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A Case Study

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Acknowledgement

Preface

The aim of the Research Centre on Zero Emission Buildings (ZEB) is to promote the realization and diffusion of zero emission buildings. The goal of creating buildings that do not contribute to climate change is defined here in its most ambitious form: zero emission buildings must achieve a balanced carbon footprint throughout the course of their whole existence, including construction, operations, and demolition.

Especially in the case of larger buildings, professional actors assume a central role during the long use-phase. Buildings and their use are subject to constant change, components age and wear out, new tenants may move in and new patterns of occupancy and use are established. As anyone working with managing, operating and maintaining buildings will be able to confirm: only to keep a large office building in line with its original specifications entails new challenges almost every day. The efficiency and quality of these (often invisible) activities influence – both directly and indirectly – a building's energy consumption. The goal "zero emission" can only be sustained through the best possible interplay between the building, its various technical components and patterns of use. Consistently and continuously optimizing and stabilizing this interplay is therefore the most important task of building operations from the perspective of the ZEB Centre.

Recent decades have brought considerable changes in the technical and organizational constitution of building operations. On the one hand, under the name facilities management today we find a decidedly more professional and more holistic approach, especially in the operation of larger buildings and building complexes. At the same time, the advent of Information and Communication Technologies (ICT) has resulted in new possibilities for the real-time monitoring and maintenance of buildings. The significance of these changes for the goal "zero emission", their potential, and their challenges are therefore essential research topics for the ZEB Centre.

Within the ZEB centre's work, this report joins a series of case studies of professional building operation using new ICT tools. The premier goal of this work is to learn from practical experiences with existing systems and modes of organization, and to ensure that the resultant knowledge flows into future developments – not only in Norway and not only within zero-emission buildings.

This type of research is thoroughly dependent on the willingness to share with us the knowledge so arduously acquired in practice. This report would therefore not have been possible without the friendly reception that we encountered during the course of this case study. We especially thank the staff of the technical operations center for their support as we conducted our project.

Prof. Dr. Thomas Berker
Trondheim, 07 October 2013

Contents

1. Introduction: Objectives and Initial Considerations of the Research Project

This report presents findings of a research project that investigated the problems and problem-solving strategies in the remote operation of large non-residential building complexes. It is based on a three-day observation of the working processes in the "Technical Operations Center" of a larger airport in a German-speaking country in spring 2012. The observation was supplemented by interviews with the staff of the operations center and document analyses.

The investigation devoted special attention to the management level, i.e. the user interface of the central control and monitoring system (CCMS) used for remote building operation, and how building operators interact with these[1]. For the "usability" of this interface between human personnel and building technology has a substantial impact on whether and to what extent the CCMS, which monitors, coordinates, and controls the numerous complex functional processes of the facilities of the building technology and those specific to an airport, is able to fulfill its designated task and support the operations center staff in ensuring a smooth remote operation of the airport buildings. Satisfactorily carrying out this task poses a huge challenge to current building management systems. The tremendous amount of available building data can lead to strain as well as to problems and delays in the discovery and diagnosis of errors (cf. Seem, 2007). This is all the more evident, the more extensive and complex the building technology is and the larger the area / number of buildings to be monitored and controlled.

As previous investigations have shown, the diagnosis and correction of malfunctions is still relatively easy with a manageable number of buildings to be monitored and equally manageable technical installations. This is especially the case, when the technical staff in the operations centers is familiar with the physical buildings and their installations, so that the data output through the interface of the respective control technology can be linked with knowledge about the "real" facilities (e.g. about their construction and placement in the building) (cf. Bye & Glöss, 2012). When the complexity of the facilities and the size/number of the buildings become greater, however, the demands on the technical staff and on the user interface of the CCMS increase in terms of what is required to maintain an overview of the current building and facilities states in order to ensure their smooth operation.

Against this background, the operations control center observed in this report and the control system used there prove to be a highly relevant subject of investigation, since the airport buildings are distinguished, first of all, by a comprehensive automation of building operations, and secondly by their enormous size and number (300 buildings with a total area of approximately 2.4 million m^2). This size is additionally attended by a complex structure of the organization of the building management as well as the feature of being a highly sensitive building complex with a high degree of public traffic and airport-specific security regulations. In this way, the airport clearly differs from other institutions previously investigated within the framework of the larger Norwegian research context (cf. Bye & Glöss, 2012). It also seems to be confronted with considerably higher demands for smooth building operations.

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1 Three functional levels are differentiated in building automation: the management level, the automation level, and the field level. The functions of the field level are found in switching, positioning, reporting, measuring, and counting. This means that sensors and actuators that open and close valves, for instance, are to be located at the field level. The tasks of the automation level are found in monitoring, calculating, optimizing, and in steering and regulating. Data input and output is carried out here, and programs are executed, in which it is defined, for example, that when the outside temperature sinks (below certain levels), the valves of the heating system are opened. The management level is the interface between human and machine. This serves to monitor automated building controls. To this end, status indications and alarm signals, for instance, are output at the management level, and certain programs can be triggered or mechanisms "overridden". This means, for example, that certain measurement values can be manipulated and that the running programs can be modified in this way.

How building operations run and the buildings are kept "under control" in light of these framework conditions, which demands thus arise for the technology as well as the staff and the organization of building management, and which problems and problem–solving strategies arise in the everyday work of the technical operations center, are the subjects of the following considerations. These first describe how the technical operations are conducted in theory and which procedures and resources are thereby (supposed to be) used (Chapter 2). Following this and in comparison, the problems and problem-solving strategies are outlined that occur in everyday practice (Chapter 3). The investigation concludes with a summary and suggestions for possible improvements (Chapter 4).

2. Remote Building Operation in Theory

The operations center monitors a total of three hundred buildings with 28,000 rooms with a total area of approximately 2.4 million m². Operation and controlling of the buildings are automated as far as possible. The responsibility for this lies with the CCMS, which regulates, controls and monitors 14,000 program-controlled facilities with a total of about 220,000 data points. These facilities include

- facilities for ventilation and air conditioning
- heating facilities
- cooling facilities
- smoke extraction facilities
- electrical systems
- lighting systems
- sun protection
- sanitary facilities
- passenger transportation facilities
- and many others. In total, there are about 1500 address codes for different types of facilities

Considering the size, number, and complexity of the buildings and facilities, disruptions are part of normal operations[2]. In general, these must be recognized and rectified promptly. This is specifically the responsibility of the technical operations center. An important (although not the only) instrument to assist the operations center staff in monitoring, registering and eliminating errors is the user interface of the CCMS. The importance of the control system also becomes clear in the following characterization of the main task of the operations center, which I have taken from a presentation about the work of the operations center by the head of the operations center[3]. According to this presentation, the main task of the operations center consists in

> "monitoring and [...] ensuring the correct functioning of building-technology and airport-specific facilities and systems, in order to assure smooth operations. The operations center staff is aided by a control and monitoring system, which steers, coordinates, and monitors the numerous complex functional processes."

Two crucial factors are emphasized in this depiction: (1) the operations center staff that is responsible for smooth building operations, and (2) the central control and monitoring system that is described as the most important resource for this responsibility. In this chapter I will discuss both factors, beginning with the staff and the formal organization of working processes in controlling and ensuring the correct functioning of the technical facilities and systems.

2.1 The Formal Organization of Work in the Technical Operations Center

A closer look at the work in the technical operations center shows that two different units of work must be distinguished. First of all, there is the actual technical operations center, which is responsible for conducting higher-level technical operations. This area of responsibility comprises

1. the monitoring of the CCMS, which is realized primarily through the user interface and alarm management of the building control system;
2. the power system management of the medium voltage power grid of the airport;
3. the coordination of troubleshooting in the event of damage.

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2 Approximately 500 automatically registered disruptions occur every day. Urgent action is required for about 10% of them. In addition, roughly 40,000 disruptions are processed annually through the disruption report call center.
3 The original presentation was in German.

Alongside this, there is also the "technical disruption report call center". This responds to telephone notifications of disruptions. In addition to the automated disruption notification by the CCMS, it is also possible for disruptions to be reported via telephone by human beings, who make contact with the technical disruption report call center through an in-house telephone number. The disruptions so reported are registered here and passed on to the responsible departments. The problems reported by telephone are mostly "soft" or "felt" disruptions, or those that cannot be automatically registered through the CCMS. Per year there are about 40,000 disruptions relating, for example, to the subjective sensation of warmth on the part of employees in the offices or at the service counters in the terminals[4], or to broken doorplates and missing furnishings[5]. Three employees work at the disruption report call center, divided into an early shift and a late shift, so that the disruption report call center is generally available from 6 am to 6 pm (during the core working hours). Outside regular working hours, the call center is taken over by the staff of the technical operations center, who is permanently present. There are significantly fewer telephone reports during this period, however, because airport business is considerably reduced in the evenings and at night.

In the operations center itself there are fourteen employees working 365 days a year in three shifts around the clock. This means that the technical operations center is always open. In each shift two operations center employees work together, who normally form fixed teams.[6] These generally consist of one very experienced staff member and one less experienced staff member. Additionally, one of the operations center staff members must be a trained electro-technician authorized to operate the medium voltage power grid. In addition to these three shifts, there is also a fourth "middle shift", in which additional staff members are present during the regular working hours. During this middle shift they support the other staff members as needed or take care of other jobs that additionally arise. The middle shift, however, also serves the ongoing training for which the staff members are themselves responsible. This is a matter of going over problems that have previously occurred, expanding knowledge about technical operations, or further familiarizing oneself with the actual airport buildings and facilities.

During regular working hours the operations center employees are responsible for monitoring the CCMS (and the medium voltage power grid) and processing automatically reported disruptions. Specifically, this means that the disruptions are either treated directly by the operations center staff through the building control system (by unlocking or overriding[7]), or the responsible organizational unit is commissioned to resolve the problem on site. Responsible organizational units are generally so-called object teams, which are respectively responsible for the maintenance and repair of facilities and furnishings in certain buildings. Thus there are object teams for (1) office and commercial properties, (2) Terminal 2, retail and third-party customers, (3) air traffic properties, and (4) Terminal 1 and the central area of the airport. The object teams are composed of technical staff with different areas of expertise (electricity, metalworking, gas-water-heating installations, etc.). As so-called disruption-removers, they are responsible for carrying out maintenance and repairs on site in the buildings and facilities. In addition to these object teams, however, the responsibility for special areas (e.g. security technology)

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4 In particular, there are often more reports from female employees at the service counters during the winter, as several operations center staff members told me. The reason for this has been determined as being that the temperature in the terminals during the winter months is based on the assumption that most people are traveling in warming winter clothes. Employees of the airlines or car rental companies in the terminals, however, are required to wear uniforms. For women this usually means wearing short skirts and blouses.

5 These are cases that occurred during my stay.

6 The team constellations change in case of vacation, illness or new employees.

7 Disruptions are suspended with unlocking. Overriding or "fixing" facilities is done primarily outside regular working hours. In this case, data points are manipulated through the facility control system, so that the facilities no longer operate on the basis of actual values, but rather on the basis of specified values. Under certain circumstances, this allows facilities to continue to run despite an existing disruption, until the disruption can be resolved by technical staff on site.

may lie with other organizational units, and specialized workshops that exist in addition to the object teams carry out larger repairs[8].

For the procedures in dealing with disruptions (as well as for all other working procedures) there are clearly specified instructions that exist in the form of flow charts and the accompanying explanations in table form. The following figures show the instructions for handling automatically reported disruptions.
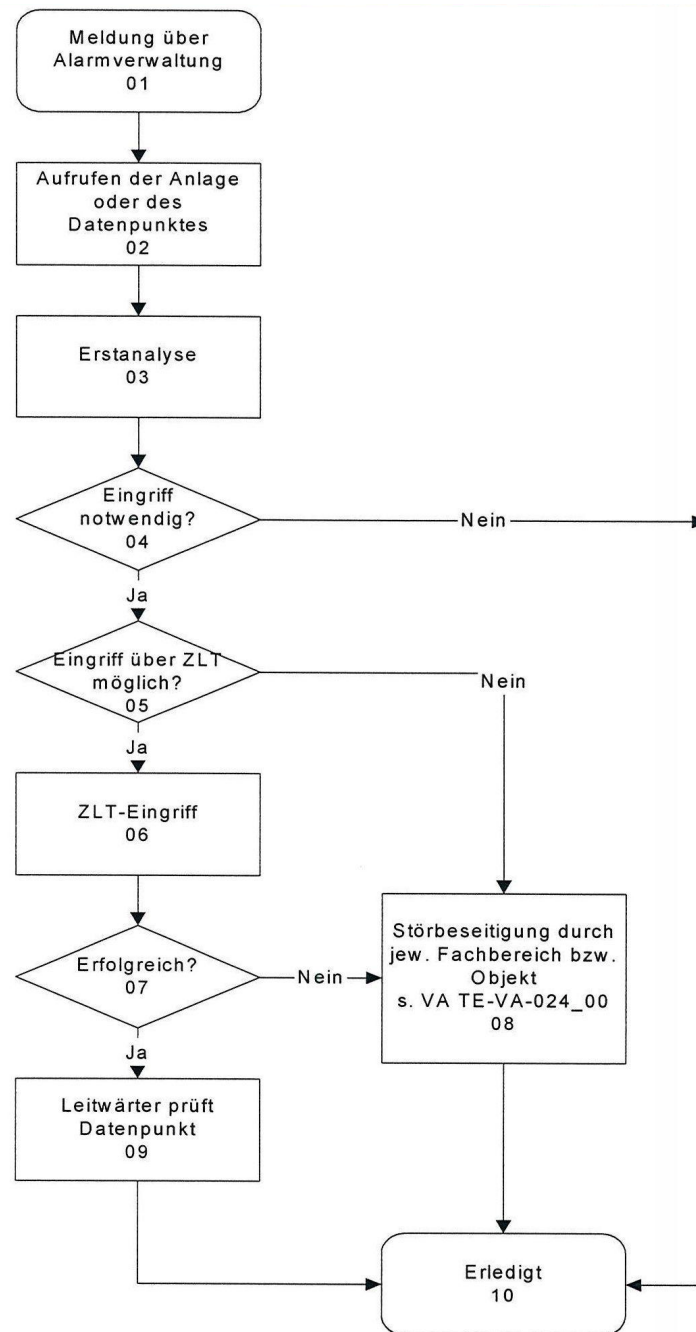

Figure 2.1   Process Map

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[8] In Chapters 3.1.3 and 3.2.3 I will discuss in more detail how it can be difficult in practice to determine who is responsible for a repair, because there are further exceptions and "gray areas" of unclear responsibility. In addition, responsibilities also partly change over the course of time.

