

Integrating ergonomics in design processes: a case study within an engineering consultancy firm

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Abstract. This paper reports on a case study within an engineering consultancy firm, where engineering designers and ergonomists were working together on the design of a new hospital sterile processing plant. The objective of the paper is to gain a better understanding of the premises for integrating ergonomics into engineering design processes and how different factors either promote or limit the integration. Based on a grounded theory approach a model illustrating these factors is developed and different hypotheses about how these factors either promote and/or limit the integration of ergonomics into design processes is presented along with the model.

Keywords: engineering design processes, organizational design, explorative case study

1. Introduction

Integration of ergonomics into design processes can contribute to the creation of safe and healthy work places [1-3,5-7]. In Denmark there has over the past five years been a development in the area of engineering consulting, where a lot of the larger engineering consultancy firms have established ergonomic divisions within the company organization. This has happened while the public funding for occupational health services has been phased out and the area has been privatized. From an ergonomic point of view this is an interesting development as it might create new possibilities to integrate ergonomic knowledge in the design of new work places. However the integration of ergonomic knowledge in engineering design processes is new to a lot of the ergonomists and the engineering designers.

In this paper a case study within one of these engineering consultancy firms is presented, where engineering designers and an ergonomist were working together on the design of a new hospital sterile

processing plant. The objective of this paper is to get an insight into how ergonomic knowledge can be integrated into engineering design processes and get a deeper insight into how different aspects influence the integration of ergonomic knowledge in design processes. The research question for the paper is:

What promotes the integrating of ergonomic knowledge in design processes and what are the limitations?

2. Method

An explorative case study was conducted. The case material was collected through interviews, a document study and to a minor degree observation. 12 semi-structured interviews were carried out within the engineering consultancy firm and the hospital organization. The first author also visited the sterile processing plant, observed the employees while they were working and interviewed them concurrently. The engineering consultancy firm provided full

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access to the company's database for document and project handling. Here a total of 9251 documents were related to the project.

Based on a grounded theory approach [4] the case study was unfolded: The documents were sorted and prioritized where the focus was to uncover all documents revealing anything about the meeting between design and ergonomics. The document study involved going through minutes of meetings, project presentations, project plans, drawings, working documents and an ergonomic guideline document. To get an insight on the timeline of the project and to uncover when and how ergonomics was integrated into the project a physical wall with a timeline displaying all the relevant paragraphs of the explored documents was created. This visual method was very useful to create an overview of the design process. Furthermore all interviews were transcribed. Afterwards all data material was coded for the theme "ergonomic knowledge in design processes". In this process codes were formed and through rearranging the different codes, categories emerged. The model presented in Figure 1 was constructed when searching for relations between the categories. In this process hypotheses about the correlations was formed and the model can in itself be seen as a hypothesis.

3. Case description

When the case study unfolded the ergonomists had been employed in the engineering consultancy firm for a couple of years. Organizationally, spatially and financially the engineering departments and the ergonomic departments were separated.

The case study concerned the design of a new sterile processing plant and the engineering consultancy firm was to do the logistics and the layout of the sterile processing plant. For the engineering designers this is a standard configuration job, where they adapt a standard design for sterile processing plants to the local settings at the hospital in question. However in this specific case the locations designated for the sterile processing plant was rather cramped and based on preliminary discussions with the head of the ergonomists "hospital group" the engineering designers decided to involve one of the engineering consultancy firm's own ergonomists in the design job. The ergonomist chosen for the design job had no prior experience in being part of a design team. It was also the first time for the project manager to involve an ergonomist in one of his projects.

Besides the ergonomist, the design team consisted of a consultant, C1, who was a nurse, the project manager, who was a trained engineer, several other engineers. The head of the hospital division in the engineering consultancy firm also participated in the design. Prior to engaging the ergonomist in the design job the design team had carried out user-meetings, conducted a capacity analysis and made an outline for the logistics and flow in the sterile processing plant. Sketches for the layout of the plant had also been made. The job of the ergonomist was to complete an ergonomic guideline document stating her recommendations for the sterile processing plant. In the design process she cooperated mainly with C1 and was invited to visit the future locations for the sterile processing plant along with C1 where they spoke to some of the future users of the sterile processing plant. Furthermore the project manager, C1 and the ergonomist had meeting where the project manager and C1 presented the ergonomist with their layout sketches. The ergonomist commented on the sketches and in this way contributed with her knowledge on ergonomics. The ergonomist also participated in a couple of the internal project meeting in the engineering consultancy firm. After the completion of the ergonomic guideline document the ergonomist left the project. For the rest of the design team the design job ended shortly hereafter with the hand-over of a project proposal summing up their design solutions. The ergonomic guideline document was circulated along with the project proposal to actors inside the hospital organization and to the hospital's turnkey contractor.

