Socio-spatial implications of converging physical and digital infrastructures for crisis management: Ethnography of two service technician working environments of a power provider company

Claudia Müller
CSCW in Organisations
Institute for Information Systems
Hölderlinstr. 3
57068 Siegen
claudia.mueller@uni-siegen.de

Volkmar Pipek
CSCW in Organisations
Institute for Information Systems
Hölderlinstr. 3
57068 Siegen
volkmar.pipek@uni-siegen.de

ABSTRACT

The basis of this article is an ethnographical study conducted in a German electricity provider company. The energy supply sector is an important domain in the field of emergency management research since electricity providers maintain an important infrastructure in various crisis scenarios. There exist many dependencies and interrelations between power infrastructure providers and authorities and corporations in cases of emergency. The maintenance workers of electricity infrastructures deal on a daily basis with problems that may emerge into a crisis on a larger scale. Our paper focuses this special division of the company – service workers in two different regions, one department located in a major German city and the other in a rural area. The categories of *convergence of physical and electronical working appliances and infrastructures* and *socio-spatially bound knowledge* serve to understand and analyse the work practices of the service workers as preliminary investigations to system development. Within these categories we also comment on the methodological implications for ethnographic analysis and technology development processes.

Keywords

Ethnography, Crisis Management, service work, in situ, socio-spatial bound knowledge

INTRODUCTION

The basis of this article is an ethnographical study conducted in a big German electricity provider. The energy supply sector is an important domain in the field of emergency management research as it is as infrastructure provider often affected in the realm of various crisis circumstances. There exist many dependencies and interrelations between power infrastructure providers and authorities and corporations in cases of emergency. Thus, the domain of power providers deserves attention in research on information systems for crisis response and management, which up to date is a research gap in this community.

According to Star and Ruhleder's (1996) notion that " […] infrastructure is fundamentally and always a *relation*, never a thing.", and the findings from recent research in the realm of cyber infrastructure which point at human, social and organisational aspects coagulating in technical artefacts (cf. Lee et al. 2006) we apply a qualitative research approach to shed light on practices on "old" physical electrical infrastructures and "new" digital ones.

Ethnographic methods are increasingly important in the design of safety- and time-critical information systems, as a large body of research work in different domains, such as of medical operators, control centers, firefighting work, and emergency work reveal (e.g. Büscher et al. 2008, Denef et al. 2008, Landgren 2006, Mackay 2000).

RELATED WORK

In recent years, ethnographic methods gained such high attention because they help identifying and integrating the human factors and social aspects of cooperative and coordinative work (Hughes et al. 1994, Randall et al. 2007) into system design.

Another interesting aspect of our study - besides the power supply domain - is a focus on service and maintenance work on infrastructures. There are ethnographic studies in the realm of waste water treatment (Bertelsen and Nielsen 1999) or on coordinative practices of distributed workers in a power plant (Kjeldskov et al. 2006) but local practices of service workers in power infrastructure realms have not been subject of research up to date. As technological support of crisis management of a power provider and its related communication and coordination surfaces to the public, to authorities and companies, it deserves an examination of communication, coordination and cooperation structures of the different stakeholders and company departments involved, the service workers as operating personnel in situ deserves special attention.

Research aiming at converging existing physical electrical infrastructures with new digital infrastructures to be developed at the beginning needs knowledge upon how the physical infrastructures are dealt with and are worked with. From a knowledge-management perspective working appliances (not only) of local service work teams are inherently bound to situated knowledge (cf. Normark and Randall 2005). The physical electrical infrastructure as centre of their work by this is embedded in a wider knowledge context – it is spatially embedded, in their tools and artefacts, in form of spatial orders of colleagues in the workplace (Strübing 2005). The perspective of the embeddedness of the physical infrastructures in socio-cultural (infra) structures in our work is used as a lens for the ethnographical study. Here, the interplay and convergence of "old" and "new" infrastructures is paid certain attention to.