Process Step	Brief Description	Responsibility		
		R	C	I
01	Report of a disruption via alarm management. Report is generated automatically.	■		■
02	The technical facility containing the disrupted datapoint is called up by the staff member on duty via Alpha O/I or PRCVIS	■		
03	The staff member conducts an initial analysis of the disruption	■		
04	Based on the results obtained, the staff member decides on an intervention.	■		
05	The staff member checks whether an intervention is possible or necessary via the CCMS. If no CCMS intervention is possible to resolve the disruption, the staff member passes the disruption on to the responsible staff member in the relevant department (see Process Step 08).	■		
06	If an intervention is possible through the CCMS, the staff member carries it out.	■		
07	If an intervention through the CCMS is not successful, the staff member informs the staff of the relevant department or object (during their regular working hours).	■ ■		
08	Disruption is resolved by a staff member from the relevant department. Report from the specialized department to TEGL, when the work is finished.	■ ■		■
09/10	TOC staff checks that datapoint is free from disruption, documentation follows automatically. The disruption is then checked off.	■		

R: Responsible
C: Cooperation
I: Information

Figure 2.2   Brief Description of the Process Steps[9]

Along with dealing with automatically reported disruptions, it can also happen that the technical operations center is tasked with resolving disruptions reported by telephone, if the staff of the disruption report call center decides that the reported disruption is the responsibility of the technical operations center.

There are further additional tasks outside regular working hours. While the technical operations center is staffed around the clock, this is not the case with the other technical areas of work at the airport. For this reason, the technical operations center takes over conducting technical operations outside regular working hours in the place of the specialized departments and interdepartmentally. Specifically, this means that after 6:00 pm (on weekends after 4:00 pm) the technical operations center takes over the disruption report call center, and after 7:00 pm and on weekends also IT disruptions, for which a separate technical support center is responsible during regular working hours.

On top of this, the workshops and the object teams, with the exception of the team responsible for Terminal 2, stop working at 4:00 pm. For the team responsible for Terminal 2, the work day ends at 7:00 pm. Until 11:00 pm there is still a late shift, which is then responsible for all areas and only consists

9Translated from German.

of two people, whereas during the day there are generally fifteen to twenty staff members to deal with disruptions. This means that in the evening there are only limited possibilities for carrying out repairs on site, and after 11:00 pm there is no more personnel available at all on site. Disruptions that occur at night can therefore not easily be passed on to the responsible specialized areas. In this case, the technical operations center carries an even greater responsibility. If they are not able to resolve the disruption through the CCMS, they have to decide whether remedial action is absolutely necessary before morning. In this case, they must either go to the defective facility to repair it themselves, or they must inform the services on call. Both alternatives have disadvantages, however. Leaving the technical operations center carries the risk that other disruptions may occur in the meantime, which cannot be dealt with by those remaining in the technical operations center by themselves. On the other hand, it is also possible that the technical operations center employee on duty does not have the requisite specialized skill to repair the affected facility. This would be the case, for instance, if a trained electrical engineer and a refrigeration technician are on duty, but a problem occurs in the sanitary facilities. Contacting the services on call, however, is associated with additional costs and means that a person on call must be disturbed at home and called to the airport. This also means that it takes some time for the person on call to arrive on site to remedy the disruption, and this results in additional financial and personnel costs, so that the necessity of this action must be carefully weighed. Consequently, especially outside regular working hours when only a few technicians or none at all are still present at the airport to deal with disruptions, the technical operations center staff is faced with the challenge of balancing security and economic considerations in the case of disruptions and reaching decisions appropriate to the situation.

Coordination of the Technical Areas through Additional Software

Whereas the monitoring of the building control system and the medium-voltage power grid is primarily conducted through the alarm management of the CCMS, additional software is employed for coordinating the technical areas in case of damage occurrences. "Customer reports" are prepared with this program using a fixed input form. The figure below shows a screenshot of an exemplary customer report, which in this case is based on a disruption report by telephone.
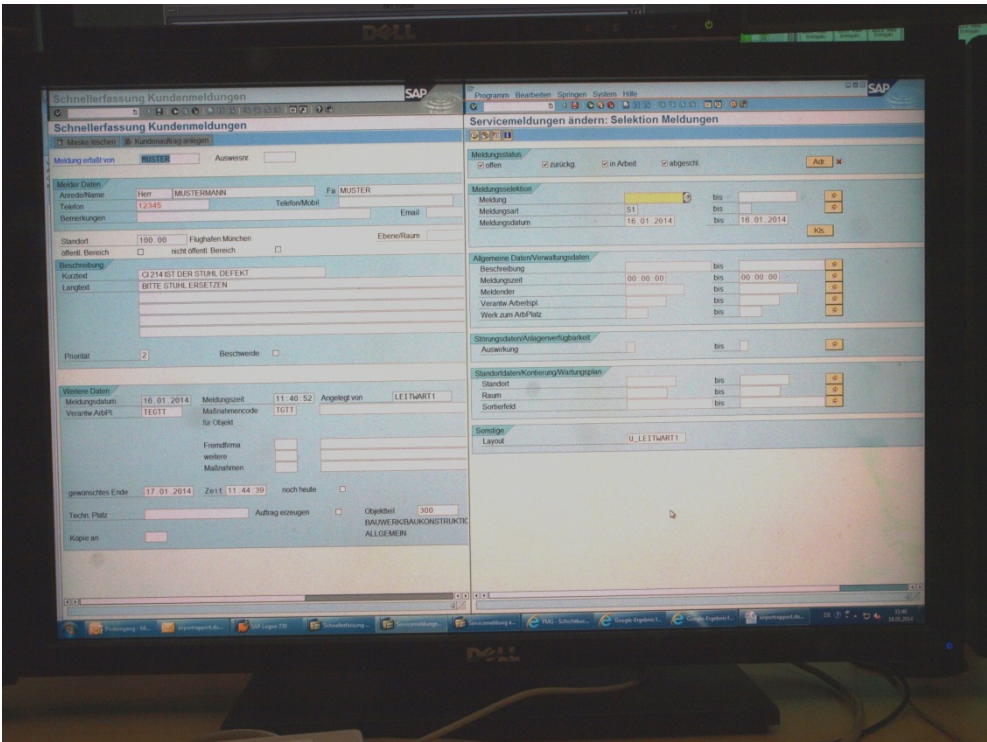

Figure 2.3   Fast entry of a customer report

Entries are made in this input form according to defined schemata, in which some entries are required and others are optional. The required entries include information about the person reporting the disruption, including names and telephone number (field "reporting data" (in German: "Melder Daten")), about the location where a disruption has occurred ("location" ("Standort")), a brief description of the reported disruption and a definition of its priority (both in the field "description" ("Beschreibung")), and finally an indication of which work unit is responsible for the repair (in the field "further data" ("Weitere Daten") under "responsible workplace" ("Verantw ArbPl")). The person making the report is also automatically registered (written above in blue "Meldung erfaßt von"), as well as the workplace where the disruption was reported and the time when the report was made (both in the field "further data" ("Weitere Daten") under "entered by" ("Angelegt von")). Once all the entries have been made, clicking on the corresponding button above in the input form generates a "customer report". This way the report is automatically sent as a work order to the department responsible for dealing with the disruption. In general, these are the object departments responsible for each respective building. However, there are also exceptions to this rule, which actually occur quite frequently, as far as I was able to observe (cf. Chapter 3.1.2 and 3.2.3).

The relevant department is subsequently responsible for eliminating the reported disruption and closing the customer report when the work is done, in order to mark the disruption as resolved. However, closed reports can still be re-opened at any time, should the problem occur again. Based on the report, it is possible to determine who originally reported the disruption and who was responsible for resolving it. This is how the basic orientation of the "service field building management", which also includes the technical operations center, is formally implemented. This basic orientation provides for a "consistent customer orientation/object organization" and a "clear assignment of responsibility for costs, quality of service, and results for each customer".[10]

As mentioned above, there are also formal procedure instructions that define the individual work steps for dealing with disruptions. These procedure instructions and the standardized input form of the administration program are intended to secure the smooth course of eliminating disruptions. This appears as clearly defined and unambiguously specified. What is noticeable in the process map (cf. Figure 2.1) is a high degree of similarity with circuit diagrams.[11] In this way, a certain idea of the tasks of the staff of the technical operations center is "pictured", which envisions the staff primarily as executors of clearly defined and technical processes. The instructions, however, only provide information about what is to be done in which order. Exactly how these work steps are to be realized and which skills are needed for this, is omitted. This appears to be unproblematic and in need of no further clarification.

The actual autonomy and self-reliance of the processes of decision-making and action in the technical operations center and the systematically occurring problems in the treatment of the individual work steps are not depicted in this way, however. Self-responsible action on the part of the technical operations center staff is instead treated primarily as an exception. In one of the procedure instructions for treating disruptions in the service field of building management, for instance, it says that a technical operations center staff member "can deviate from the procedure instructions, depending on the boundary conditions". According to this understanding, in other words, exceptional situations must be given, in order for the technical operations center staff to deviate from the regular "following instructions" and start to improvise. Otherwise they are expected to carry out clearly delineated tasks using the respectively defined tools. Whereas the software for preparing customer reports is the central tool for coordinating the specialized technical areas, the CCMS is the central resource for monitoring building operations and for the diagnosis of disruptions. The interface of the CCMS will be discussed in more detail in the following section.

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10 I have taken this from a presentation on building management at the airport.
11 On this, see the process visualization of the technical airport facilities in Chapter 2.2.

2.2 The Central Control and Monitoring System and its User interface

The interface of the CCMS displays information about the current states of the facilities, automatically reports disruptions and allows for remotely manipulating the technical facilities to eliminate disruptions (through unlocking and overriding). It is therefore the crucial interface between *humans* (technical operations center staff) and (building) *technology*, and an important tool for identifying and resolving malfunctions. In the best case, disruptions can already be registered and resolved with the help of the CCMS, before they are even noticed by people or "customers"[12] in the buildings. An example of this would be, for instance, if a ventilation facility is out of order, it is immediately registered and subsequently repaired, before the air in the rooms belonging to the facility becomes stuffy and the facility disruption thus becomes perceptible to the people in the rooms.[13]

The user interface allows various views of the processes running in the building and of the state of the facilities. Thus there are *overview representations, process images, alphanumerical representations of the data points*, and a separate *alarm management*.

There are *overview representations* for the most important facilities in the main buildings. These include, for instance, ventilation and air conditioning facilities in the Terminals 1 and 2. The reason why these are so important is that the terminals are the central hub of the airport, and the facilities that provide and monitor the indoor air in terms of purity, temperature and humidity are centrally important for the well-being of the people in the buildings. The following figure shows an overview of the facilities in Terminal 2.
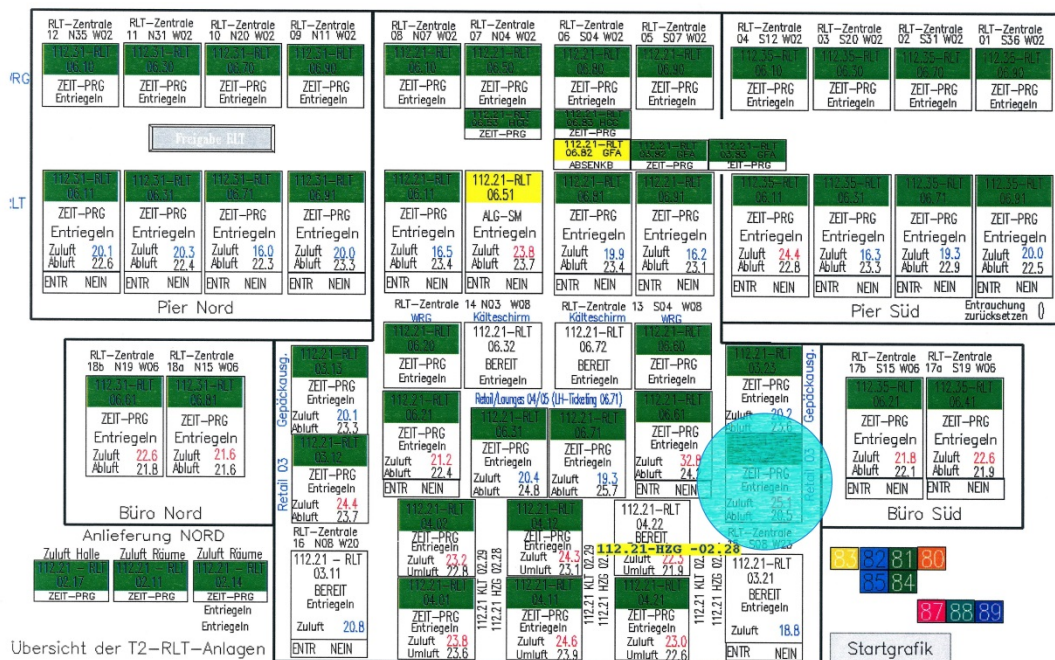
Figure 2.4   Facilities Overview Terminal 2

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12 From the perspective of the technical operations center, all persons in the airport are considered customers, not only passengers, but also airport personnel present in the buildings and working there.

13 This scenario represents the technical operations center staff's ideal image. It gives them satisfaction when they succeed in keeping malfunctions unnoticed. At the same time, a problem of the work in the technical operations center is reflected in this, a problem that it shares with other forms of technical "service work": when the work is done well and everything functions smoothly, it remains invisible and unnoticed. The work always only attracts attention if malfunctions occur. This characteristic of "service work" frequently results in recognition problems. For more on this, see Chapters 3 & 4, and Shapin (1989) and Suchman (1995).

In the facilities overview the facilities located in certain building sections are grouped together. All the facilities marked green are running normally. Yellow markings indicate that certain values in the respective facilities are currently not maintaining normal values, but without passing the given boundary values that would trigger a disruption. In the latter case, the facility would be marked red. The facilities overview here thus shows that, with the exception of two facilities, everything is currently in the "green range". In this view Terminal 2 appears as a collection of ventilation and air conditioning facilities structured according to certain areas (piers, office building, etc.). These facilities can be in one of three states (functioning, functioning outside the normal value, malfunction). This enables a highly specific look at the airport buildings and the technical processes running in them, which focuses only on certain functions (ventilation and air conditioning technology facilities) and fades others out, but which contains an overview of the essential information about the states of the facilities at the same time. It is possible to switch between different overviews or display multiple overviews next to one another. In this way, various important technical facilities can either be monitored virtually one after another to check their functioning, or they can be opened up parallel to one another.

