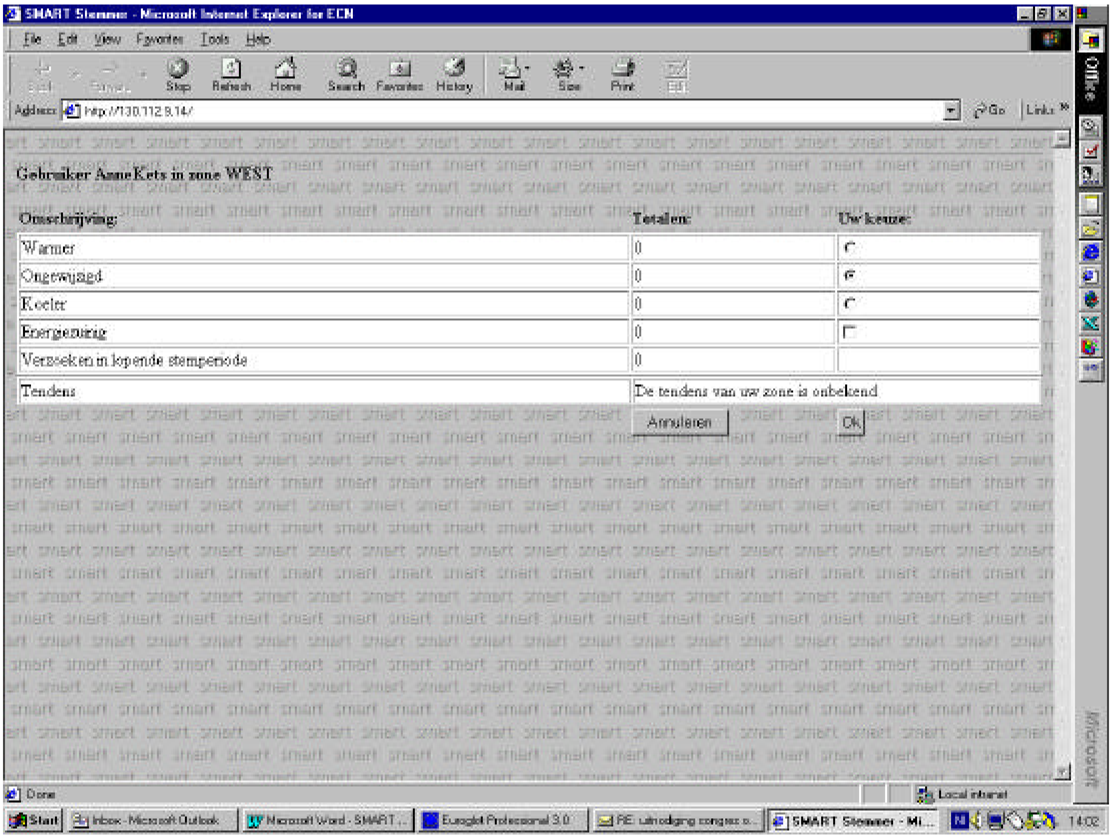


Figure C.1 *The smart interface*

29) How user friendly is this screen to you?
[ ] User friendly, it is completely clear what you have to do to enter your preferred settings
[ ] Quite user friendly
[ ] Not user friendly at all, I still have problems trying to understand how best to enter my preferred comfort settings

30) Can you indicate if you understand the concepts used on the Smart screen? Can you encircle your choice in the table below? You can choose the following possibilities:

- Yes I understand the concept
- partially I have an idea what is meant by this concept
- No I don't understand the concept

Table C.3 *Understanding concepts used in Smart*

Concept	I understood the concept *right after the introduction of Smart*	I *now* understand the concept
segment	Yes/ partially/ no	Yes/ partially/ no
warmer	Yes/ partially/ no	Yes/ partially/ no
unaltered	Yes/ partially/ no	Yes/ partially/ no
colder	Yes/ partially/ no	Yes/ partially/ no
Energy saving	Yes/ partially/ no	Yes/ partially/ no
Requests in the present voting period	Yes/ partially/ no	Yes/ partially/ no
Tendency	Yes/ partially/ no	Yes/ partially/ no
Annul	Yes/ partially/ no	Yes/ partially/ no
OK	Yes/ partially/ no	Yes/ partially/ no

31) If you didn't completely understand the concepts used on the Smart screen, which effect does that have on the way you enter your comfort settings into Smart?
[ ] I didn't vote/I don't vote
[ ] I voted/ I vote but I don't use the possibilities I don't understand
[ ] I voted/ I vote although I'm not sure about the possible consequences of my voting behaviour

32) Do you think you know what happens when more people within one segment enter their comfort preferences into the Smart system?
[ ] No
[ ] I think so but I'm not sure
[ ] I'm quite sure what Smart does when more people enter their comfort preferences into the Smart system

33) What do you think what Smart does when several comfort preferences are entered?
……………………………………………………………………………………………………
…………………………………………………………………………………………………….