Another guide to the empirical study is the notion on socio-spatially bound knowledge contexts. By this we examine regional differences of the two (city and rural) application fields and related differing work processes and practices which may affect emergency management system use. As the operating departments and the control centres of power providers avert bigger crisis situations in their daily practise, we conduct this study from this specific perspective by focussing both, routine practices and practices in a past crisis in retrospective. Additionally, the focus on routine work practices is important from the point of view of the system design. As a crisis management system is expected to be easy to use in the crisis situation its integration in the daily routine is an important aspect of system design. The perspective also has methodological implications.

THE FIELD STUDY: TWO SERVICE WORK DEPARTMENTS OF AN ELECTRICITY PROVIDER

The case study is part of a larger research project aiming at improving emergency communication and management. As emergency management of an infrastructure provider concerns many different stakeholder groups inside and outside the company fieldwork has been accomplished on different sites. For intersections of external and internal communication and coordination needs interviews and participant observations in different control centres, telephone hotlines in case of power outages, in a call centre and in two service work departments have been conducted. The latter departments – local service workers in two different regions (a major city and a rural area) – are in focus of this paper.

We conducted about 40 hours of participant observation, 13 semi-standardized interviews and informal conversations and one focus group to gather data upon the service workers daily routine work with special emphasis on their use of artefacts and locally bound procedures. Additionally, in the interviews we tried to reconstruct their cooperation, communication and coordination work in a past crisis situation affected by a hurricane in 2007 which caused widespread damages and power outages.

The power provider controls and operates high, medium and low voltage networks in a 20.000 square metre area by means of a large network management system. An important functionality of the system is the support of fault diagnosis and management, which is highly automated for high voltage and medium voltage networks. Fault diagnosis on the low voltage networks, in contrast, differs, as no telemetred sensor data is electronically available in the control centres. That's why the information of a low voltage network fault is dependent on customer calls reporting a loss of service. Besides the customers themselves as information sources, the information of the distribution structures of the low voltage networks is saved locally in the service technicians' working environments (in their local offices and in local transformation stations), which is one reason for the need of highly experienced local service technicians.

The task of the local service technician teams besides analysing low voltage network faults is maintenance and repair work of the physical power infrastructure in the low voltage network and the switching substations between medium and low voltage.

The two service work departments differ in their staff formation due to different local structures. The team in the rural area) consists of about 15 staff members and is responsible for a large rural area. The team consists of a supervisor and his deputy, electronic technicians and few apprentices. Management work of communication and coordination with the next higher area manager, who is located about 50 kilometres away, is only accomplished by the team supervisor.

The second observed team is located in a major city with about half a million inhabitants. Staff structures are different, as here there are five teams responsible for different city areas collocated in the same building. Also, the next higher area manager to the five team supervisors is collocated in the same building. We observed one team, consisting of the supervisor, the deputy supervisor and about 6 electronic technicians and one apprentice.

Both teams meet every morning. In this meeting the supervisors distribute tasks of the day. In each team, one of the technicians is on 24h standby to be contacted by the control centre in case of power outage and respective need of immediate repair work. The standby staff is during this time assigned with tasks which may be interrupted immediately easily. During the standby time the respective technicians receive urgent tasks by the control centre via SMS on their mobile phone and also via an on-board computer in their cars which is connected to a GPS-supported GIS system. Using this technology, the dispatcher in the control centre also may track the status of the work orders and staff members and the allocation of responsibility what helps him searching for the nearest technician to the outage case. The board computer is connected to the large powerline network management system, providing navigation and order processing facility in the car. If a standby person is assigned by the control centre, the respective supervisor is informed via SMS or email depending on the urgency of the assignment.

Convergence of physical and electronical working appliances and infrastructures

Albeit the two examined service work teams are mainly assigned very similar working tasks from a managing point of view, observing the use and support of the network and emergency management system in our study showed many differences with regard to the use of physical and electronic working appliances and infrastructures and the managements' initiatives towards a higher convergence of powerline networks and ICT infrastructure.

