A control center design revisited: learning from users' appropriation

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Abstract. This paper aims to present the lessons learned during a control center design project by revisiting another control center from the same company designed two and a half years before by the same project team. In light of the experience with the first project and its analysis, the designers and researchers had important feedback already used to suggest changes for the second project. The opportunity to learn from a previous project was unique, but the knowledge gotten out of it shows the importance of having this feedback from project to project instead of just 'repeating' previously used design solutions.

Keywords. Workspace design; User involvement; Post-occupancy evaluation; Ergonomic work analysis.

1. Introduction

Each project is unique. However, much can be learned from previous projects and experiences. Many designers (both architects and engineers) are aware of that. Nevertheless, it is rare that they have the opportunity, or even the time, to go back to their own designed places and analyze the outcome after the users' appropriation and use of those spaces.

In ergonomic interventions, different reference situations are visited and analyzed in order to increase the understanding of the activities that will be performed in the new space to be designed (Daniellou, 2004). But even in these interventions, it is not common that designers, or ergonomists, have the chance to do these analyses in reference situations in which they have contributed to the design.

Analyzing in a systematic and structured way built spaces in use can lead to different benefits. Short-term benefits include feedback on problematic situations in the analyzed spaces and identification of appropriate solutions used. Medium and long-term benefits include "*feedforward of the positive and negative lessons learned into the next building cycle*" (Preiser, 1995).

The aim of this paper is to present the lessons learned during a control center design project by revisiting another control center from the same company designed two and a half years before. The design and research team was mostly the same in the two projects, what makes this a quite rare case where the same professionals could analyze the appropriation by the users of their own project. We were able to use this feedback not only as input to a new project, but also as lessons learned for other future projects.

The questions behind this intervention and research were: 1) What was learned from the analysis at the first designed control room? 2) What was done in a different way at the second project due to this evaluation? The answers to these questions lead to a discussion on the learning possibilities by users' appropriation of the designed spaces and so to the main research question of this paper: What can be learned by revisiting a previously designed workspace when it is already in use?

2. Methods

The intervention presented in this paper happened in 2009 due to the demand for a control center renovation project. The control center (A) is part of a natural gas processing terminal in Macaé, Brazil. The project team was mostly the same designing another control center (B), the national operational control center for oil and gas transport distribution, for the same oil company two and a half years before. As the managers were satisfied with the first outcome, they asked the project team for a similar architectonic result. The project team, which had architects and ergonomists, decided to use the first control center as a reference situation to learn from its appropriation by the users instead of "copying" it.

The project had duration of eight months, from the first meetings to the final design documents handed in. The project team, in number of seven and from which the authors were part of, were also researchers from the Federal University of Rio de Janeiro. During the design process of the control center A, we used a combination of two methodologies: the post-occupancy evaluation (Preiser et al., 1988) and the ergonomic work analysis (Guérin et al., 2006).

2.1 The external reference situation

The reference control center B was in use for one and a half years when we carried out the post-occupancy evaluation. The project team made five visits within two weeks to the control center making small interviews with selected users and doing some observations. During these visits, one of the researchers, who was not part of the control center B project team, applied the following techniques: open interviews with the users, guided walkthrough, questionnaires and environment monitoring.

The researcher conducted in total seven open interviews with different users of control center B. The interviewees were: operators from the control room; administrative personnel; employees responsible for the cleaning, for the cafeteria and for the security; staff of the center of documentation and information (internal library); and the building maintenance staff. In these interviews users spoke freely about both the positive and negative aspects that influenced the accomplishment of their tasks.

The same seven users accompanied the researcher in a guided walkthrough at the control center facilities and pointed out problems, mostly from architectural perspective, in all areas visited. The researcher took pictures of all items mentioned. As the main focus of the analysis was the control room, the researcher asked all four groups of operators and shift coordinators to respond the questionnaires, 51 people in total. The questions were related to air conditioning, acoustics, lighting, furniture and dimensioning of the support rooms. The users' feedback was supplemented by environment monitoring of light and noise levels.

2.2 The control center to be renovated

The control center A had the demand for renovation due to the increasing number of production units in the terminal. The existing and operating control room, however, was

still an important reference situation for its own redesign and renovation. We carried out both the post-occupancy evaluation and the ergonomic work analysis there.