Individual facilities can be selected from this overview position, to take a look at the states of the facilities not only "from outside", but also to observe the internal processes. This is especially what the *process images* are for. Clicking on one of the facilities in the overview representations displays its process image. For the facility 112.21-RLT 03.22, which is marked in Figure 2.4 with a blue circle, the process visualization looks like this:
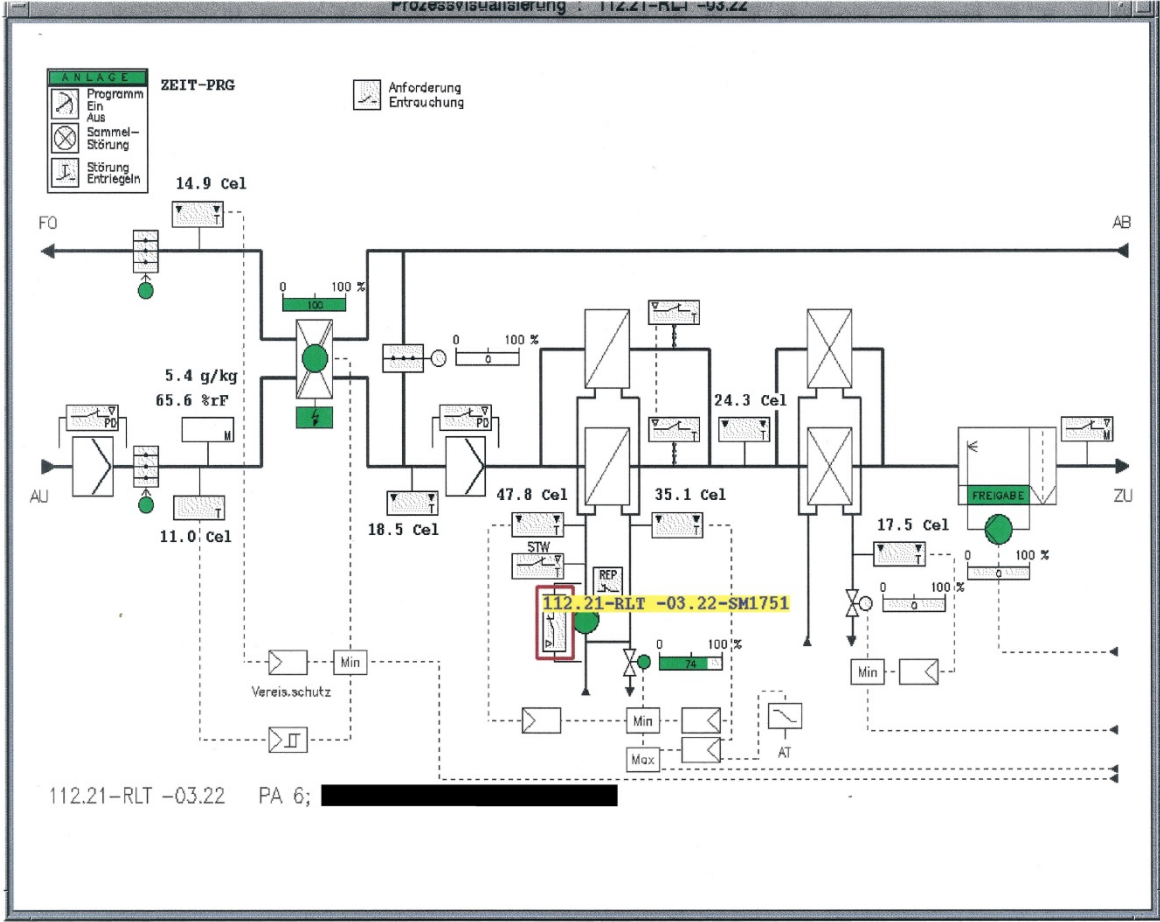

Figure 2.5   Process Visualization

This is a ventilation and air conditioning technology facility that is located on Level 03 in the service and retail area in the South Hall in Terminal 2. This is indicated by the alphanumerically coded facility designation.[14] The process image shows a schematic representation of the facility, the data points belonging to this facility, their states (these are again marked in color), and current measurement values. In addition, the arrows on the left and right indicate that the depicted facility is connected to further processes, which can also be called up, so that it is possible to click through the process images and further follow the processes belonging to the facility or connected with it. In this way, it is possible to take a look into the facility, its internal processes and also its connected processes. This should allow determining exactly where the problem is in the facility in case of a disruption.

However, it is also possible to go yet another step into detail. Information about the individual *data points* in the facilities can also be called up. The address of any of the data points, which are also alphanumerically coded in the overall facility, can be displayed. The address provides information about which facility the point belongs to and also about its function. The highlighted data point in Figure 2.5 has the address 112.21-RLT-03.22-SM1751. This address identifies it as the point SM1751[15,] which belongs to the facility 112.21-RLT-03.22. Further information about the data point can additionally be called up, for instance information about what is measured at the respective data point, or a context menu providing information about its current state. The following figures show this additional information. In Figure 2.6 we see that the differential pressure is measured at the data point, whereas in the context menu in Figure 2.7 it is evident that there is no disruption and the data point is currently not being externally controlled. Through this context menu it is also possible to intervene in the facility from the outside.

Figure 2.6   Display of the Device Type
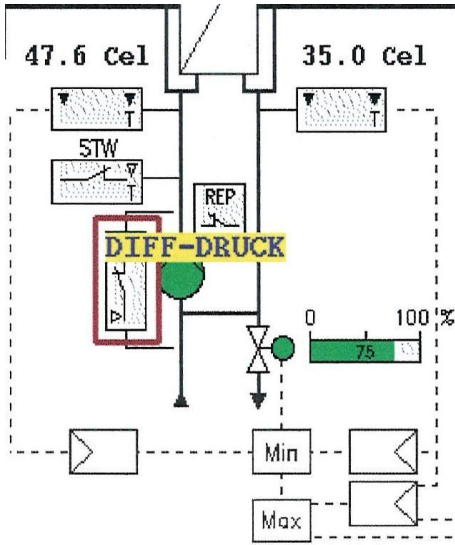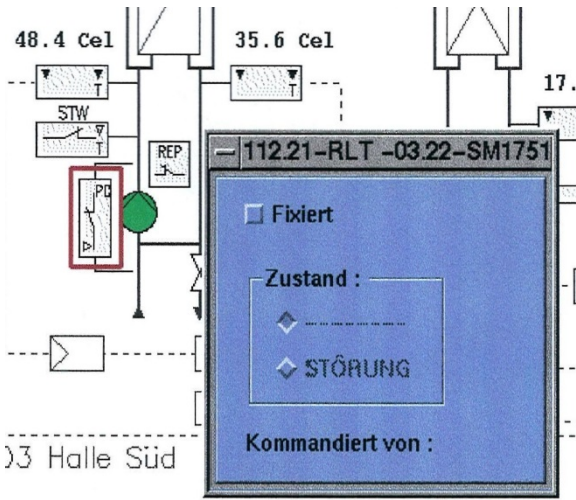

Figure 2.7   Display of the Data Point State

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14 This address means that the point is located in building section 112.21 (112 represents Terminal 2 and 21 the building section within the Terminal, the South Hall), to which a ventilation and air conditioning technology facility (RLT) belongs, which is to be found on Level 03 and has the sequence number 22.
15 This is its function code.

It is thus evident how the interface of the CCMS makes it possible to virtually control and influence the technical facilities, to move through them while zooming in and out, and to thus switch between various levels and degrees of detail in the representation.

A connection between virtual and real facilities is established in that there is always a sign on the field devices on site with the data point address and information about what is being measured there. In addition, the code at the end here is given four more signs indicating the type of device followed by a three-digit sequence number. The following figures show what this looks like on the field device that is represented in the CCMS by the data point 112.21-RLT-03.22-SM1751. The "F" at the end of the code indicates that this device belongs to the category of safety equipment.

Figure 2.8   Field Device with Data Point Address   Figure 2.9   Label on Field Device

Through the alphanumerical coding of both the virtual data points and the field devices, the facility representations in the interface of the CCMS are unambiguously linked with the real facilities in the buildings. This is especially important when the CCMS reports disruptions, and repairs must be made on the field devices by those responsible for eliminating the disruption. What matters here is that disruptions indicated on the computer can also quickly be located within the real facilities.[16]

Because the alphanumerical coding of the data points enables an unambiguous identification of them both within the virtual representation of the facilities and of the real facilities, this alphanumerical coding also has a central function in the *alarm management* of the CCMS. The alarm management is displayed in four separate windows with different colours: a dark blue window, a light blue window, a green window, and a red window. Different types of disruptions are displayed in these windows, whereby the dark blue window plays the most important role in the everyday work of the technical operations center. All disruption reports accumulate in this window, although with some delay. In the green window, on the other hand, the disruptions are displayed that are automatically given high priority by the CCMS and therefore categorized as critical, so these are displayed immediately, as soon as they are registered. These include the outage of facilities important to safety (e.g. smoke extraction), the outage of (a part

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16 In Chapter 3 I will discuss in more detail why difficulties may nevertheless arise in this case.

of) the management level of building automation, and the outage of facilities required for the smooth operation of air traffic.

The light blue window displays disruptions in the medium-voltage power grid of the airport, and the red window displays disruptions of the building automation system. The latter are generally only noted by the technical operations center and taken care of by a different department that is responsible for building automation (TEG-SG building automation). The following figure shows the dark blue alarm window, in which all disruption reports are accumulated:
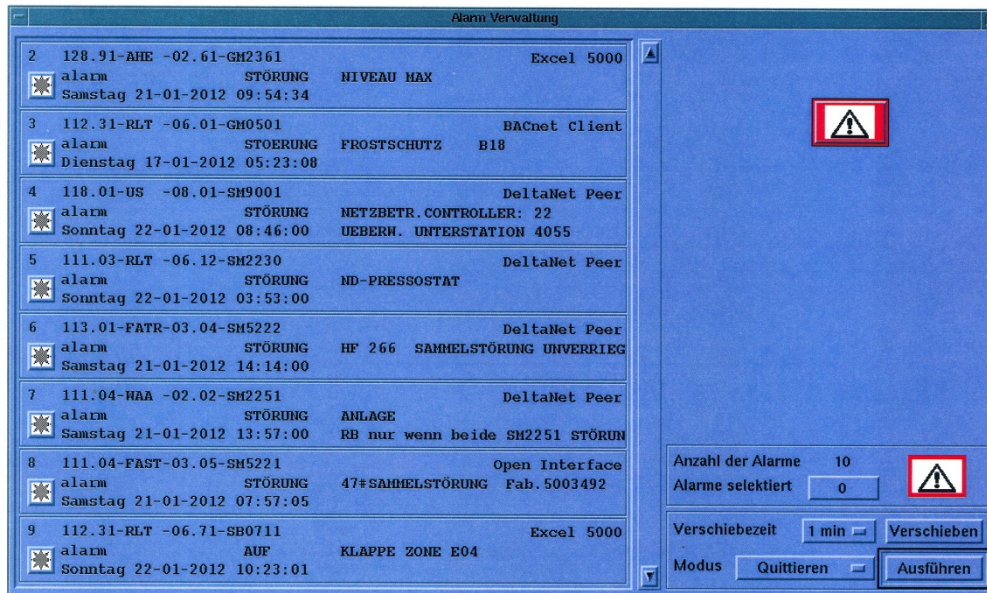
Figure 2.10 Alarm window of the CCMS interface

The sequence of the displayed disruptions is not oriented to the time of the disruption report. Instead, the disruptions are sorted according to urgency as defined in the program. They remain displayed in the alarm window until they are repaired or checked off.[17] At the same time, the system is so programmed that an alarm signal sounds when disruptions are accumulated. The technical operations center staff, however, deactivated this function. In everyday work it actually never happens that the alarm window is empty, which means that the alarm signal would be sounding permanently. This would in turn massively hinder work, as one technical operations center staff member expressed to me with the words, "that would drive you crazy". On the other hand, however, the sound also misses its intended function of calling attention to new reports, if it is heard permanently. In light of this situation, the settings of the alarm management were modified, so that the alarm signal only still sounds when reports come up in the green alarm window, to which the CCMS assigns the highest urgency.

In practice, the CCMS is monitored around the clock by two technical operations center staff members at a time. The user interface is displayed on three monitors respectively. Different types of facility representations can thus be displayed parallel to one another. The following figure shows one of the two workplaces of the technical operations center staff members.

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17 "Checked off" signifies an intervention on the part of the technical operations staff. This is done by marking a report and then selecting the button "quittieren" ("check off" - lower right in the alarm window). The report is then removed from the window and the system notes that the report has been acknowledged. Disruption reports are handled in this way, for which no action is required (for various reasons).

Figure 2.11   Workplace in the technical operations center with six monitors

The three upper monitors show the interface of the CCMS, other programs are running on the lower monitors. The left monitor and the middle screen show various overview representations, and the screen on the right shows the alarm management with the different colored alarm windows. All the windows can be closed and opened again and can be shifted among the monitors.

In summary, it can be stated that the way the CCMS and its user interface function clearly demonstrates the intended use of the technology. The tasks assigned to it consist of:

1. *Registering disruptions*. This is realized through the data points, which register the current facilities data respectively. If these deviate from defined normal values and accordingly exceed the defined boundary values, this is registered as a disruption.

2. *Localizing disruptions*. As disruptions are always collected at data points that are unambiguously alphanumerically coded, each disruption can also be unambiguously localized and attributed to specific facilities.

3. *Prioritizing disruptions*. This is carried out schematically through the previously determined categorization of facilities and disruptions as critical or non-critical. The outage of smoke extraction facilities, for example, is automatically assessed as critical.

4. *Reporting disruptions*. Disruptions registered at a data point are passed on without delay to the data server via the building automation network and from there to the computers in the technical operations center, so that disruptions are promptly displayed through the alarm management. In addition, the alarm signal ensures that the attention of the technical operations center staff is immediately called to the new disruptions.

These four tasks run simultaneously (at least from the perspective of the human personnel) and are then found bundled in the disruption reports in the alarm window of the CCMS interface. The registered disruptions are displayed here according to their priority and localized through the data point address. Following the activity of the software, the role of the human personnel is to perceive the reported disruptions, discover their causes, and to initiate and monitor the resolution of the disruption. The recognition and resolution of disruptions is accordingly formally separated into a clear division of labor and a sequential series of activities by humans and machines. The CCMS carries out the first four

steps, which are followed by further steps carried out by the human technical operations center staff according to predefined procedure instructions (cf. Chapter 2.1). These human activities can in turn be differentiated into four different actions:

5. *Perceiving disruption reports*. The alarm management is intended to call attention to disruptions through the sound of the alarm signal and a blinking alarm signal, so that the staff perceives the entrance of a disruption through audiovisual notification.

6. *Diagnosis of the cause of disruption*. To this end, the staff calls up the technical facility belonging to the disrupted data point and conducts an initial analysis of the disruption.[18]

7. *Initiating countermeasures*. A decision is made on the basis of the initial analysis as to whether an intervention is necessary, and then whether the necessary intervention can be carried out through the CCMS or must be passed on to the responsible specialized department. Countermeasures are initiated on the basis of these decisions.[19]

8. *Monitoring disruption resolution*. After the disruption has been resolved, the previously disrupted data point is checked that it is free from disruptions. If the data point is free from disruptions, the disruption is thereby concluded. If this is not the case, then countermeasures must be newly initiated.

In this way the division of labor between human and machine is formally organized, and the technical staff of the technical operations center is primarily defined as executive personnel. The staff members are responsible for handling disruptions and using the resources provided for this. The CCMS is responsible for disruption reports and serves as a tool for the analysis of disruptions; the software for customer reports serves the unambiguous and transparent distribution and documentation of responsibility for resolving disruptions.

The distribution of tasks for the disruption report call center is somewhat different. Here the customers reporting disruptions serve as the equivalent of the CCMS and take over the first four tasks: they notice a disruption and call the disruption hotline to report the disruption, indicating where the disruption is located and how urgently the disruption needs to be resolved in their view. The tasks of the disruption report call center then consist of receiving the disruption reports and initiating countermeasures on the basis of them by conveying customer reports to the responsible specialized departments. The tasks 6 and 8 described above are omitted here. They are taken over by the responsible specialized department instead, which undertakes a diagnosis of the disruption according to procedure instructions and controls the results after the measures have been carried out. To this end, the customer (the person who reported the disruption) is informed about the measures, and the report is closed when the customer is satisfied.