The hospital was in charge of the implementation and start-up phases at the sterile processing plant. In this phase they once again chose to contact the engineering consultancy firm for assistance. A consultant, C2, who was also a trained nurse, was assigned the job. Her job was to support the hospital with overall guidance, help the hospital do specification requirements of new equipment and implemented a computers system for stock-control. She was also handed the ergonomic guideline document.

When the first author visited the sterile processing plant it turned out that not all recommendations given in the ergonomic guideline document had been implemented at the work place. It also became evident that there were issues related to ergonomics that the ergonomist and the project team had not addressed, for instance problems related to the psychosocial working environment and chemical aspects.

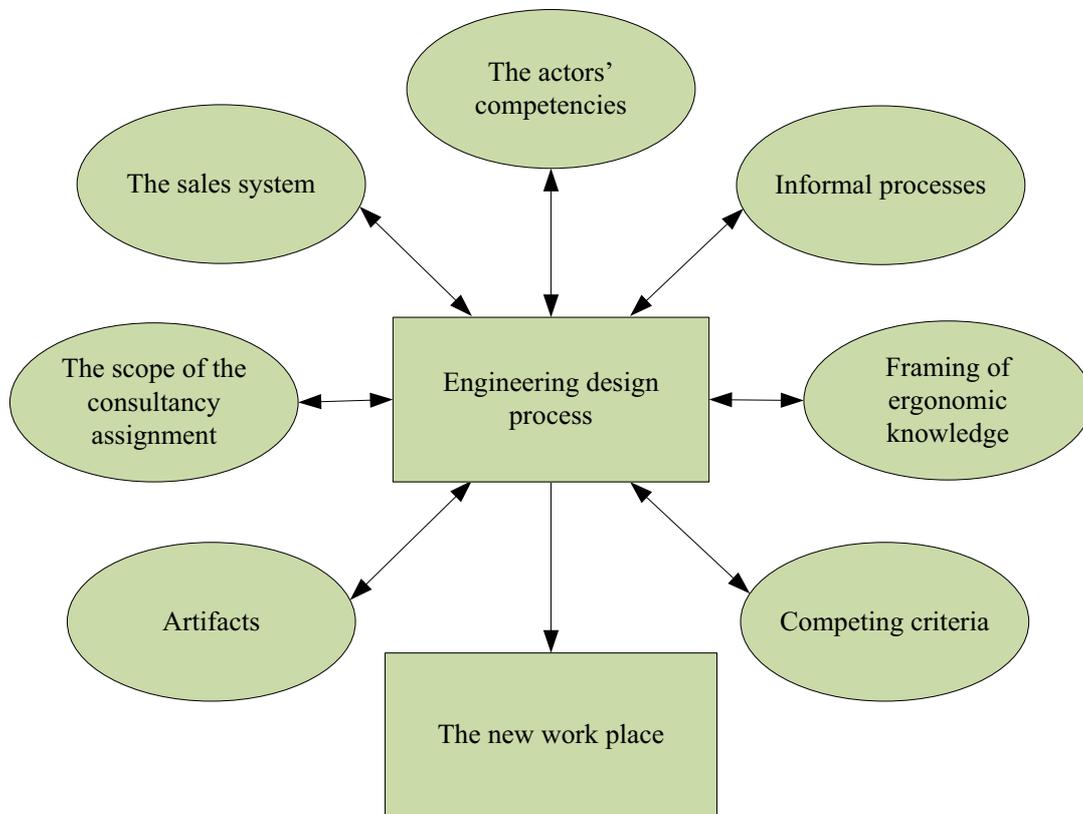


Figure 1
The different factors affecting the integration of ergonomics into work place design

4. Results

Based on the case study described above the model presented in Figure 1 was formed. The model illustrates the different factors which emerged through the data analysis.