First of all, the regional conditions afford different physical working appliances: in the rural team, because of the electronic infrastructures consisting mainly of aerial power lines, in the city area power lines mainly located beneath the earth. Both teams need different materials for repair and maintenance work. Also, the cars and the respective equipment differ: in the city area cars are smaller because they do not need as much materials as the rural team (such as e.g. ladders) but also because they often have to work in underground parking lots and generally finding parking lots in the city is a problem.

There also are significant differences in the utilisation of digital devices. In the rural team mainly the supervisor and his deputy are the persons working in front of the PC doing documentation, reporting and ordering work. The PCs are located in the office they share. There is another office with two PCs, which are used for special tasks being usually conducted by two staff members. The rest of the team does not use PCs in their work at all.

The standby staff is expected to process their documentation work via the device in the car. But in both areas this device is not used due to perceived usability problems. The car device consists of a small screen and a remote control which serves as input device. Entering data via the remote control for the mechanics is inconvenient as it takes too much time. Instead of entering data into the car device the rural staffs write notes on a paper sheet. When they come back to the office after having done their job they inform their supervisor and hand him over the sheet, then he processes the information into the system. This is different in the city team: here, every staff member processes the documentation on a staff PC in the office himself. The city staff also processes the documentation of their daily work on a staff PC, the rural team, in contrast, reports everything to the supervisor who takes over the complete documentation work on the PC.

With regard to the use of the board computer in the car, the navigation functionality is rarely used by the rural team members as they have a wide knowledge of the area. In contrast, the city team uses the navigation functionality more often because of the complexity of the area and despite the poor usability of the system. The similarities among the teams in using the mobile device in the car only happen in connection with the coordination work with the control centre, i.e. when the dispatcher has assigned standby personnel with a task they must confirm via the car device that they accept it and start working on it. By this, the dispatcher knows that this person is busy and cannot be contacted until his job is done.

In general, the city team uses more digital devices in their daily work than the rural team. An example for different use of technology for the same task is dealing with planned power outage periods necessary for network maintenance. Planned outage periods need a perfect coordination and communication with the control centre staff. The city team prepares and coordinates planned outages with the control room using a Microsoft Outlook calendar to apply for outage periods. These are being affirmed by the control room personnel. At the day of the operation the service technician and the control room staff coordinate the concrete situation and each single step of the disconnection additionally via (mobile) telephone. In contrast, the preparation of the planned outage in the rural area is accomplished by an announcement via telephone. This means for the control room personnel having to fix the date and to assure that the information is present in the control room at the planned day.

The city team is generally more often confronted with new prototypical technologies and devices aiming at improving workflows and often serves as test bed. Not all service workers in that area are happy with that as the testing of new technologies means to learn new practices and embed them in consisting workflows. The prototypical state of the devices often causes use problems and by this, disturbance of workflows. The technicians have different modes to tackle these problems from willingly using and testing new tools to absolute decline. Especially older technicians are often sceptical and refuse using the new devices in their work, whereas many younger team members who are generally more affine to new technologies like to test the new devices. These attitudes sometimes affect technologies which are expected to be used by the management. Here the younger technicians often take over part of the tasks from their older colleagues. In general, the different attitudes and handlings of the new digital devices and tools are being tolerated and covered by the team.

The difference of attitudes towards new digital infrastructures and devices is also visible between the rural and the city team. The rural team has a more negative attitude towards new devices and digitalisation of work flows, mainly combined to fears their jobs being destroyed in the long term and based on their little contacts to digital working appliances. In addition they seem to fear that they lose their status of expertise which is inherently bound to working with the physical power infrastructures, the power lines. A certain proud and identification with their job gets visible in that they often compare themselves with fire fighters and emergency doctors in crisis situations with power outages.

In contrast, the strong readiness of using digital working appliances in the city team (mainly coordinated by the younger team members and also related to their general access and integration of computer use in their daily routines) is also visible in a self-developed tool. This is an informal Excel-sheet (only developed and used by the city technicians and in fact not wanted by the management) where they collect situated information on how to easily access hard to find customer power boxes and other relevant knowledge to make the invisible power infrastructure more visible and easily accessible in their work. But here, again, many older technicians report related knowledge to their younger colleagues who maintain and complement the sheet for them. But the sheet as such is highly appreciated by all technicians. In contrast, the management does not like suchlike local and simple initiatives as they want their introduced systems to be used to foster formalisation.