On the whole, it appears that the distribution of tasks between the CCMS and the technical operations center, or the customers and the disruption report call center respectively, is formally clear, the courses of action strictly regulated, and the necessary tools (CCMS, customer reports, telephone) available. The smooth conducting of technical operations presents itself as a task that follows specified tracks and consists of a sequence of clearly defined steps.

This is contradicted, however, by my observations of the working processes in the technical operations center. The observations show that the formal processes and resources described so far are contrasted by an actual practice, in which certain problems systematically recur, which confront the staff of the technical operations center with practical difficulties in carrying out their work tasks. These difficulties

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18 Cf. Figure 2.2
19 Cf. ibid., especially the process steps 04 and 07.

are not depicted in the procedure instructions and cannot be resolved solely with the aid of the tools provided.[20] With this background, Chapter 3 will focus on pointing out the problems that systematically occur in the *everyday work* of the technical operations center, as well as on the required skills and additional tools and resources needed to cope with these problems. This will result in a practice-based description of the work processes in the technical operations center, which deviate from the formal description presented in this chapter.

The difference between formal and real work processes and ways of using technology leads to insights that can provide suggestions for improving and simplifying the work processes in the technical operations center. For it is in the deviations from the planned procedures that the actual demands on the technology and the staff are clearly revealed. Looking at the interface of the control system, this means that it becomes recognizable to what extent this system can support the technical operations center staff in ensuring the smooth operation of the airport buildings. In this respect, the additionally employed tools promise instructive insights, for the employment of these tools clearly indicates deficiencies in the available CCMS interface, which must be balanced out with other resources.[21]

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20 For outside observers, these problems and the skills and tools needed to resolve them remain largely invisible. What is externally visible, on the other hand, is the description of clearly defined courses of action and the tools provided for them. This can be regarded as typical for technical service professions, which often appear to the outside as clearly regulated routine jobs, but which prove to be highly complex activities at a closer look, requiring abilities for improvisation and creative problem-solving (cf. Orr, 1998; Winsor, 2000).

21 From the perspective of the social studies of technology it is not at all surprising that existing software exhibits deficiencies in practical use. Studies from the fields of human-machine communication and computer-supported cooperative work "often furnished evidence of the problematic design of a system, describing how the system detrimentally impacted peoples' work activities and even showing that a system had to be worked around" (Button, 2000, p. 328). From this follows that dysfunction can never be completely avoided. Nevertheless, the focus on relevant weaknesses can provide suggestions for improving the software, even though new problems will certainly emerge later.

3. Remote Building Operation in Practice

The aforementioned problems apply primarily to four aspects that make it more difficult to carry out single steps of work in specific ways:

1.   Airport buildings and facilities are non-stable formations. On the one hand they change over the course of time and gain new functions and designations. On the other, they also assume different forms of appearance (assembly of technical facilities with alphanumerical data point addresses vs. assembly of spaces and buildings with public designations [of function]). In this way they become "multiple objects", which makes it more difficult to *localize* disruptions.

2.   Disruptions and their causes cannot be treated schematically, because new sources and types of errors are constantly appearing, which prove to be unique. This makes the *diagnosis* and *prioritization* of disruptions difficult.

3.   The organizational structure of building management is complex and dynamic, so that responsibilities change and are sometimes ambiguous. This makes the *initiation of countermeasures* difficult, because responsibilities for dealing with disruptions are sometimes unclear.

4.   Dealing with customers has to accommodate contradictory organizational demands that have to be harmonized with one another. This makes the work of the disruption report call center difficult.

These four aspects will be discussed in more detail in the following (Chapter 3.1.), in order to clarify the challenges and problems arising in everyday building management. Following that I will describe how and with which resources these problems are dealt with in the everyday work of the technical operations center (Chapter 3.2). The point is to take a closer look at the working processes that are taken for granted and considered unproblematic in the way they are outlined in the procedure instructions, and to show in detail how these working processes run in practice and which problems must be dealt with in the course of that. This is intended to reveal which complex activities and skills are needed for the implementation of the individual work steps, which tend to remain hidden in the purely formal description of the working processes.[22]

3.1   Four Recurring Problems in Remote Building Operation

3.1.1   Airport Buildings as Non-stable, "Multiple Objects": Problems in Localizing Disruptions

When I speak of airports as non-stable formations, at first glance this does not seem very comprehensible, since buildings are constructed of steel and cement and for a long period of use. I do not mean to contradict that. The crucial point that I want to draw attention to, however, is that varying principles of arranging the representation of buildings exist, which are only partially joined to one another. The real physical building is only one of several forms that the building assumes. The "virtual" buildings represented through the interface of the CCMS are represented primarily in the form of facilities and data points, which are located in numerically coded building sections and levels. This is the primary form in which the technical operations center staff perceives the airport buildings and which they use to move (virtually) through the buildings. For the people moving in the real, physical buildings, on the other hand, the buildings consist primarily of spaces (in which the facilities may be found). Accordingly, for orientation in the buildings they use two-dimensional floor plans that enable overviews of the spatial order of the buildings and allow them to find their way in the buildings.

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22 Using a term from science and technology studies, it could be said that the point is to open up the "black box" of the actual working processes.

There is a high degree of overlapping between the physical buildings and the two-dimensional floor plans. They follow an order that is primarily structured according to spaces, on the one hand, and which contains, on the other hand, no numerical designations of function, but rather alphabetical designations, such as *Terminal 2, Office Building 1 North or Parking Garage P6*.

In contrast to this, the building representation differentiated according to technical facilities only roughly overlaps with the spatial order. The facilities in the physical buildings are usually not openly visible, but are instead hidden in separate areas or behind paneling. At the same time, the facilities representation that is displayed through the interface of the CCMS does not precisely indicate the spaces in which the individual field devices are located that belong to the facilities. The numerical coding of the data point address only supplies information about the building sections in which the facilities are located. However, this is usually only a very rough indication, because the building sections in the physical buildings are usually subdivided into numerous spaces. In addition, the individual data points that belong to a facility are sometimes located at a different level than the facility itself. This makes it systematically difficult to localize disruptions. When they are reported through the CCMS, precisely locating them in the real building poses a challenge. Conversely, it is difficult to find out through the CCMS which facility is responsible for a disruption, when disruptions are reported by telephone.[23] The following figures are intended to illustrate the differences between the various principles of arrangement.
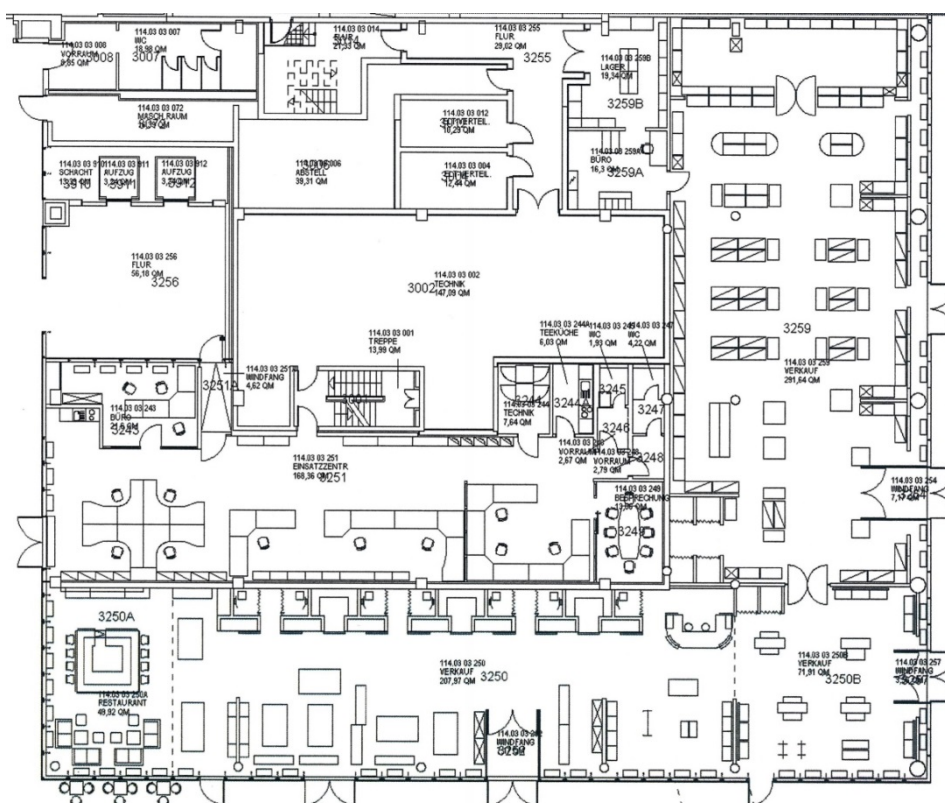

Figure 3.1   Building Floor Plan

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[23] There are also further types of building representation, which I will not list at this point. They will still be significant, however, in the course of further explanations. The intention here is to point out the parallel existence of these different arrangements.
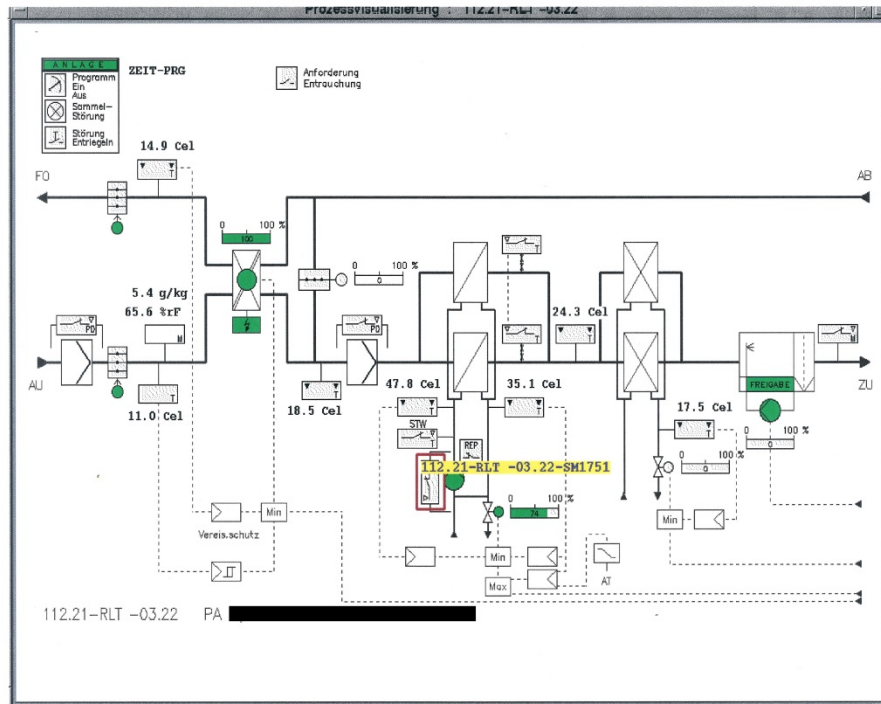
Figure 3.2   Technical Facility

Whereas the airport buildings present themselves to the people moving in them primarily as three-dimensional spaces, Figure 3.1 shows a floor plan of the building section, in which the technical operations center is located. This represents a two-dimensional depiction of the building, which establishes a high degree of matching ratio to the real building, as it follows the same principle of arrangement: the organization of the building according to spaces. Figure 3.2 again shows the process visualization of the air conditioning and ventilation technology facility (RLT) 112.21-RLT-03.22, which was described in Chapter 2.2. This facility is also located in Terminal 2. Its representation, however, follows a completely different principle of arrangement than the floor plan. It does not display a spatial order, but rather a technical order by representing the setup of the air conditioning and ventilation technology facility schematically. Only the numerical code indicates where it is *approximately* located within the framework of the spatial order. It is located in building section 112.21, in other words in the main building of Terminal 2 and there on Level 03. Where *exactly* in the main building the individual field devices belonging to the facility are set up, is not made clear in this way, however.

In addition to the parallel existence of different principles of arrangement in the representation of buildings, the airport buildings also change over time. They are renovated and given new designations and functions. At the same time, however, the old functions and especially the old designations do not completely disappear, but instead continue to exist partly parallel to the new designations. Old building names often continue to be used especially in the general language use of the airport employees, although they officially meanwhile have different names. Consequently, in practice different designations are often used for identical buildings, and there is therefore a sense of ambiguity in this case. In a way, this means that the past continues to live on in the present.

In summary it could therefore be said that the airport buildings present themselves not only in their stable physical form, but always also in other forms, in which different spatial, technical and temporal orders are expressed. Using a term from science and technology studies, the airport could accordingly be grasped as a "multiple object" (cf. Law & Singleton, 2005), which assumes different forms depending

on the context, which only enter into partial connections with one another.[24] With this background, a crucial task of the work in the technical operations center is to strengthen the connections between these different *modes of existence* and to link them to one another in such a way that the smooth operation of the airport buildings can be maintained.

3.1.2 Barely Manageable Number and Diversity of Facilities and the Constant Emergence of New Sources and Types of Disruptions: Problems in Diagnosing and Prioritizing Disruptions

According to the existing procedure instructions and the intended functionality of the CCMS, the diagnosis and prioritization of disruptions does not present a major challenge. Prioritization is automatically undertaken by the CCMS, and the facility information available through the CCMS equally allows for quickly determining causes of malfunctions and initiating countermeasures (cf. chapter 2.2). Contrary to this description, however, it is evident in practice that the diagnosis and prioritization of disruptions can never be run through according to a pre-defined scheme. A staff member from the technical operations center aptly expressed this as he remarked that real problems can never be solved schematically. Accordingly, in his opinion, every situation requires its own problem-solving, whereby the path to these solutions is not defined, nor can it be depicted in the procedure instructions.

The difficulties in diagnosis and prioritization arise just from the enormous number and diversity of the facilities. As described in Chapter 2, the buildings of the airport are controlled through 14,000 facilities. This alone already makes it difficult to be familiar with all facilities, which would be a condition for adequate diagnosis. In addition, however, there are also completely different types of facilities. For instance, there are approximately 1500 address codes for the facilities, which illustrate the tremendous diversity. These range from exit barriers (code: AFS) all the way to access control systems (code: ZKS), and from heating facilities through sanitary facilities all the way to electrical medium voltage power grid circuit facilities. This means that very different specialized skills (heating technology, sanitary technology, electro-technical skills) are necessary in order to be able to understand how the facilities and their process visualizations function. The significance of the available facilities information and process visualizations is not obvious by itself, but can instead only be grasped with the corresponding specialized knowledge. Yet the diversity of the facilities makes it impossible for every technical operations center staff member to have a comprehensive specialized knowledge for all the different types of facilities. In practice it therefore repeatedly becomes a problem to find out what certain data mean and which problems are at the base of disruption reports. The researcher Shoshana Zuboff calls this problem, which principally arises in the remote control of technical facilities, a *problem of reference* (cf. Zuboff 1985: 11), meaning the difficulty of determining real facility states solely from information that is available virtually.