In the middle of Figure 1 is the **engineering design process**. This box was placed in the middle of the figure to illustrate that the engineering design process is a premise of integrating ergonomic knowledge into design of new work places inside an engineering consultancy firm. Hypotheses about how the categories surrounding the “engineering design process” promote and/or limit the integration of ergonomics into the engineering design process were formed and these are described in the following.

4.1. The actors' competencies

The actors' competencies have great impact on the engineering design practice when it comes to integrating ergonomics in the engineering design process. For all the involved actors it is rather new to integrate ergonomics in design processes and this leaves them with a question of how and when to integrate ergonomics in the design process.

Engineering designers have experience in being part of engineering design process, but the area of ergonomics is new to them and this limits their ability to see how and when it is beneficial to integrate ergonomics into the engineering design practice. It promotes the integration of ergonomic knowledge when the engineering designers identify challenges they consider to be related to ergonomics, such as a lack of space.

The ergonomists on the other hand have professional competencies in the area of ergonomics and

have a lot of experience and knowledge on the ergonomic-related problems that might arise at a given work practice. The engineering designers see this knowledge as beneficial because the engineering designers normally don't see the day to day running of the work practices they design. This promotes the integration of ergonomic knowledge into the engineering design practice. However only a few ergonomists have experience with being part of a design process and this limits the integration of ergonomic knowledge in the engineering design practice. The terminology used in engineering design is unfamiliar to the ergonomists, and this might limit their ability to bring ergonomic knowledge into action when engineering designers discuss aspects related to the design process or the design solutions.

The case study shows that consultants, trained as nurses, participate in design processes in close cooperation with the engineering designers. They contribute with a practical founded knowledge on both work practice and ergonomics and are deeply involved in the user involvement. The ergonomic professionals describe themselves as having a holistic view on the work practice, having a lot of experience with user involvement and having good competencies in fulfilling the role as a process consultant. Even so they are only invited to participate in the design process as a support function. This limits the integration of the ergonomic expert knowledge. It seems that the ergonomists do not have the competencies to "sell" their process-related competencies to the engineering designers, and this limits the possibilities for bringing their ergonomic knowledge into action. However when both the consultants and ergonomists are involved in projects the combination of the consultant's practical experience and the ergonomist's expert knowledge on ergonomics is a fruitful combination.

4.2. Informal processes

Informal processes are very determining in relation to whether or not ergonomics is integrated in projects. One of the premises in engineering design is that the engineering designers are in charge of the design job and the design process. From this position they involve the ergonomist when they find it relevant. As a starting point the engineering designers are open towards integrating ergonomics in their design processes and this openness promotes the integration of ergonomics in the design process. Good working relationships between the engineering designers and

the ergonomists promote the openness towards integrating ergonomics in the design job. Preliminary dialogues between the engineering designers and the ergonomic professionals also seem to promote the integration of ergonomics in design processes as the preliminary dialogues forms the basis for integrating ergonomics.

Nonetheless the engineering designers only wish to involve the ergonomists to a limited degree in design processes. The ergonomist is not invited to take part in the planned process of user involvement and is not invited to participate in the design process before the basic principles for the design job has been established. The ergonomist only participates in a few of the internal project meetings and appears as being loosely connected to the project. This hampers the possibilities for bringing ergonomic knowledge into action in the design process.

When informal processes are crucial in relation integration ergonomics it becomes person-dependent whether or not the ergonomists are involved in the design jobs and if involved, how many hours are allocated to ergonomics on the project.

4.3. Framing of ergonomic knowledge

There is a framing of the ergonomic knowledge which is brought into action in design processes. The framing is affected both by the engineering designers and the ergonomists opinion on which aspects of ergonomics it makes sense to address in the design jobs. When designing new work places both the ergonomists and the engineering designers find it most relevant to integrate physiological aspects of ergonomics and to a minor degree physical aspects of ergonomics. Within engineering design practice there seems to be a predominant view on work places as "physical container for work processes" and hence more organizational and chemical aspects of ergonomics are not addresses in design processes.

Furthermore the engineering designers regard ergonomics as one discipline: They involve several engineering designers with different engineering expertise, but only a single ergonomist. This limits the possibilities for bringing different areas of ergonomics into the design process.

The ergonomic knowledge which is being brought into play in the design processes is based upon Danish legislation on occupational health and safety and can be characterized as institutionalized ergonomic knowledge.