34) What is the effect of 'not being sure of what happens when more than one comfort preference is entered within one segment'?
[ ] This has no effect
[ ] I don't use Smart as often if I would do otherwise
[ ] The way I enter my comfort preferences becomes more extreme because of this uncertainty. E.g. I enter my comfort preferences more frequently
[ ] This has another effect viz.………………………………………………………………

35) Do you have further remarks on the way comfort preferences can be entered into the Smart system?
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………………..

Energy saving

36) Do you use the option 'energy saving' when you enter your comfort preferences into the Smart system?
[ ] Yes, because……………………………………………….
[ ] No, because……………………………………………
[ ] Sometimes, it depends on……………………………..

37) Do you have an idea what Smart does when the option 'energy saving' is checked?
[ ] Yes
[ ] No

38) What do you think are the actions taken by Smart when the option 'energy saving' is checked?
……………………………………………………………………………………………………
…………………………………………………………………………………………………….

39) Would you like to receive more information on what Smart does when the option energy saving is marked?
[ ] No, I don't have to know what happens when I check the option 'energy saving'
[ ] Yes, I would like to know what Smart does when the option energy saving is checked

40) Would you like to know the energy saving effects of your actions?
[ ] No, Smart can take care of energy saving
[ ] Yes, I would like to know how much energy I save
[ ] Yes, I would like to know how far my comfort level is decreased to enable energy saving

All together: What do you think of Smart?

41) What is your opinion on the usefulness of Smart in view of your experiences with the system?
[} Smart is not useful, because…………………………………………………………………
[ ] Smart is not useful because……………………………………………………………………..
[ ] Smart is useless because……………………………………………………………………….
[ ] I don't know

42) Did in your opinion your comfort level increase when Smart was introduced?
[ ] No, my comfort level decreased when Smart was introduced, the office temperature is now too low for me (lower than it was before Smart was introduced)
[ ] No, my comfort level; decreased when smart was introduced, the office temperature is now too high for me (higher than it was before smart was introduced)
[ ] No, my comfort level is more or less the same as before the introduction of Smart
[ ] Yes, my comfort level increased when Smart was introduced because………………………

43) Smart could be used to group people according to their comfort preferences. What do you think of this idea?
[ ] I think it is a good idea viz…………………………………………………………………
[ ] I don't have an opinion on this issue
[ ] I don't like the idea because……………………………………………………………..

44) Would you like to receive some more information on Smart?
[ ] Yes
[ ] No,
[ ] Maybe, it depends on the kind of information

45) Do you have suggestions that can be used to improve the functioning of Smart?
…………………………………………………………………………………………………
………………………………………………………………………………………………….

C.2 Second questionnaire: Answers

The questionnaire was answered by 22 persons. It was striking that not all questions were answered by every person. The reason for this was mostly that not all persons had access to Smart in the preceding period.

Question 1

Table C.4 *Second questionnaire, answer question 1*

Age	Times mentioned
18-25	1
25-35	3
35-50	8
50+	10

Question 2

Table C.5 *Second questionnaire, answer question 2*

Gender	Times mentioned
Male	11
Female	11

Question 3

Table C.6 *Second questionnaire, answer question 3*

Working place	Times mentioned
Part 1	7
Part 2	8
Part 3	1
Part 4	5
Between different parts	1

Question 4

Table C.7 *Second questionnaire, answers question 4*

Participation in the group interview	Times mentioned
Yes	8
No	14

Question 5
The mark given was 6,5 with a standard deviation of 1,2.

Question 6
In the following figure it is indicated how often the various temperature assessments were made.

Table C.8 *Second questionnaire, answers question 6*

	Too cold	Nice and cool	Not too warm but also not too cold	Nice and warm	Too warm
Temperature in the morning	0	2	13	1	5
Temperature round noon	0	0	12	2	7
Temperature at the end of the day	0	0	9	2	10

Question 7
In the following figure it is indicated how often the various ventilation assessments were made.