In addition, disruptions must also always be considered in their context. This means that always new disruptions and disruption causes arise, so that identical disruption reports can be based on different causes. Accordingly, disruptions can never be analyzed independently from the current state of the building and from the existing context information, which must always be taken into consideration in diagnoses and is important for a prioritization of disruption reports appropriate to the situation. However, the CCMS provides no assistance for this kind of contextualization of disruption reports, because it always reports and prioritizes disruptions schematically and independent from context.[25] So further information about current operations and processes in the building must be obtained, in order to be able

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24 In my view, this marks an important difference from previous descriptions of "coordination centers" in social sciences literature. These descriptions emphasize that it is the task of coordination centers to maintain a spatio/temporal order (cf. Suchman, 1998), whereas the task of the technical operations center, as I see it, is primarily to connect different spatio/temporal orders with one another.

25 On the difference between machine, plan-based, and human, situative agency, cf. Suchman (2007).

to appropriately recognize the causes and urgency of disruptions. This problem becomes obvious in that, for example, there are always some disruption reports displayed through the CCMS that relate to maintenance work currently being undertaken on the facilities reported as malfunctioning. It also happens that disruptions are reported for facilities that have recently been removed and are therefore no longer functioning, or that certain disruptions are permanently displayed over a longer period of time, because the necessary replacement parts for the repair are lacking.

This shows that there are no generally valid procedures for disruption diagnosis and prioritization. They must always be carried out situatively and require additional specialized and situation-specific knowledge that is not accessible through the CCMS. In addition, there is a problematic marginal condition in the diagnosis and prioritization of disruptions in that both processes run under tremendous time pressure, especially in the case of critical or major damage events, so that they must be dealt with very quickly, leaving little time for thinking.

3.1.3 Building Management as a Complex Organization with Differentiated and Changing Responsibilities: Problems in Initiating Measures and Allocating Responsibility

As described in Chapter 2.1., an important part of the work of the technical operations center consists of taking over coordination in the case of damage occurrences and commissioning the responsible specialized areas with repairs, if an intervention via the CCMS is not possible. It is accordingly defined in the procedure instructions that reports go to the teams responsible for the respective objects according to standard procedure. Here responsibility is thus clearly tied to certain objects, so that it appears simple to assign each building to the relevant specialized area.

There are exceptions, however, which do not follow an object logic, but rather a logic of functions. Reports relating to security technology, for instance, and disruptions of fire-fighting facilities go to the respectively specified teams. The case is the same for cleaning that is needed. Relevant reports go to a team especially specified for these jobs. Although that still sounds relatively clear, it is evident at a closer look that there are many further deviations, and the responsibilities lie not only with departments within the airport, but partly also with external companies. Cleaning jobs, for instance, are partly contracted to third-party companies, and external companies are even completely responsible for certain sub-areas. These include the elevators in the buildings, baggage transport facilities, or the passenger bridges. There are accordingly many deviations from the standard and overlaps between object logic and function logic, when certain areas in the buildings for which object teams are responsible, for instance, actually belong to the responsibilities of a different specialized field. Just as problems systematically arise in the localization of disruptions due to the different logics of building representation (spatial arrangements vs. facilities arrangements), here there are also difficulties in initiating countermeasures due to the different procedures in the allocation of responsibility (object logic vs. function logic). In addition, there are changes in responsibilities over the course of time due to internal restructuring or new contracts with external companies. This also makes it systematically more difficult to unambiguously allocate responsibilities. In keeping with this, during my stay in the technical operations center I was able to observe how customer reports returned to the technical operations center from specialized departments because they were not the ones responsible.

The structuring of the buildings according to areas of responsibility additionally proves to be a further element of the airport as multiple object, which must be conjoined with the other elements (technical and spatial "modes of ordering"), so that a localized disruption can be assigned to the right specialized department.

3.1.4 Contradictory Requirements in Dealing with Customers: Problems with the disruption report call center

Similar to the way the airport buildings present themselves as multiple objects, in a certain way callers also present themselves in different roles at the same time. They are simultaneously both "customers", who call with a concern of their own that they want the disruption report call center to take over, and "sensors", which from the perspective of the technical operations center serve the aim of smooth building operations and are therefore expected to provide precise information that can be translated into customer reports.

From the perspective of the staff in the disruption report call center, disruptions reported by telephone therefore lead to the problem of contradictory organizational requirements in dealing with the callers. On the one hand, the general principle of a "consistent orientation to customers" demands that every person who reports a disruption must be treated as a customer who entrusts the disruption report call center with their concern. In keeping with their position as customer, what applies here is that the staff of the technical operations center must orient themselves to the wishes of the customers and convey to them that their problems are being taken seriously. On the other hand, what is in the foreground in the interests of smooth building operations is that the callers provide precise information about the disruptions, which is oriented to the clearly defined fields of the fast entry system for "Customer reports" (cf. Chapter 2.1).

As described at the end of Chapter 2.2, from the perspective of monitoring the buildings, the function of the callers consists of them functioning as the equivalent of the CCMS. However, since they generally express the "felt" disruptions less precisely than the CCMS, it is sometimes difficult to find out exactly what is disrupted and where exactly there is a disruption. Accordingly, the customers generally have to be steered (if not to say: configured) during the telephone call, in order to fulfill their function as "sensor" or "data point". This consequently means that orientations to contrary objectives must be harmonized with one another during a telephone disruption report.

3.2 How the Problems Described are Dealt with in Practice

How the four fundamental problem complexes described in Section 3.1 are dealt with in practice is the subject of the following considerations. These are oriented to the sequence in the depiction of the problems. This means that I will start with the *practice of localization*, followed by the *diagnosis and prioritization* of disruptions. The third point will cover *initiating countermeasures*, concluding with the *disruption report call center*.

3.2.1 Localizing Disruptions in Practice

At the purely technical level, localizing disruptions does not initially present a problem. As described at the end of Chapter 2.2, disruptions that are collected at data points are unambiguously localized through the alphanumerical coding of the data points. In this way, they can be promptly identified as part of certain facilities. Information about their location in the buildings is contained in the first six sign positions of the address key.

This type of localization is entirely sufficient, if the automatically reported disruptions can also be resolved through the CCMS. Problems can arise, however, if it is not possible to resolve the disruption through the CCMS, so that a person has to take action directly at the disrupted facility. In this case, the coded localization may not be specific enough, for various reasons, so that it is difficult for the technical staff to find the actual site of the disruption in the building.

Insufficient match between data point address and position of the facility (point) in the real buildings

Through the data point address it is possible to, without problems, determine in which buildings and building sections the disrupted facility is located. This is helpful for an approximate determination of the respective facility position within the real building, but it is insufficiently precise for finding a concretely disrupted field device that is part of the facility on site. The building sections are subdivided into further spaces, and the data point address supplies no indication of the space in which the disrupted facility is located within the building section. Nor do the process visualizations of the CCMS provide relevant information. These process visualizations only show facility plans without linking them to the floor plans of the buildings and building sections (cf. Figure 2.5). The CCMS thus provides a purely facility-based image of the airport buildings that only roughly corresponds to the physical buildings by localizing facilities in certain building sections. From the perspective of those moving in the buildings, however, the buildings are primarily organized according to visible spaces and not according to facilities and the corresponding alphanumerical addresses. Those responsible for resolving the disruption on site, who are moving in the real buildings, must therefore know in which spaces the disrupted field devices are located. For this, the data point address supplies only approximate information.

As a technical operations center staff member told me, the data point addresses can sometimes even be misleading. They are oriented to the address of the facility, to which the data point belongs, so that the point can also be unequivocally identified as part of this facility. For this reason, with the data points belonging to a facility, the codes for the building section, facility, level and sequential number are identical and correspond to the designation of the facility. Only the function codes are different. Thus, for example, the data point 112.21-RLT-03.22-SM1751, which is highlighted in Figure 2.5, is clearly marked as part of the facility 112.21-RLT. The problem is, however, that contrary to their coding, the individual data points of a facility may be located on levels other than that of the facility itself. This can be exemplified by sensors, for instance, which measure the outside temperature and are therefore located on the roof of a building, but belong to a facility like 112.21-RLT 03.22 located on level 3.

In light of the insufficient match between the technical representation of the buildings and facilities in the CCMS and the organization of the facilities in the physical building, additional knowledge and further resources are needed to establish a connection to the localization of the disruption in the real building from the technical localization of the disruption through the data point address.

Elementary to this is, first of all, extensive *experiential knowledge*, which derives from knowledge of the local circumstances in the buildings and an accompanying familiarity with the real physical structure of facilities in the buildings. Staff members with experience in eliminating disruptions have this kind of experiential knowledge from their everyday working practice, and they are familiar with the buildings in which they move, so that they generally know where they have to look, if there is a disruption to be resolved at data point 112.21-RLT-03.22-SM1751, for instance. However, this only applies to *experienced* staff members, especially those from object teams, who usually only move in certain buildings and are consequently also familiar with those buildings. The object teams responsible for Terminal 2, for instance, are familiar with the local circumstances in Terminal 2, but not with the circumstances in Terminal 1 or in the office buildings. As mentioned in the introduction, the size, number and complexity of the buildings and technical facilities at the airport make it impossible to be familiar with everything.

Specifically for this reason, object teams were created, which are respectively responsible only for specific areas/buildings, so that they can maintain an overview of their respective areas of responsibility. The problem, however, is on the one hand that inexperienced people may still have trouble with orientation in the buildings, because they do not yet have a sufficiently precise "mental building map".

On the other hand, however, the object teams are not on site around the clock, but only on work days and only during regular working hours. In the evening there is only a limited late shift until 11:00 pm, and from 11:00 pm until morning there is only staff on call. With both the night shift and on-call duty, however, the object organization is suspended, so that those responsible for resolving disruptions outside regular working hours also have to work in buildings, where they are normally not in service. In this case, it often happens that they cannot find their way and have to request more precise information from the technical operations center about the real location of the disruption. The case is similar for the staff from the specialized workshops, when they are commissioned to carry out more extensive repairs, or for external companies that carry out repairs in the airport buildings.

This means, in other words, that outside regular working hours and in cases where inexperienced employees are on duty, who do not have extensive knowledge of the buildings in which they are moving, a further important task of the technical operations center consists of steering those responsible for repairs to their service location. For this, more precise information is needed *in fact* about the location of the disruption, rather than simply indicating the component number of the malfunctioning facility – even though this is *formally* sufficient for preparing a customer report. For this reason, the staff of the technical operations center has to be as knowledgeable as possible about the real location of the facilities and field devices in the buildings. They gain this knowledge on the one hand – similarly to the experienced personnel dealing with disruptions from the objects – from experience and familiarity with the real local circumstances in the buildings, and on the other hand from additional technical resources, which they partly prepare themselves.

Technical operations center staff members gain knowledge about the real buildings both through a longer training phase when they are first employed and through ongoing walks through the buildings – especially during the middle shift. When new technical operations center staff members are employed, they go through a long training phase until they are able to independently carry out their work in the technical operations center. This phase is not formally regulated, but my interview partners estimated that it normally lasts between one and two years. An obligatory part of this phase in the beginning consists of sitting in on the various object teams and specialized workshops and accompanying them through repairs in the buildings. In this way new employees are to familiarize themselves with the facilities and buildings. In addition, they are self-responsible for keeping themselves continually informed and further familiarizing themselves with the buildings and facilities. This is done primarily during the middle shifts, when the technical operations center staff are not fixed to one of the two technical operations center workplaces. If the jobs that come up allow it, they also go through the buildings during this time, especially those buildings in which changes have been made or those that have been newly built. They also develop mental maps for themselves in this way, which help them to direct other people through the buildings.

The significance of this kind of experiential knowledge for the staff responsible for conducting technical operations is emphasized in various social sciences studies about building operations (cf. Aune, Berker & Bye, 2008; Bye & Glöss, 2012). Considering the size and number of the buildings and facilities at the airport, however, it is not possible for the technical operations center staff to be familiar with everything and to remember what they have seen once, even if they regularly take walks through the buildings. This has already been emphasized. Additional resources are therefore required, to which all technical operations center staff can take recourse, and with which knowledge is shared and made accessible to all.

These resources are available in the form of additional databases, overviews and programs, which are regularly maintained and expanded, and which thus contain explicit and fixed knowledge in a form accessible to all the staff of the technical operations center. Particularly notable here are a program for searching spaces, a cooling facilities database, and a smoke extraction facilities database. Additionally,

telephones and walkie-talkies are also indispensable tools, for they make it possible to establish and maintain contact with those responsible for resolving disruptions in the buildings. At the same time, they can also assume the function of a remote control, when it is a matter of directing persons who do not know how and where to find a disrupted facility to the site of operations.

The program for searching for spaces and facilities is also of crucial importance for this purpose. This is a web-based application containing the floor plans of all the airport buildings and information about the site of technical facilities. This enables searching for spaces and facilities. In this way, in addition to the purely facility-specific representation from the CCMS, the staff of the technical operations center can also access a two-dimensional representation of the buildings oriented to the real physical spaces. On the one hand this serves finding out where facilities, repair workers or employees of external companies are located, if they have lost their orientation, but on the other hand it also serves as a mental aid for updating one's own mental building plan in order to direct people to where they are needed.

This program is supplemented by the room data sheets, also previously mentioned, which were prepared by the staff of the technical operations center themselves. Figure 3.3 shows a screenshot of the room data sheets. In the middle it can be seen how data point addresses and physical buildings are interlinked. Thus it is recognizable that the field devices belonging to the data points 111.02-RRUM-04.28 and 111.02-RREG-04.49 are located in room A4-228 on Level 04 in building section 111.02.
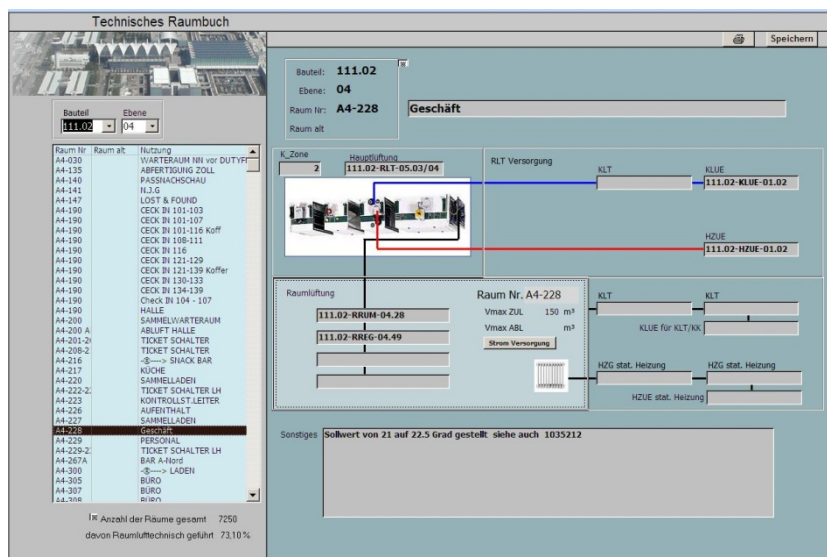
Figure 3.3   Room Data Sheets

With the way the facility-based technical representation of the airport buildings and the physical spatial structure are interlinked, as outlined here, the program reacts to what is missing in the space and facility search. Although this search function contains information about where technical facilities are located, it remains imprecise, similarly to the CCMS. It does not cover all the processes running in a facility and the exact position of individual facility elements. This means that here as well, field devices that belong to a facility on Level 03, but are located on the roof of a building, are not represented in their real location (cf. Chapter 3.1). This, however, is exactly what the room data sheets enable, as they contain schematic representations of facility points in their real, physical location. Ideally, the technical operations center staff make new entries in the room data sheets whenever new problems arise in the localization of facility elements, so that they know the next time where the facility elements are exactly located, which are not easily found. One problem with this, however, is that it is an ideal case, but the room data sheets are not maintained accordingly in everyday work. For this reason, in comparison with

the 14,000 facilities that exist in total, only a relatively small number of them are represented in the room data sheets.