4.4. Competing criteria

The category competing criteria illustrates that ergonomics is one out of many different aspects with are important in relation to work place design. Other criteria in an engineering design process can for instance be hygiene or financial aspects and these criteria conflict with ergonomics from time to time.

In relation to the overall design process the design actors have to make a decision on whether or not to integrate ergonomics and if they decide to involve an ergonomist to what extent the ergonomist should be involved. This weighing is done in relation to the overall budget of the project.

At the specific design job ergonomic recommendations are weighted in relation for instance hygiene or and financial considerations and whether or not the recommendation makes sense in the given work practice. The weighing is being done without the expertise of an ergonomist. This limits the possibilities for ergonomic considerations being implemented at the new work place.

4.5. Artifacts

“Artifacts” concerns the artifacts which stood out as important in relation to integrating ergonomics in the engineering design processes. In this case the artifacts were:

- An ergonomic guideline document
- Layout sketches

The ergonomic guideline document was created to pass on the ergonomic recommendations given by the ergonomist and in this way promote the integration of ergonomics in the design process. It turns out however that some recommendations were implemented at the new work place, while others were rejected due to “conflicting criteria”. Hence ergonomic “packages” in the form of written documents are weak in integrating ergonomic knowledge in the design process.

The layout sketches were used as means to facilitate a dialogue about ergonomics in relation to the design object in question. In this context of use they help to bring ergonomic knowledge into action. The limitations of the layout sketches as means to bring ergonomic knowledge into action are that they contribute to the framing of the work place as a “physical container of work processes”. Thereby the sketches influence the framing of the ergonomic knowledge being brought into action in the design process.

4.6. The sales system

The sales system also affects the engineering design practice and the integration of ergonomics into the design process. The category “the sales system” relates to the sale processes the engineering consultancy firm engages in.

The engineering designers are economically in charge of the design processes and have the main contact with the clients. They are in charge of allocating hours to the different members of the design team. This limits the possibility for ergonomists being allocated enough hours to being involved throughout the design process.

In relation to the category “the actors’ competencies” it is a hypothesis that the engineering designers do not have the competencies to see when and how it is beneficial to integrate ergonomics in a design process. Thus they do not have the competencies to describe and *sell* to the clients how they can benefit from involving an ergonomist throughout the design process. This is a barrier to the integration of ergonomic knowledge in the design processes.

There is also a problematic related to “the payment of ergonomics”. Who is to pay for integrating ergonomics in design processes, the client or the consultancy firm? It limits the integration of ergonomic knowledge in design processes that it implies extra expenses to involve an ergonomist. With this given it promotes the integration of ergonomics if the client is prepared to pay extra and limits the integration if the client is not prepared to pay for the extra expenses. It promotes the chances of the client paying extra if the client has positive experiences with the ergonomists from the engineering consultancy firm.

4.7. The scope of the design job

This category is closely related to the “the sales system”. The scope of the engineering design job was established in a dialogue between the engineering designers and the client. The design team was to complete an extended project proposal and then leave the project, while the hospital themselves were in charge of the implementation and start-up phase of the sterile processing plant. More specifically the scope was to do the logistics and layout of the sterile processing plant. As mention in the category “framing of ergonomic knowledge” mainly the physiological and physical aspects of ergonomics was dealt with in the design process. A different scope like for instance “designing a new department for a sterile

processing plant” might have invited to bring more the organizational aspects of ergonomics into action and also have made it possible for the ergonomist to bring their process-related competencies into action.

A lot of important decisions about the future design of the work place are being made by the client in the implementation phase. It limits the integration of ergonomic knowledge that the engineering design processes do not include the implementation phase. If the engineering designers are contacted to do follow-up on their design solution in the implementation phase they do not contact an ergonomist even when they make decisions that have impact on the working environment. This limits the implementation of ergonomic recommendations at the new work place and limits the value of involving an ergonomist in earlier phases of the design process.

A hypothesis in relation to this is that the engineering designs are not good enough to challenge the client on the scope of the design job and on the decisions the client make during the design process.

5. Discussion

The results show that the integration of ergonomic knowledge into engineering design processes is affected by many different factors.

Table 1 displays factors which promotes the integration of ergonomic knowledge into engineering design processes. The limiting factors identified in section 4 have been turned around and are presented as potential promoting factors in

Table 1.