The same researcher responsible for the post-occupancy analysis at the control center B applied it also at the control center A. He made four visits to the control center within two weeks and applied the following techniques: open and semi-structured interviews; and questionnaires. He conducted the open interviews with operators from the control room, administrative personnel and employees responsible for the cleaning. The semi-structured interviews, he conducted with one operator from each of the four teams at control room. In these interviews the users talked about both the positive and negative aspects that influenced the accomplishment of their tasks. Again, as the main focus was the control room, the researcher asked operators and shift coordinators from all five groups to respond the questionnaires, 73 people in total. As for the control center B, the questions were related to air conditioning, acoustics, lighting, furniture and dimensioning of the support rooms.

Two other researchers were responsible for the ergonomic work analysis. They had several visits during the first three months of the project when they had interviews with the users and also did structured observations to the activities carried out by the operators in the control room in the different working shifts.

3. Results

The results of this intervention can be presented in three levels: 1) the analysis of the first designed control center; 2) the analysis of the control center to be renovated; and 3) the lessons learned from one project to the other, meaning not only what was done in a different way at the second project due to the experience with the first project but also the overall lessons taken out from this rare opportunity. The results presented here focus on the control room of both projects, as this is the main environment of the control centers. The analysis performed also had this main focus, although covering all other environments of the control centers.

3.1 The analysis of the external reference situation

The general result from the post-occupancy evaluation of control center B was that it met the use demands. During the interviews and the walkthrough, the operators and other users mentioned they were satisfied with the control room and the overall project. The major positive aspects pointed out by the users, also regarding the questionnaires, were the lighting of the control room and its furniture (both operating consoles and chairs).

Lighting was considered a positive aspect, being rated by 80% of the operators as good or optimal. They pointed out the dimmer regulation in the room and the task lights as good improvements from the previous control room they operated from. This was an important issue during the project, as there was bad lighting in the previous control room and a challenge to meet good lighting with a high ceiling and the differences in how the operators liked to work best: with more or less overall and direct light. However, a maintenance issue was highlighted: due to the high ceiling, it is necessary to build scaffolding to change the lamp bulbs, which cannot be done while the control room is operational.

The furniture was also satisfyingly rated by more than 80% of the operators. That was also a much studied issue during the project, as the operators spend all their shifts seated operating from their consoles (workstations supporting six computer monitors, keyboards, telephone, radio, working papers). The operators were asked about the chairs in terms of comfort and its possibilities of adjustments, and about the consoles in terms of space on

top for all equipment and general dimensioning.

Negative aspects were also mentioned during the interviews and rated with the questionnaires. The main negative aspects raised by the operators were acoustics, air conditioning and support rooms.

Acoustics was the main problem identified: 98% of the operators pointed out the existence of noise in the control room, mostly coming from the external area of the building. This problem is directly related with both the location of the control room in the crossing of the two main streets in Rio de Janeiro's city center, and the failures within the execution of some of the acoustics design specifications (e.g. sealing gaps in the window frames).

The air conditioning was raised as a problem for half of the operators due to the difficulties in regulating the room's temperature. The explanation was the location of the temperature sensors too close to the air diffusers, which are at the high ceiling, and that can only be accessed by the building's maintenance personnel.

The support rooms were not considered satisfactory by most of the operators. The restrooms were rated poor or very poor by 79% of the operators, while the kitchen nook was rated poor or very poor by 61%. The main problems identified were due to reduced size of the men's restroom and the kitchen nook, even if both were meeting the specific regulation standards.

3.2 The analysis of the control center to be renovated

The post-occupancy analysis of control center A gave us feedback on the actual conditions of the current operational control room, which served as input to identify what could be kept or had to be changed during the renovation process. The results from the questionnaires and interviews allowed us to identify the main positive and negative aspects of the physical environment.

The operators rated lighting as a positive aspect. But even though more than 70% of the operators rated lighting as good or optimal in relation to the overall lighting and to the work station lighting, during the interviews some operators pointed out the existence of glare and reflections on the monitors caused by the artificial lighting of the control room. The furniture let the operators divided when rating it: 58% were satisfied with the operating consoles and their sizes. However, the interviews helped us identifying problems like: the positioning of the monitors hampering their visualization by the operators and the existence of too many keyboards and mouses in each console. Regarding the chairs, only 37% of the operators were satisfied.