In addition to the room data sheets there are also databases for the cooling facilities and for smoke extraction facilities that have been prepared by the technical operations center staff themselves. These databases establish links between real spaces and the facilities mentioned. The background for these databases is that both cooling facilities and smoke extraction facilities are especially important. In case of fires, the smoke extraction facilities have a life-saving significance, because they draw the smoke out of the buildings to the outside. It is therefore especially important that disruptions in these facilities are promptly and precisely located and resolved. The same is true for the cooling facilities. Although these have no life-saving function, they are responsible for cooling the server rooms, for example, and thus have a tremendous importance to the whole of airport operations. The aforementioned databases were prepared for this reason. However, these databases are also incomplete, because they are not systematically maintained. Similarly to the room data sheets and the space and facility search, they are important resources for precisely localizing facilities in the real buildings and are thus important supplements to the experiential knowledge of the technical operations center staff, but because completeness and systematization are lacking, the problem cannot be ultimately resolved with them, so that the precise localization of disruptions remains a permanent problem that regularly occurs and has to be dealt with. What would be important here, in my opinion, would be to find systematic solutions based on the existing resources, which would also be continually expanded and maintained. However, this cannot be the task of the technical operations center staff. Read more on this in Chapter 4.

Which facilities are responsible for disruptions reported by telephone?

In some cases, the problem of localizing disruptions takes place in an order exactly opposite to the one just described. It can happen that disruptions reported by telephone fall into the area of responsibility of the technical operations center and require manipulations of the technical facilities.[26] This is the case, for example, if someone complains that the temperature in their office is too low. The room climate can principally be manipulated through the ventilation and air conditioning technology facility, which controls the spatial air conditions. Accordingly, the question arises here as to which facility it is that must be accessed, in order to raise the air temperature in the relevant room, and the relevant facilities must be deduced from information about the spatial location.

This is not always easy, especially when not only one, but rather multiple ventilation and air conditioning technology facilities are in operation on the level of the building section in which the office is located. The process images of the technical facilities, which can be called up via the interface of the CCMS, contain no information about which heaters are operated by them in which rooms. Conversely, there is only a limited possibility to directly deduce the facilities that control these heaters from the specific rooms or the heaters in them through the program for the space and facilities search or the room data sheets, for example. This means that the previously described technical resources only conditionally help to identify the right facility.

If it is not clear which facility is responsible for the air temperature in a certain room and no experiential knowledge about this is available, then a (sometimes protracted) search is needed, in which the limitedly available resources are applied, and the technical operations center staff have to attempt to draw conclusions about the positions of the facilities and their function in relation to the real spaces through a precise investigation of the process images of the possibly relevant facilities and the space-based representation as it is found in the space and facilities search. For this, the staff's own

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26 If there is a report, on the other hand, that a door sign has fallen off somewhere, it is sufficient to pass the report on to the responsible object team that can remount the sign.

specialized knowledge, experiential knowledge about the principle setup of facilities in the airport buildings, but also the exchange among the technical operations center staff on duty are absolutely essential, as are the abilities of *abstract and analytical thinking*. These make it possible to abstractly envision the function of the facilities and additionally to establish connections between the different facility representations, in order to be able to formulate, test and evaluate hypotheses. What is required here is therefore the *ability to reach logical, inductive conclusions*. This is what makes it possible to filter patterns out of incomplete information, which form the basis for creating hypotheses. Accordingly, the search for facilities can resemble detective work, where indications for a solution to the problem are searched for on the basis of available data, and then these indications are connected into conjectures, which can be pursued and tested. As one technical operations center staff member told me, this is one of the greatest challenges, but it is also fascinating at the same time. It is also associated with a sense of satisfaction when the problem is finally successfully solved.

The problems described so far and the strategies and resources for localizing disruptions reveal that the airport buildings and the technical facilities built into them form a complex phenomenon, which can be represented and structured differently, depending on the position, knowledge and task of the people in the buildings. Against this background, the central task and challenge for the technical operations center staff in localizing disruptions consists of establishing connections between the virtual buildings and facilities of the control technology and the real buildings and facilities made of steel and concrete. In summary, the required abilities for solving this task can be described as *translation skills*, which enable the technical operations center staff to make a connection between the different ways of perceiving building and facility states. Only in this way is it possible to sufficiently localize disruptions that occur, in order to resolve them in the real facilities.

However, because the difference between the two forms of the airport buildings seems too great in many cases to, without problems, create these kinds of connections, the resources described above, which provide additional types of building representations and partly link the different types, are necessary to establish connections between the two different forms of the airport buildings. These are:

1. two-dimensional floor plans of the buildings that are oriented to their spatial structure (space and facility search),

2. two-dimensional unit location plans that refer to the real buildings and connect them with their numerical codes,

3. modified unit location plans that insert official and conventional building designations into the plans specified in (2),

4. connections between technical facilities and three-dimensional, spatially structured buildings, such as those found in the room data sheets and the smoke extraction and cooling facilities databases.

These additional resources serve as *mediators*[27] or connecting tools, which enable overcoming the difference between virtual and real buildings and facilities by establishing connections between them that were previously lacking. In combination with the *translation skills* of the technical operations center staff these *connecting tools* enable making a connection between the different ways of perceiving building and facility states. In this way, disruptions can be localized so that they can be found in both the CCMS and in the physical buildings. This opens the door to the next working step: prioritizing disruptions. The following section is devoted to this aspect.

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[27] On the concept of mediators, cf. Latour (2005, p. 37ff).

3.2.2   Diagnosis and Prioritization of Disruptions

As described in Chapter 3.1, problems with diagnosing and prioritizing disruptions arise due to the sheer number and diversity of the various facilities as well as to ongoing changes (in the form of maintenance work, facilities shut down, repairs…) in the facilities and buildings. In addition, the time pressure under which diagnosis and prioritization are carried out also makes this important working step more difficult. In light of these framework conditions, the automated alarm prioritization of the CCMS proves to be only conditionally helpful. As I mentioned in Chapter 2.2, the alarm management of the CCMS undertakes a prioritization of disruption reports based on predefined criteria, which determine the position where the disruptions appear in the alarm window. Reports with a high priority are displayed at the top of the list, while reports with a lower priority move to the end. According to information from the technical operations center staff, however, a schematic prioritization conducted in this way proves to be unsuitable in practice. In keeping with this, during my stay in the technical operations center I had the impression that disruptions are not worked through from top to bottom in a linear way, but instead that the alarm window is permanently kept in view and scanned. The order of working through disruptions then results from the prioritization determined by the technical operations center staff, not from the automatic prioritization. This serves more as a pre-selection, from which the staff determine what will be dealt with when on the basis of their own criteria.

Against this background, certain characteristics, skills and abilities of the technical operations center staff, along with resources other than the automated alarm management, prove to be decisive for successfully conducting this working step. The staff emphasized to me that without characteristics like *decision-making capabilities, frustration tolerance* and *persistence* in tracking down and solving problems, an appropriate diagnosis and prioritization of disruptions would not be possible in many cases. The necessity of introducing appropriate immediate measures under time pressure requires these characteristics. It is imperative that the causes of problems are determined, in order to take *appropriate* measures. This calls for persistence. At the same time, however, often only incomplete information is available, so that decisions are not based on undisputedly certain knowledge, but rather on well-founded hypotheses. These can prove to be correct or not. Decision-making capabilities are therefore required in every case, in order to make a decision about one cause and a clear decision about urgency, and to act on this basis. The problem here is that every decision can turn out to be false in retrospect, which in the worst case can result in substantial damage. This is where frustration tolerance comes into play, because it is important to be able to deal with mistakes and bear the trouble that may consequently result from them.

Particularly in light of the possible mistakes that can occur with the diagnosis and prioritization of disruptions, a dilemma of working in the technical operations center is clearly expressed. If everything is done correctly, then the achievement of the technical operations center staff remains invisible. Making correct decisions leads to the smooth functioning of building operations, and no one notices what happens behind the scenes. Decisions only become visible if mistakes are made, which can also have serious consequences. This dilemma goes hand in hand with the problems of the acceptance of the achievements of the technical operations center staff, which are partly clearly formulated by the staff members. As one staff member described his work situation to me: "There are days when you lose, and there are days when the others win. And that's what we deal with every day." This means that the positive consequences of correct decisions that are evident in smooth building operations are not attributed to the technical operations center staff as being responsible for their own achievements, because they are not even noticed. Incorrect decisions, on the other hand, which result in negative consequences, are attributed wholly to them. In this light it is clear that the diagnosis and prioritization of disruptions is one of the most important, but also one of the most difficult jobs in the technical

operations center.[28] Accordingly, in addition to the characteristics described above, which the technical operations staff has to bring with them, there are also further skills and abilities that are needed.

As with the localization of disruptions, in this working step it is also absolutely necessary for the technical operations center staff to have both *specialized* and *experiential knowledge* about dealing with technical facilities. This knowledge forms the necessary background to be able to make diagnoses at all. On the basis of this knowledge, then the previously described capabilities of *abstract and analytical thinking* come into play (cf. Chapter 3.2.1), which contribute to dealing with the "reference problem" (cf. Chapter 3.1.2) between virtual representations of facility states and their real states. It is only in this way that the existent fundamental knowledge can be related to constantly new situations and applied in such a way that it allows for an appropriate evaluation of the current disruption.

Additional Resources

In the face of incomplete information, however, one's own knowledge and abilities are sometimes insufficient to be able to identify the causes of disruptions and determine the urgency of the disruptions in a way that is appropriate to the situation. For this reason, additional resources are used to supplement incomplete information.

What is quite basic, but still eminently important here is the exchange with the other technical operations center staff members. During my stay I was able to observe a constant, practiced course of action with a division of labor among both staff members respectively on duty, which the staff members themselves described to me as a "blind understanding" among colleagues. Normally, both staff members always have an eye on the alarm management on the one hand, but on the other also an eye on the colleague and his activities and attention focus. In this way they ensure that each is always informed about what the other is doing, see which disruptions the other is currently dealing with, and can accordingly turn to other disruptions. This establishes an unspectacular and unspoken cooperation and a workflow, in which disruptions can be worked through without having coordination problems occur. At the same time, there are recurrent brief interactions and processes of coordination in between. This is especially the case when something conspicuous or serious happens, so that both then turn their attention to one disruption, communicate with one another about the occurring problem and trace it to its origins. This shared focus on one disruption also results in giving it highest priority, which is reflected in the attention devoted to it. Here the technical operations center staff benefit from the fact that the two staff members on duty generally have different specialized backgrounds, so that they can draw from different areas of knowledge, thus covering a broader spectrum of knowledge that can be used to form hypotheses about the causes of disruption. The exchange with the colleague also serves to check whether one's own hypothesis is correct or not. The condition for these collaborative processes of diagnosing and prioritizing disruptions is the simultaneous presence of both technical operations center staff members in a shared space of perception, in which they can mutually observe their respective activities, and in which shared attention to certain problems can be established as needed.

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28 This becomes most obvious outside regular working hours. The buildings are most heavily populated during the day, so that serious malfunctions are noticed at some point in any case, and the object teams and workshops are also fully staffed at the same time, so that quick interventions are possible in an emergency. The situation is quite different in the evening and at night, however. Since human "sensors" are missing then, the technical operations center staff must decide solely on the basis of the technical data available to them and envision how an automatically reported disruption will actually affect the conditions on site. Misjudgments here can lead to serious and especially to expensive consequences. One technical operations center staff member, for instance, told me about a mistake in the past that resulted in flooding in one building section and caused a high amount of damage.

In addition to the colleague's expertise, the Internet also serves as a further knowledge source. According to information from the technical operations center staff, they specifically search the Internet for missing information, if the exchange among colleagues does not help them enough.

What is especially important, however, is to remain informed about current and longer-lasting anomalies that can influence the operation of facilities. Maintenance work or building construction changes can lead to an accumulation of disruption reports through the alarm management, even though they are not due to acute disruptions at all, but rather to maintenance or building work. Whereas the CCMS reports everything that violates defined boundary values as a disruption without context, the technical operations center staff must be able to distinguish whether a disruption report is in fact due to an acute facility disruption or whether it is due to other causes.

This is made possible in that maintenance work, for example, is always filed with the technical operations center and then logged out again. Additionally, repairs that cannot be carried out immediately or facilities that are dismantled are always communicated to the technical operations center as the coordinating instance. This information is conveyed through channels such as telephone or customer reports, so it is not linked with the CCMS. Because this information is important for an evaluation of disruption reports appropriate to the situation, however, it is registered in a different way. A further resource for this is the *shift* log. This shift log is a computer program developed by the staff of the technical operations center themselves in the form of a database. All anomalies are noted in it, which occur during a shift, so that they are also accessible to the subsequent shifts. The entries remain in the shift log until they are taken care of. In this way it is possible to make important anomalies accessible to everyone beyond the duration of a single shift. In a print-out of the shift log that was made for me on 13 March, for instance, there are still several entries from January and February. Planned repairs of facilities are considered especially important, so these are not only entered in the digital shift log, but also always printed out in addition, so that they are not forgotten.

At every shift change the shift log is also discussed, and the old shift informs the new shift about all special occurrences that have come up while they were on duty. This is intended to ensure that the technical operations center staff are always informed about the current situation in the airport buildings and are able to correctly assess disruption reports on the basis of this knowledge.[29] Similarly to the resources described in Section 3.2.1., the shift log, Internet searches and the (shift change) discussions among colleagues all also serve as *connecting* tools, which make it possible to link automatically reported disruptions with other current occurrences in the buildings (maintenance, dismantling, rebuilding…), in order to counter the missing information and deficiencies of the CCMS that operates purely schematically.

3.2.3   Introducing Countermeasures

If disruptions cannot be resolved directly through the CCMS, the responsible specialized areas must be commissioned to resolve the disruption. In this context it becomes a practical problem, in light of the complex organization of the building management, to find out who is respectively responsible for concrete disruptions (cf. Chapter 3.1.4). These responsibilities are not displayed through the CCMS nor through the fast entry mask, through which customer reports are prepared and passed on to the responsible areas. For this reason, once again additional resources and processes are needed, so that customer reports can be sent to the right addresses.

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29 However, the existing solution of the shift log does not appear to optimally fulfill its intended function. During the period of my stay there were discussions of new solutions, and I was told that the existing self-programmed shift log does not completely do justice to all the demands. Especially older entries tend to be repeatedly overlooked, and the log is not maintained as well as it actually needs to be.