Table C.9 *Second questionnaire, answers question 7*

	Not enough	Sufficient	Too much, it is almost like drafting
Ventilation in the morning	5	14	0
Ventilation around noon	9	10	0
Ventilation at the end of the day	10	8	1

Question 8
The mark given was 2,6 with a standard deviation of 0,8.

Question 9

Table C.10 *Second questionnaire, answer question 9*

Action	Times mentioned
Adjust clothing	10
Open windows	6
Temperature regulation by means of Smart or thermostat	3
No answer given	3

Question 10

Table C.11 *Second questionnaire, answer question 10*

Reason not to use Smart	Times mentioned
Action taken is routine	10
I don’t think of Smart when I want to regulate my temperature level	5
The action taken has a positive effect	7
The action taken also have other advantages	4

Here it must be noted that some respondents filled in more than one option

Question 11

Table C.12 *Second questionnaire, answer question 11*

Action	Times mentioned
Adjust clothing	8
Open windows	8
Temperature regulation by means of Smart or thermostat	2
No answer given	4

Question 12

Table C.13 *Second questionnaire, answer question 12*

Reason not to use Smart	Times mentioned
Action taken is routine	7
I don't think of Smart when I want to regulate my temperature level	5
The action taken has a positive effect	9
The action taken also have other advantages	3

Question 13

Table C.14 *Second questionnaire, answer question 13*

Actions taken	Times mentioned
No action taken because of positive assessment of the high temperature	0
No action taken due to low interest	5
First action: clothes adjustment Action taken afterwards: temperature regulation by means of Smart	6
First action: temperature regulation by means of Smart Action taken afterwards: clothes adjustment	4
First action: complaint to building operator	4
No answer given	3

Question 14

Table C.15 *Second questionnaire, answer question 14*

Link or short cut to Smart	Times mentioned
Yes	11
No	9
No answer given	2

Question 15

Table C.16 *Second questionnaire, answer question 15*

Reasons Smart not linked to computer	Times mentioned
Not interested in Smart	2
Procedure to do so unknown	7
Other reasons	10
No answer given	3

Question 16

Table C.17 *Second questionnaire, answer question 16*

Use of Smart to regulate comfort level	Times mentioned
Yes, a few times a day	2
Yes, a few times a week	7
No, almost never	10
No answer given	3

Question 17

Table C.18 *Second questionnaire, answer question 17*

Effect noticed	Times mentioned
Never uses Smart, so no effect noticed	7
Although Smart is used, no effect noticed	9
Complaints disappear gradually when Smart is used	3
Effect is clearly noticed	0
No answer given	3

Question 18

Table C.19 *Second questionnaire, answer question 18*

Consultation process when Smart is used	Times mentioned
Without consultation	11
With consultation beforehand	6
No answer given	5

Question 19

Table C.20 *Second questionnaire, answer question 19*

Assumed reason consultation process	Times mentioned
Check own feeling	2
To ascertain that others are not disadvantaged	3
To persuade others to enter same temperature setting	1
Other reason	0
No answer given	16

Question 20

Table C.21 *Second questionnaire, answers question 20*

Reason not to use Smart	Times mentioned
Not necessary/ no time	2
Unknown	0
Smart not on top of head when temperature I regulated	6
Consultation process	0
Expectation that smart has less effect than possible actions	5
Other reasons	2
No answer given	7

Question 21

Table C.22 *Second questionnaire, answer question 21*

Frequency opening/closing windows in relation to the situation before the introduction of Smart	Times mentioned
Higher frequency	1
Same frequency	17
Lower frequency	0
Not answered	4

Question 22
Periods of time when it is not possible to regulate the office temperature sufficiently.
The following time periods were mentioned:

- afternoons (too warm)
- when the weather is sunny
- mornings (too cold)
- dependent on the weather
- mornings (too warm)
- after the lunch (too warm)

Question 23

Table C.23 *Second questionnaire, answer question 23*

Assessment pop-up screen	Times mentioned
Convenient (reminder to vote)	6
Convenient when regulation of the time the pop up screen appears can be regulated	7
Inconvenient (concentration)	3
Inconvenient (other reason)	0
Not answered	6

Question 24

Table C.24 *Second questionnaire, answer question 24*

Preferred frequency pop-up screen	Times mentioned
Never	2
Once a week	0
Once a day	2
Repeatedly during the day	7
During start up computer	3
Not answered	8