The negative aspects identified with the questionnaires were air conditioning, acoustics and the support rooms. The air conditioning was rated as poor or very poor by 74% of the operators, being the major problem reported. According to the operators, the control room temperature is too low due to the need of chilling the machines from the equipment room that shares the same air conditioning system. Besides, the air flow is not well distributed, leading to differences in temperature within the room. Acoustics was also a problem mentioned by the operators: 83% pointed out the existence of noise in the control room, mainly from talks among operators, by phone or by radio (with the field operators). The support rooms were also rated poor or very poor by most of the operators: the restrooms were poorly rated by 66% of the operators and the kitchen nook by 54%, both due to the small size not meeting the demand.

The ergonomic work analysis, in turn, enabled a detailed understanding of the operation activities and the need for the different support rooms. The analysis allowed us to identify issues such as: the number of monitors needed in each console, the need for a workstation inside the control room for the automation personnel, the interaction and

communications among operators that impacts the room layout and the need for a meeting room connected to the control room.

3.3 The lessons learned from one project to the other

Many were the lessons learned from one project to the other, both with the post-occupancy evaluation carried out and the visits by the whole project team to the control center in use. We observed aspects related to the activities of the operators and related to issues discussed during the project that were not covered by the techniques applied with the formal evaluation. Both results complement each other on what was learned from control center B's analysis. Four cases can exemplify the main lessons learned during this intervention.

One example was the observation of the end-use of some of the support and administrative rooms: while the training room not initially on the architectural program was actually in use by the operators, the rooms for the two shift coordinators never had its use as expected. In fact, the coordinators' rooms were a demand coming from the company's management but their need was not observed during the ergonomic analysis. They ended up being support rooms for operators in training.

Another example was the observation, followed by the complaints, that the restrooms and kitchen nook were too small to meet the demand for all the operators. In both cases, the number of toilettes and the size of the kitchen nook were meeting the specific standard regulations. However, it was clear that meeting the standards was not enough.

Yet another example was the uncovering that some problems might be caused by failures in the execution. Even with detailed acoustics studies and specifications, we identified sealing gaps in the window frames in the control room, leading to higher noise levels coming from outside than what was expected. We could observe that not taking into consideration the execution possibilities during the detailing design had an impact on following the specifications.

A last example was the recognition that taking maintenance into account plays a major role in achieving good design solutions. The difficulties of maintenance of the lamps in the high ceiling of the control room, e.g., were not considered during the project. Even with a satisfying result in terms of lighting, the change of the lamp bulbs lead to maintenance problems: the bulbs are changed once a year, when the operation happens for a couple of days from a back-up room and it is the only opportunity for scaffolding to be mounted inside the control room.

From these major lessons learned within the analysis of control center B, some could be put into practice in the project of control center A. Examples were the review of the architectural program, identifying the need for support rooms with the ergonomic work analysis; and the re-dimensioning of the kitchen nook to meet not only the standards but also the real demand from the operators.

4. Discussion and Conclusion

The design of any space is not over yet at the project phase, it continues to happen during the execution phase and with the users' appropriation of the built space. Having the chance to revisit a workspace previously designed by the same team was really unique. The project of control center B had already had an intensive analysis up to its construction and start-up phases, as reported by Conceição et al. (2008). But after one and a half years of use, changes could be noticed and it was clear this design proceeded with the appropriation of the built space by the different users.

As Villarouco et al. (2012) point out, the built space is part of a process of continuous

improvement of the working activities. With a structured analysis and evaluation of this space, centered on ergonomic principles, much can be learned that leads to the improvement not only of the analyzed space but also of future spaces to be designed.

The cases highlighted within the results presented exemplify what can be learned by revisiting a previously designed workspace when it is already in use. The end-use, or the actual use, of the designed rooms shows us that no matter what was planned during the design phase, the users will make use of the spaces in the way that best fits for their needs and activities. Following even the specific and recognized standards and regulations does not ensure demands to be met. In both cases, the ergonomic analysis of reference situations can help identifying the 'real' needs and demands. Giving attention to construction means to meet specifications and to maintenance of the systems proposed are key elements to meet good design solutions. A better integration with those responsible for the execution of the project allows the difficulties and possible problems to be foreseen already in the design phase. Integration with the maintenance team should also be considered, but mainly including the observation of the maintenance 'users' during the ergonomic analysis allows a more complete understanding of all the activities that are in fact carried out in each space.

This intervention allowed us to learn not only these specific lessons, but also the key lesson of getting experience and design inputs for future improvements through feedback from previous projects. We do not argue to have a formal procedure or methodology to analyze and gather feedback from previous projects. Instead we highlight the outcome of such an opportunity of learning by looking back into previous projects. We learn by doing, but also by understanding how to do it better.

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