Ideally, the existing procedure instructions are sufficient, which determine that the standard procedure for reports is to send them to the respective object teams assigned to certain buildings. A simple aid that helps employees to determine responsibilities are the plans of the airport, in which all the buildings belonging to the area of responsibility of a specialized field are marked in the same colour. Figure 3.4 shows an excerpt from this kind of plan.
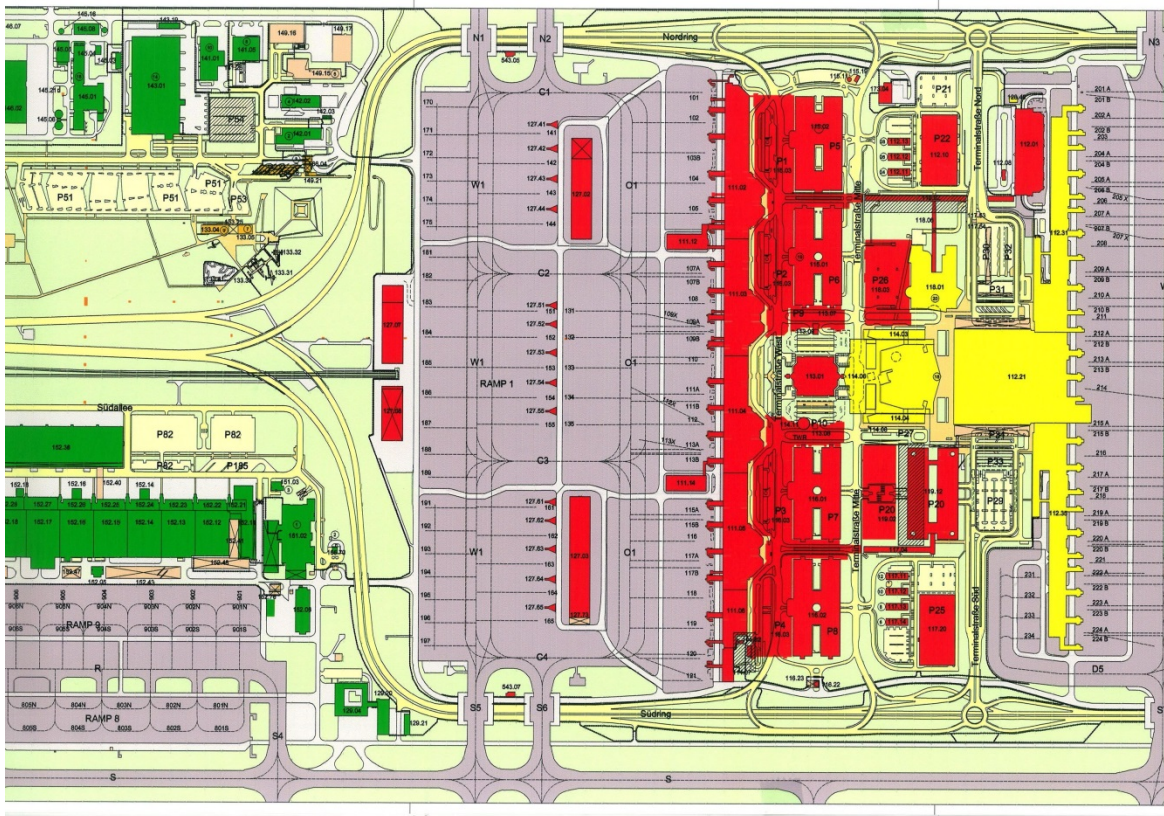

Figure 3.4   Plan except with areas of responsibility marked in colour.

This plan exists in laminated form as a desk pad at all workplaces – both in the disruption report call center and in the actual technical operations center itself. The entire plan is clearly visible in Figure 2.11 at a technical operations center workplace under the computer keyboard. The buildings marked in color (red, yellow, and green) each belong to the area of responsibility of certain object teams. These colored markings make it possible in a "normal case" to quickly grasp at a glance which object team is responsible for a reported disruption.

As I have already mentioned in Chapter 3.1.3, however, there are many exceptions to this normal case. In part, there are different responsibilities based on function within the object-oriented areas of responsibility, and responsibilities also partly change over the course of time. This cannot be depicted with the rigid plans, however, because they always only note the distribution of responsibilities at the moment when the plan was made, and they are only oriented to object logic, but not to function logic in terms of assigning responsibility for resolving disruptions.

The function logic that deviates from the object logic particularly presents a problem when disruptions are reported by telephone. With disruptions displayed through the CCMS, it is generally already clear through the address code of the data points whether certain disrupted facilities belong, for example, to safety technology facilities. In this way, it would quickly be clear that the unit responsible for safety technology is responsible for this disruption, rather than the team that is actually responsible for the

object, in which the safety technology facility is located. In contrast to this, people who report disruptions by telephone often do not know the difference between safety technology facilities and other facilities. This can consequently lead to the wrong specialized department being commissioned with the repair. This problem was described to me particularly with the example of doors. Doors may belong to the area of responsibility of object teams as well as to the area of responsibility of the team responsible for safety technology. This depends on whether a door marks a boundary between public and non-public areas of the airport or not. Thus it happens that simply a defective door is reported, so that the responsible object team is informed. On site, however, the team realizes that the door functions as transition to the non-public area of the airport, so that the responsibility lies with the safety technology team. In this case the customer report goes back to the technical operations center and has to be sent out again – this time to the right team.

Similar problems can also occur at other boundaries, such as where transitions between different object-based areas of responsibility lie. During my stay at the technical operations center, for example, it happened that a defective lamp in the area between a terminal and a large square was reported to the technical operations center by telephone. Here the staff were not sure whether this was the responsibility of the team responsible for the terminal or the team responsible for the square. Therefore, they first started by determining the exact location of the lamp through the program for searching spaces and facilities. Although they succeeded, this localization brought no clarity in reference to responsibility, because the lamp was located in the intersection between the two areas of responsibility. Against this background, two further resources remained: a look into the so-called "disruption manual" and the principle of "trial and error".

The disruption manual, like other resources used in the technical operations center, is a self-constructed tool. The disruption manual is a database, in which anomalies in terms of responsibilities for disruption occurrences are entered and stored. These kinds of anomalies relate, for instance, to changed responsibilities following a re-organization, or responsibilities that are not clear at first glance. Whenever problems have occurred with identification, but have been resolved, entries are to be made in the disruption manual, so that these problem solutions are not lost and the database can serve as a quick knowledge and research source. This case occurred during my visit with the disruption report call center. In keeping with the color marking on the unit location plan (green), a problem that had come up in an airplane hangar was passed on from there to the department responsible for air traffic properties. It turned out, however, that due to restructuring shortly beforehand, the aforementioned department was no longer responsible for the hangar area where the disruption had been reported, but an external company instead. This restructuring was not recognizable on the plan, which had been made before that. Consequently, the staff member attached a sticker with the new information to the appropriate place on the plan, thus bringing it up to date, but she also entered the new information into the disruption manual. The new information was thus made accessible to all the staff members in the technical operations center, so that customer reports can be sent to straight to the right address in the future.

If there are no indications to be found in the disruption manual in the case of a current assignment problem, however, the only thing that helps then is the principle of "trial and error". This means that one of several apparently plausible possibilities is selected and a corresponding customer report prepared. If the trial is successful, then the problem is solved and a relevant entry should be made in the disruption manual, if possible. If the customer report has been sent to the wrong address, however, it is sent back by the erroneously commissioned department. Ideally, as in the case described above, the returned report should be accompanied by information about which department is responsible instead. If this is not the case, then the report is sent again to a different department on the principle of "trial and error". This goes on until the correct addressee is found.

This shows how intersectional problems systematically occur due to the complex and changing organization of responsibilities within the building management. In some cases these problems can only be accommodated through improvisation (trial and error) and a subsequent disambiguation and fixing of responsibilities (disruption manual). These subsequent attempts to transform ambiguities into unambiguousness are always only temporary solutions, though, because responsibilities are always changing, so that responsibilities once fixed can always be dissolved again. Thus it is also evident in this working step that and how a way of dealing with the unstable and multiple object "airport" has to be found in the technical operations center.

3.2.4   The Disruption Report Call Center

In addition to the 220,000 data points that register disruptions, the people in the buildings also serve as important "sensors" for registering disruptions. This fact is accommodated by the disruption report call center. The possibility of reporting disruptions by telephone is so important, because on the one hand not all of the processes in the buildings can be automated and monitored by the CCMS (e.g. chairs missing at ticket counters), and on the other hand because subjective factors are also important for smooth building operations oriented to the principle of a "consistent customer orientation". Against this background, the subjective sense of well-being of the people in the buildings plays an important role. This subjective sense of well-being, for instance in relation to the room temperature, can indeed differ from the defined "normal" facility values, so that certain room temperatures are already registered as a disruption by people, even though the relevant ventilation and air conditioning technology facility is running without disruption from a technical perspective.

As described above, the people who report disruptions by telephone are both "customers" and "sensors" at the same time. Following my observations, the way of dealing with these contradictory roles is distinguished primarily by the way the customer orientation is explicitly expressed at the beginning and the end of the conversation and runs in the background throughout the conversation, whereas the configuration of the callers as "sensors" is explicitly at the center of the main phase of the conversations.

What was noticeable about the telephone conversations that I listened in on is that they always start with a friendly self-identification of the staff member on duty. This is followed by a phase in which the caller can calmly describe their problem. The conversation always ends with a binding statement assuring the caller that someone will take care of their problem, in that it will be passed on to the responsible department or directly resolved. On the whole, the conversations are characterized by a consistently friendly tone using the collegially informal form of address, and sometimes there is laughter in between. The customer orientation is clearly expressed in this atmosphere that is both friendly and binding at the same time.

The configuration of the callers as sensors, in comparison, is carried out during the main phase of the conversation through purposeful questions. Similar to the automated disruption reports, what is especially important here is what is disrupted and where is the disruption.

What is disrupted?

A simple example of a corresponding "configuration" of the caller is provided by an excerpt from a conversation that I witnessed during my stay in the technical operations center. A call came in from a person working in an office within the airport. She reported a problem with the air conditioning and said that it was consequently unbearable in the room. From the perspective of the technical operations center, however, this information turned out to be insufficiently precise. The staff member who took the call therefore asked her to more precisely define the term "unbearable". He asked what that meant, whether it meant that it was too cold, too warm or too stifling. In this way he aimed to find out more

exact information about the possible type of disruption. Differently formulated, it could be said that it was a matter of finding out whether the customer calling was functioning as a thermometer or as a CO_2 measuring device and accordingly reporting an abnormal temperature or an abnormal CO_2 value.

To be able to ask such purposeful questions, the staff member needs the ability to be able to envision the setup of an air conditioning unit and the different types of data points associated with it. In other words, what is needed here is a *capacity for abstract thinking* and again *translation skills*. The staff member must have the ability to mediate between the layperson perspective of the caller expressing her uncomfortableness with the current room climate and his own expert knowledge about the function of technical facility states. What is crucial for this is being able to translate one kind of knowledge (expertise) into another kind of knowledge (lay knowledge) and vice versa. On the one hand, it is therefore necessary that he transfers his own technical understanding of the function of the ventilation and air conditioning technology facilities into generally comprehensible questions and accordingly "translate" increased CO_2 levels into subjectively perceived stifling air. On the other hand, however, it is also important to transfer the statements of a person sitting in her office and feeling uncomfortable into information that the technical operations center can work with.

Where is the disruption?

When disruptions are reported by telephone, the question arises as to which facilities are responsible for a disruption perceived in a certain building section. The staff member taking the call first has to find out where the caller is located in the airport. Then the corresponding facility must be ascertained. Similarly to the way the callers must be led to provide precise information about the *type* of disruption, it is also necessary to obtain helpful information from them about the *location* of the disruption and to configure them accordingly. I was told, for example, that when some callers are asked where they are, they answer simply "at the airport" or say, "I don't know, no idea". In these cases, only purposeful questioning helps to determine where these people are. A typical question for this is, for instance, "What do you see?", in order to obtain clues about the exact localization of the caller through a description of the location. This method only works, however, if the respondent is sufficiently familiar with the buildings to recognize the location from the description. This illustrates again how important it is for the technical operations center staff to be familiar with the real buildings as well, not only with the virtual representation displayed through the CCMS.

At the same time, however, this method also reaches its limitations, especially if the caller is in a remote area of the airport with which the technical operations center staff is less familiar. A staff member from the disruption report call center told me that it is difficult to find the person if they do not know where they are. In these cases, the "disruption reporters" are sent to look for room and building names or requested to ask other persons whether they can provide information about their location. From the perspective of the technical operations center staff, it can be said that more precise information is needed, the more unfamiliar the area is to the staff, which the caller is calling from. For the terminals, which make up the central buildings of the airport, approximate information is sufficient to precisely locate the persons calling from there. If a person calls, for instance, and says they are at the check-in counter in Terminal 2, this is entirely sufficient to determine their exact location.

Alongside the callers' sometimes inadequate knowledge of a place, another challenge also arises in localizing them. Sometimes they know exactly where they are and can provide clear information, but this information generally does not correspond with the numerical coding of the building sections. This is because the building and room designations attached to the physical buildings follow a logic different from that of the coding of the data point addresses. For instance the main building of "Terminal 2" is generally referred to as "Terminal 2" and not with the code "112.21", and upon my arrival at the airport on the first day, I was requested to go to room E140 in the "building headquarters", rather than to

building section "100.04". For the technical operations center staff this means that the location information given for the public designations of rooms and buildings always has to be translated into the numerically coded building section designations, because this is necessary for preparing customer reports and searching for facilities.

For the important and central buildings this is usually possible without great effort. The staffs of the technical operations center and the call center usually know from experience which building sections in the terminals have which designations. For the building sections where these correspondences are not known, however, additional resources must be used again. Thus the program for searching rooms and facilities is also used here. However, the plans described in the previous section (Chapter 3.2.3), in which the areas of responsibility for the buildings are represented, also play an important role here, because the numerical codes for the respective buildings are also marked on them. The plans thus make it possible to identify not only areas of responsibility, but also buildings and building sections along with their numerical codes. Nevertheless, they do have one deficiency, in that they do not contain the public designations of the buildings. The call center staff, in particular, counters this by adapting the plans to their needs[30]. The adaptations are made by attaching stickers to the plans with further building designations corresponding to the public building designations. In this way, building locations, numerical codes and conventional designations are linked with one another in one resource. Figure 3.5 shows a section of a modified unit location plan on the desk of a staff member of the disruption report call center, which roughly corresponds with the section shown in Figure 3.4.

Figure 3.5   Unit location plan modified with stickers

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30 I did not observe these adaptations at the technical operations center workplaces. This is presumably because the technical operations center staff only takes over telephone disruption reports outside regular working hours, and there are significantly fewer disruption reports during this time, so that they are less dependent on these adaptations.

The unit location plans modified in this way help to quickly find the building designations given by telephone on the plan and then read out the numerical code. Thus a staff member can quickly find the taxi stand at Terminal 1, for example, which can be seen in the figure at the center top, and then she knows where to look for its numerical code (115.11) on the plan.

As far as I can see, there are no other resources that enable deducing the code of a building/section from its public designation. The room and facilities search does not include this kind of function, as far as I know. The legends of the unit location plan are also oriented to the numerical coding and numerical codes that are assigned to other building designations, but not vice versa. This makes it more difficult to deduce the numerical coding of buildings from their designations. The unit location plan also has other weaknesses, which the staff of the disruption report call center counters with additional resources. The weaknesses of the plan are to be found primarily in that it is static. On the one hand it only allows for a rough representation of the buildings at a scale of 1:5000. On the other hand it is also static in the time dimension and fixes building designations at a certain point in time. In contrast to this, the real airport is an unstable object (cf. Chapter 3.1.1), of which the form is always changing as buildings are added or modified, and the functions of the buildings and their designations also change.