Question 25

Table C.25 *Second questionnaire, answer question 25*

Preferred disappearing behaviour pop up screen	Times mentioned
Independent of voting behaviour	12
Dependent on voting behaviour	4
Not answered	6

Question 26

Table C.26 *Second questionnaire, answer question 26*

Preferred regulation mechanism Smart	Times mentioned
Smart by opening Smart page by yourself	5
Smart by pop- up screen	9
No opinion	3
Not answered	5

Question 27

Table C.27 *Second questionnaire, answer question 27*

Preferred aspects to be regulated by Smart	Times mentioned
temperature only	10
Temperature and small windows (directly)	2
Temperature and small windows (indirectly)	6
Temperature and internal ventilation	1
No answer given	3

Question 28
Various reasons were given.

Question 29

Table C.28 *Second questionnaire, answer question 29*

Assessment user friendliness screen	Times mentioned
User friendly	14
Quite use friendly	2
Not user friendly	0
No answer given	6

Question 30
In the following table the percentage of people that understood a certain concept is given. The percentages measured for the situation just after the introduction of Smart and a few weeks later are more or less the same. Therefore only the percentage for just after the introduction of Smart are given.

Table C.29 *Second questionnaire, answer question 30*

Concept	Measured percentage of people indicating that they completely understood the concept used
Segment	94
Warmer	94
Unaltered	89
Colder	94
Energy saving	50
Requests in the present voting period	78
Tendency	56
Annul	89
OK	94

Question 31

Table C.30 *Second questionnaire, answer question 31*

Reaction on not completely understanding the concepts used	Times mentioned
Did not vote	4
Did vote but without using possibilities that were not understood	9
Did vote although the consequences of voting behaviour were unclear	0
Not answered	9

Question 32

Table C.31 *Second questionnaire, answer question 32*

Answers given on understanding what happens when more people vote within one segment	Times mentioned
No	6
Yes, but I’m not sure	7
Yes, I’m quite sure	5
No answer given	4

Question 33
Ideas on what happens when several comfort preferences are entered within one segment. Most people indicated that the average comfort preference will be calculated**.**

Question 34

Table C.32 *Second questionnaire, answer question 34*

Effect of not completely understanding when more comfort preferences are entered	Times mentioned
No effect	6
Smart is used less	7
Comfort preferences are entered more extremely	1
Other effect	1
Not answered	7

Question 35:
- A clearer background will be appreciated.

Question 36

Table C.33 *Second questionnaire, answer question 36*

Use of energy saving option	Times mentioned
Yes	3
No	15
It depends	0
Not answered	4

Question 37

Table C.34 *Second questionnaire, answer question 37*

Idea what happens when the option energy saving is applied	Times mentioned
Yes	4
No	13
No answer given	5

Question 38
Most people didn’t have an idea what happened when the option energy saving was marked.

Question 39

Table C.35 *Second questionnaire, answer question 39*

Interest in more information about energy saving possibilities Smart	Times mentioned

No, no interest	8
Yes	10
Not answered	4

Question 40

Table C.36 *Second questionnaire, answer question 40*

Interest in energy saving effect of own saving behaviour	Times mentioned
Not interested	8
Interested in amount of energy saved	5
Interested in information on decrease comfort	6
Not answered	3

Question 41

Table C.37 *Second questionnaire, answer question 41*

Assessment Smart	Times mentioned
Useful	2
Not useful	4
Useless	3
No opinion	9
Not answered	4

Question 42

Table C.38 *Second questionnaire, answer question 42*

Opinion on change in comfort level since the introduction of Smart	Times mentioned
Decrease (too cold)	0
Decrease (too warm)	1
No change	17
Increase	0
Not answered	4

Question 43

Table C.39 *Second questionnaire, answer question 43*

Opinion on subdivision group according to comfort preferences	Times mentioned
Good idea	1
No opinion	3
Not a good idea	15
Not answered	3

Question 44

Table C.40 *Second questionnaire, answer question 44*

Interest in more information on functioning of Smart	Times mentioned
Interested	2
Not interested	6
Interest depending on the kind of information offered	11
Not answered	3

Question 45
Suggestions offered:

- It will be nice if the building will be cooled when everybody votes for a lower temperature.
- More information will be appreciated.
- A lot of people complain about drafts.