Socio-spatially bound knowledge and regionally based power outage "potentials"

This section shows empirical results on how working knowledge and working processes are strongly regionally bound and dependent on local expertise, also in terms of knowledge of proactive handling of potential emergency situations.

For example, the handling of planned outage periods differs due to regional particularities. In the city more and other stakeholders and infrastructures are affected, such as traffic infrastructure as traffic lights on large crossroads, and large organisations of structural and civic engineering. The management of planned outage periods is also coupled to time rhythms in the city: a few years ago it was easier to find time periods with only few customers affected due to the former large amount of workers in coal mining and their respective anticipable power consumption behaviour in their daily living. Power requirements generally changed in the last couple of years due to a more around-the-clock power requirement of growing business and industry which amplifies the problem. In addition, the accumulation of power consuming trade (as an example: a street with formerly many bakeries and now power consuming tanning salons) influences power distribution plans and in some cases even requires changes in the infrastructure, such as new transformers.

Other typical and expectable problems in advance of possible outages to happen in the city team are damaged substations which often happen following of a football game caused by disappointed fans. Another source of substation damage are car accidents.

Typical and expectable problems in respect to the power infrastructure in the rural area are storms and heavy snowfalls because here the power infrastructure mainly consists of aerial lines which then may become heavily affected and cause large outages.

The visibility aspect of the physical infrastructures is totally different in the city area. Cables mostly run invisibly underground. Also, identification and finding of customer power boxes is difficult due to complex housing areas, hard-to find power boxes in confusing basements of department stores, in train stations etc. To tackle this problem the city team developed the Excel-sheet reported above to make the invisible infrastructures more visible. Another problematic point of the invisibility is the vulnerability of invisible underground cables in the context of the permanent construction activities in the city (e.g. buildings and streets). In addition, there are legal rules on required distances between different origin underground cables, which means that also other organisations need information on where the power lines run. A new approach of the city power department is to open their plans of underground power lines for municipal authorities in order to have their own lines not so often affected and broken by building activities. Another reason for that is to foster a good relationship with other stakeholders in order to have reliable partners in crisis situations.

This aspect occurs often in interviews with city team members. Another important local stakeholder who might become an "enemy" in crisis situations is the local radio station which is known for reporting quite negative about the company in power outage situations. This is why cultivating the image of the company is seen as an important daily task in the city team in regard to proactive crisis management. Another locally bound aspect of visibility in the city team is the visibility of the whole company and its assessment in the eyes of the city inhabitants: as the companies' history started in the city the inhabitants strongly identify themselves with the company and watch related developments and incidents very critically.

In both service work teams there have been modes of particular attention of certain groups of people, such as distributed special telephone numbers for seriously ill persons (e.g. dialysis patients) which in the last years have been officially abolished in the context of the company's reorganisation and centralisation. However, in the actual work practice of the rural team particular attention is being continued unofficially, e.g. in form of prioritisation of local farmers during power outages in order to keep their milking installation working.

In the context of the company's restructuration new telephone numbers of the call centres for customers were published. In both local service work departments this expected change has not been successful, as customers still (especially in the rural region) call "their" local service workers in power outage situations and also in cases of other problems. Many customers are discontent with the call centres and still demand the local closeness of contact persons. In the rural area this problem in the management's view even amplifies as many rural inhabitants have relatives or acquaintances working in the local service worker teams who regularly are addressed in problem situations.

Finally, the regional differences also evoked different challenges and problems in the realm of a German-wide hurricane in 2007. The rural district was heavily affected by widespread and enduring power outages because of many destroyed aerial power lines by means of dropped trees in its extensive woodlands. The coping and rehabilitation work could not be done with the existing personnel and needed reinforcement by service workers from other less affected areas. In contrast, the same day for the city team was also busy, but could be discharged with the existing personnel. Some of them even were delegated to help in other areas.