Against this background, the staff of the disruption report call center additionally take recourse to plans of important building sections at a smaller scale and also keep older unit location plans, on which old building designations can still be seen. In this way they have an archive available to them, in which old and new designations coexist. This is important, because old designations are partly still in use, and especially airport employees who have worked there for a long time continue to use the old designations that are familiar to them. When a staff member from the disruption report call center told me this, she also said that she actually prefers the old plans for this reason. Figures 17 and 18 show an additional, more detailed unit location plan for Terminal 2, which has been supplemented with extra notes, and a section of an older unit location plan at a scale of 1:5000.
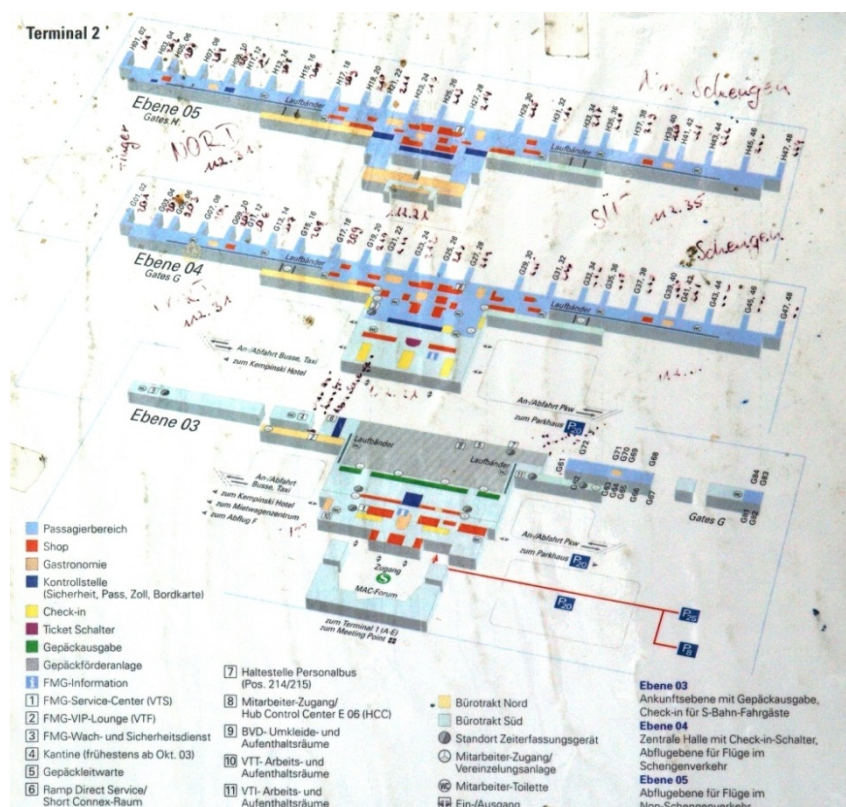

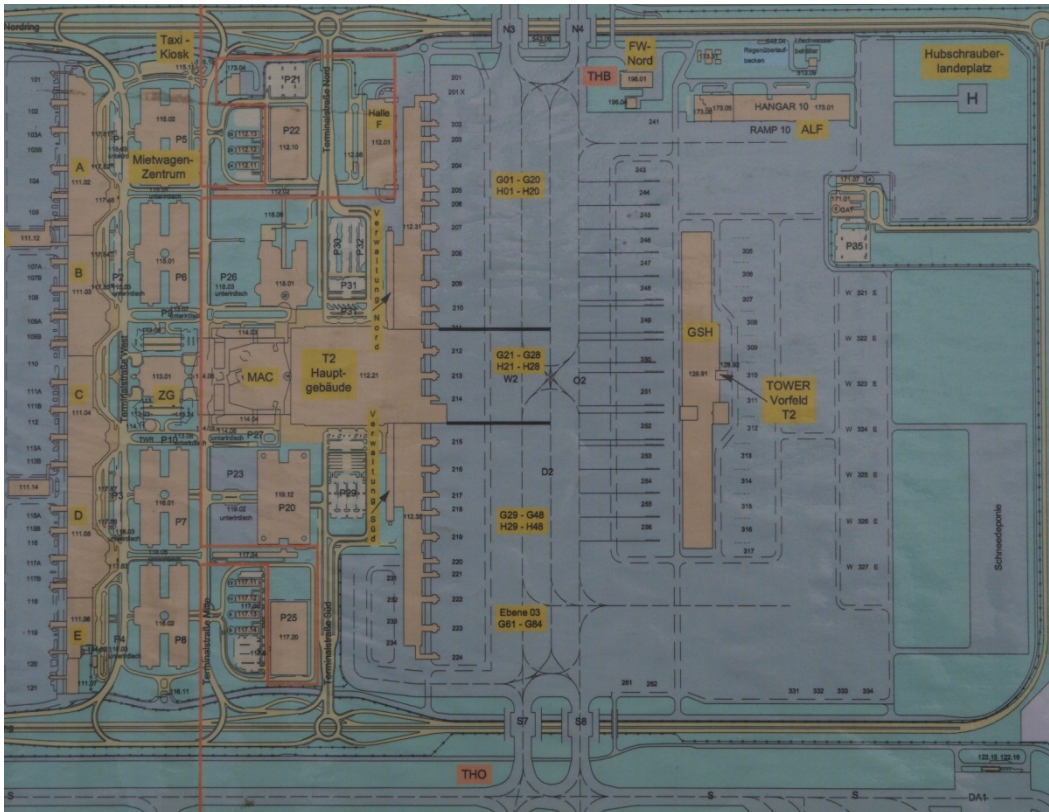Figure 3.6   Detailed unit location plan Terminal 2

Figure 3.7   Old unit location plan

Questions, knowledge, the program for searching rooms and facilities, and the unit locations plans just described are thus the central tools for finding out where a caller is located within the airport and transforming the information obtained from callers into the numerical building codes needed to further treat the disruption.

In a conversation about her work, a staff member from the disruption report call center described to me how strenuous and tedious this process can be. She remarked that it sometimes irritates her when callers "just go on and on" and say, for instance, "Yes, there now. On the left by the door, and then you go right and then left." In cases like this, where no appropriate information is communicated, she interrupts and explicitly asks what the disruption actually is that is to be reported. The disruption is actually the most urgent concern and is also at the center of the entry mask for generating customer reports. This is also where the customer orientation runs into its limitations. Whereas normally the customer is given time at the beginning of the conversation to describe their problem, and the "configuration" of the caller then ties into this, the staff member's statement shows that the beginning phase of the conversation cannot go on endlessly. The conversation takes place in the context of purposeful organizational action, which only allows limited freedom in the way the conversation is conducted, because its purpose is to report, register and treat disruptions. In this sense it is necessary to configure the communication and also the customer in such a way that they can serve as equivalents of automatically generated disruption reports. Whereas the latter systematically provide information about the facility disruption through alphanumerical coding, this information first has to be (laboriously) filtered out from the contributions of the callers.

Which priority does a disruption have?

Whereas with disruptions reported by telephone the task of diagnosing the causes is delegated to the respectively responsible department, this is not the case for prioritization. The priority of a disruption must be indicated in generating a customer report. There is a *required* field "priority", which calls for an entry of how urgent it is that the responsible department deal with the disruption. There are two choices here, which are numerically coded with the numbers 1 and 2. The number 1 stands for highest priority and is selected if the disruption endangers air traffic, while 2 stands for normal priority. Unlike what I had expected, however, this prioritization presents no relevant practical problem. Although I had assumed, in comparison with automatically reported disruptions, that determining the urgency would be more difficult due to a lack of diagnosis possibilities, this requirement is dealt with in a routine manner: in general, 2 is simply selected as the priority level. This level indicates that the disruption should be resolved on the same day. A staff member from the disruption report call center told me that she really always selects 2, and it has never actually happened that she had to select 1. Her colleagues who were present agreed with her. It seems as though this fixed procedure ensures that there are no doubts about the urgency of dealing with disruptions, so prioritization does not become a problem.

4. Summary and Possibilities for Improvement

In this research report I have explained that four problems recurrently arise systematically in the everyday work of the technical operations center. These problems must be continually dealt with and solved by the staff of the technical operations center and the disruption report call center, in order to maintain smooth operations of the airport buildings. These problems result (1) from the characteristics of the airport as a multiple object, (2) from the immense number and complexity of the technical facilities, (3) from the complexity of the organization of the building management, and (4) from the contradictory organizational requirements in the contact with "customers". These problems cannot be treated and solved solely with the help of the tools provided (CCMS, telephone disruption reports, customer reports) and the existing procedure instructions. Rather, the building operations present themselves in practice as a substantially more complex activity than in theory (as depicted in the procedure instructions).

As indicated in Section 2.1, the outlined difference between formal and real working processes and the concomitant "invisibility" of a large portion of the activities and demands is not specific to the work processes of the technical operations center observed for this report. Instead, it appears to be a fundamental and frequent problem in technical service professions. This is referred to in various works associated with the sociology of organization and technology (Orr, 1996, cf. 1998; Shapin, 1989; L. Suchman, 1995). As described by Dorothy A. Winsor (2000: 176), for instance, who deals with the significance of work instructions within organizations, "the written script of a work order is a kind of fiction describing a simple, logical sequence of actions […]. In reality, however, orders are not simple things. Rather, to be effective, they must be supported by a whole system that includes oral interaction, further texts, and the technicians' expertise. It is only after the work has been accomplished that these supports are forgotten and the work order seems to stand alone as the description and cause of the action". This also applies in a very similar way to the processes of monitoring buildings and resolving disruptions, as is clear in the present report. The technical operations center thus presents itself as the central hub, in which

1. the different elements of the multiple object airport must be connected (arrangement according to spaces, technical facilities and areas of responsibility;

2. uncertainties arising from the complexity of the facilities and the organization of the building management must be transformed into unambiguousness and decisions;

3. successful connections must be established between humans (those responsible for resolving disruptions and customers reporting disruptions), buildings and technology.

To cope with the demands described, an important characteristic that the technical operations center staff must have is what I have called "translation skills", in order to mediate between the different ways in which the airport buildings, technical facilities, and disruptions present themselves in everyday practice. That means this ability is absolutely necessary to be able to operate the airport as a "multiple object" as smoothly as possible and to meet the challenges that arise due to the complexity of the buildings (representations) as well as the organization of airport operations. Numerous resources are used for this, as I have described in detail in this report. The use of these resources illustrates on the one hand which problems exist in terms of the translation work, but on the other hand they also show how these are solved in everyday work. In this way the resources provide indications of possible improvements of the building operations and also show that the staff of the technical operations center do not primarily execute clearly given and well defined working processes, but rather creatively and competently solve problems. They adapt the resources intended for building operations to their needs and create new resources and routines when necessary, which are not provided for, but are needed to do justice to the practical demands of the workplace.

Possibilities for Improvement

The central starting point for establishing simplifications and improvements in technical building operations is found, in my opinion, in the question of how the aforementioned necessary connections between different elements of the multiple airport buildings can be systematically supported. A large portion of the translation work depends on the abilities and experience of the technical operations center staff and the self-developed, but often not systematically maintained supporting programs.

On the one hand this means that the significance of experiential knowledge must not be underestimated. What is important for connecting the different modes of ordering the airport buildings (spatially, technically, according to area of responsibility) is a precise knowledge of all these modes of arranging. A solely facility-based view of the airport buildings, as it is enabled through the interface of the CCMS, is not sufficient to meet the demands placed on smooth building operations. A familiarity with the real facilities, the real spatial order of the airport buildings, and the practical problems of those assigned to resolve disruptions in searching for disrupted field devices seems to me to be an important factor in coordinating the different departments to resolve disruptions. Accordingly, this kind of knowledge should be specifically supported. It is what first creates the preconditions for the technical operations center staff to be able to establish connections and translations between the different modes of ordering.

On the other hand, however, it also makes sense to reduce the dependency on this kind of experiential knowledge, in order to make it easier to make the necessary connections, instead of being dependent on individual experienced technical operations center staff members. However, this is by no means contrary to the importance of experiential knowledge. Experiential knowledge should first of all be recognized, just like the tools produced and used in the technical operations center itself, in order to then flow systematically into the improvement and further development of the tools for monitoring and controlling the technical facilities. It is not a matter of replacing the expertise of experienced technical control center staff, but rather of recognizing and honoring this expertise. In this way, practice-based improvements of the technology used could be developed in cooperation with the staff of the technical operations center. These improvements would then be oriented less to purely formal descriptions and assumptions about working processes, but more to the actual needs in concrete everyday actions[31]. This does not mean seeking to make specialized and experiential knowledge and the specific abilities and tools of the technical operations center staff unnecessary. That seems neither reasonable nor feasible. Instead, it is a matter of making them useable for efficient operations and thus also visible, so that they receive more recognition.

What concretely suggests itself, in my opinion, is to think about the extent to which the possibility exists of establishing stronger links between the interface of the CCMS, oriented to the representation of the technical facilities, the spatial representation of the buildings, as it is to be found in the program for searching rooms and facilities, and the representation of the buildings according to areas of responsibility. This could possibly succeed by integrating the various types of representation as different levels that could be faded in and out. This could make it possible to accelerate and simplify search and linking processes that are sometimes long and laborious.

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31   On the approach of practice-based technology design, cf. Suchman et al. (1999).

To achieve this, it also seems to make sense to me to create a database, in which the various types of facility information are linked to one another. In a database of this kind, which should preferably be developed gradually by one department, it would be possible to enter

1. the alphanumerical representation of all data points,

2. their position in the real building, including the official room designation,

3. the departments responsible for the respective facilities,

4. and current (and ideally also former) official designations of buildings (sections).

Then it would be important that the database is systematically updated and that search functions exist that enable searching for each of these four areas to obtain the corresponding additional information from the other three areas. This would mean taking up, systematizing and integrating in one system the attempts undertaken in the technical operations center with the development of the cooling facilities database, the smoke extraction database, the room data sheets, and the adaptation of current unit location plans with old designations while preserving old plans at the same time, in order to interlink different information. A database of this kind would only achieve its full functionality, however, if it is permanently maintained and updated, so that it reacts to changes in the buildings, their designations, and the organization of building management. This suggests that a database of this kind would be responsibly maintained by a central office.

More detailed suggestions are not possible on the basis of my brief stay in the technical operations center and the available data. It is possible, however, that further and more detailed starting points for improvements could be indicated on the basis of more detailed recording methods. Imaginable in this case are video and audio recordings, which make it possible to much more exactly observe and analyze which resources and problem-solving procedures are used in which way (cf. Knoblauch, 2005; Heath, Knoblauch & Luff, 2000). On the whole, however, all attempts to change the working processes and resources must in any case be undertaken in close cooperation with the staff of the technical operations center. They are the ones who must work with the programs and can best assess whether and to what extent these kinds of changes lead to improvements and simplifications in the workplace.

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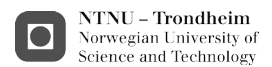
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