DISCUSSION

The empirical study revealed a variety of practices of the service workers in the two different areas. Certain modes of collaboration and communication in contrast to office work got visible. The acknowledgement of differences in work structures is especially important when designing for surfaces and communication and coordination spaces between different departments and external stakeholders (cf. Fallman et al. 2005).

In the service work teams it is especially the physically-bound character of working and learning which is connected to their bodily skills and their identities. This is an important insight for the attempt of converging the "old" electrical infrastructure with new digital infrastructures. We found out different levels of affinity towards testing and using digital tools in the two areas, which had important impact on the accomplishment of work, such as the Excel-sheet developed on the city team's own initiative. (Milis and van de Walle, 2007) found out that the use of IT for crisis management inherently is dependent on the presence of a member with IT background in the crisis management. We also found the relevance of this kind of personal affinity towards the use of new technologies. For

the preparation of the enrolment of a crisis communication system this finding may be an important hint towards developing incentives and providing better access to digital working environments.

Additionally, we have observed the daily common discussion, sensemaking and work planning in the morning an important part of the workday for coordination and learning. Similar to Orrs (1996) observed "war stories" the observed morning rounds provide space for funny stories or discussion opportunities of failures or mutual information with certain spatial knowledge important for a job to be done. These social learning opportunities have to be taken into account when thinking about centralization in the realm of emergency management system development.

In this context the teams as communities of practice overcome managerially-created disturbances of workflow by not well working devices and often changing prototypes. Also, different attitudes towards new technologies and related use practices are tolerated and covered in the community. This collective dimension in handling problematic aspects in work resembles to Dubey's (2001) notion of "clans" as a particular form of strong social and affective cohesion in organizations (Potthast 2008).

Another aspect in regard to identification with the organization is often being proud of having a high expertise in working on the physical infrastructures, which is often revealed in comparisons of the job to firefighters or emergency doctors. Especially the rural team members fear a loss of expertise and by that a change in their self-perception with the ongoing convergence of old (powerline) and new (ICT-enhanced powerline) working infrastructures. Besides the socio-spatial aspects also different spatial rhythms got visible in the two areas which have impact on proactive emergency management and also in a bigger crisis situation and should be taken into account in systems design.

Related to the identity and socio-spatial aspects is the fact that new technology support for crisis communication has to get accepted by the field workers. Fallman et al. (2005) argue that user experience is an important design challenge. We would like to stress a step before in system design in form of examining work motivation and attitudes towards the use of new technologies and further convergence of physical and digital work infrastructures. In the cases at hand new technologies seem to be too much instructed from a top-down management point of view. We have seen that – in spite of directives from the management – uses of tools are not consistent. In the development process of an emergency management system it should be taken into account to strengthen the value of the work of the service technicians in situ and amplify the advantages of using new tools in their work accomplishment from the point of view of the service workers.

CONCLUSION

We provided an ethnographical study on work practices of in situ service workers of a big power provider company in the project context of the development of a crisis communication system. Our attempt in this paper was to shed light on the differences of work practices due to physical and spatial differences of the work contexts. Focussing socio-spatial specificities in work practices and varying modes in coping with convergence of "old" (physical) and "new" infrastructures we could identify different infrastructure layers: the physical, spatially-bound infrastructure, representations of the first layer (e.g. to produce visibility of underground power lines), and articulation work relating to the maintenance of the physical infrastructure (via IT, paper sheets, in meetings). Handling and interplay within these layers is inherently interwoven with located social and historically grown practices in each team. In the work practices of the two regional teams we found many examples for the use of interpersonal coordination mechanisms instead of using formal organisational structures. This is inline with findings of Star and Ruhleder (1996) who point at the interplay of the globality of infrastructures and local practices which have to be taken into account when developing within large-scale IT systems. In our preparatory study to system design we identified relevant layers of infrastructuring from the practice view of the maintenance workers. The next step is to analyse the workers'/ teams' rationales (cf. Schmidt et al. 2007) in their practices according to the infrastructure layers in more detail.

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