Table 1
Factors which promote the integration of ergonomic knowledge into design processes

Promoting factors	Potential promoting factors
When the engineering designers identify challenges they consider to be related to ergonomics, such as a lack of space, they are more likely to involve an ergonomist.	Improving the engineering designers' ability to see how and when to integrate ergonomics into the engineering design practice.
The ergonomists knowledge on the work practice outside the scope of the engineering design jobs is appealing to the engineering designers.	Improving the ergonomists knowledge about design processes and their competencies to participate in design processes. For instance learning about the terminology.
Good working relationships between ergonomists and engineering designers promotes openness towards integrating ergonomic knowledge.	Improving the ergonomists competencies to "sell" their organizational and process-related competencies to the engineering designers.
Preliminary dialogues between the engineering designers and the ergonomic professionals about the incoming design jobs promote the chances for ergonomists being involved in projects.	Improving the engineering designers understanding of the many facets of the area of ergonomics.
If the clients are willing to pay for involvement of ergonomists in design jobs it is easier for the engineering designers to balance financial and ergonomic aspects.	Provide organizational structures/strategic decisions which can stem up for the "person-dependent" integration of ergonomics in design processes.
Clients' positive experiences with ergonomists from the engineering consultancy firm promote the clients' willingness to pay extra for the involvement of ergonomists in design jobs.	Providing ergonomic support to the engineering designers and consultants when they have to weigh the ergonomic recommendations against conflicting criteria. This implies the involvement of an ergonomist throughout the design process.
The use of ergonomic "packages" in the form of written documents promotes the integration of ergonomic knowledge when the recommendations do not conflict with other criteria of the given work practice.	Improving the ergonomists ability to argue for the integration ergonomics in design processes and hereby their ability to <i>sell</i> how the engineering designers and the clients can benefit from the involvement of ergonomists in projects.
Artifacts used means to facilitate a dialogue about ergonomics in relation to the design object in question helps to bring ergonomic knowledge into action.	Improving the engineering designers' ability to sell ergonomics to clients.
	Discuss internally in the engineering consultancy firm how to handle the fact that it costs extra to involve ergonomist in projects.
	Improving the engineering designers' ability to challenge the clients on the scope of the engineering design jobs.

In order to promote integration of ergonomics into design processes both engineering consultancy firms and ergonomic professionals can work actively with the identified promoting factors and the potential promoting factors.

Within the engineering consultancy firms organizational initiatives can be made to support the promoting factors. Since the completion of the case study the engineering consultancy firm has established formal staffing procedures in order promote

cross disciplinary work. In the light of this study this is an interesting organizational initiative and it would be interesting to access whether or not these formal procedures are able to improve the integration of ergonomics and stem the more random and informal staffing processes. In addition to the formal staffing procedures the engineering consultancy firm could also formalize preliminary meetings between engineering designers and ergonomist when new projects are introduced. Furthermore the engineering consultancy firm could introduce "cross disciplinary forums" where ergonomists and engineering designers can exchange experiences from projects. Hereby both ergonomists and engineering designers can learn about each other's professions, develop competencies in how to integrate ergonomic knowledge into the engineering design practice, establish a foundation for further collaboration *and* develop competencies in how to sell both each other's services and their combined services to their clients. Learning about each other's professions could also improve both the engineering designers and the ergonomists ability to challenge the clients on the scope of the engineering design jobs. Another way to improve this ability is to team up the engineering designers with an ergonomist during the sales processes and to use the contacts and good working relationships the ergonomists have with their clients. Furthermore it would be beneficial to discuss internally in the engineering consultancy firm how to handle the extra costs of integrating ergonomics in projects. One solution is only to integrate ergonomics to the extent the clients are willing to pay. Another solution is to decide that a certain amount of the budget for all projects should go to integrating ergonomics.

Focusing on the individual design job the integration of ergonomics could be improved by involving an ergonomists throughout the different design phases. The purpose of this initiative is to provide ergonomic support to the engineering designers and the clients in situations where different criteria conflicts and hence enhance the chances of the ergonomic recommendations being implemented at the new work place. At the individual project both engineering designers and ergonomists could benefit from carefully considering the use of artifacts to facilitate knowledge sharing.

The ergonomists needs to focus on establishing positive working relationships with the engineering designers and get into a position where they can sell their ergonomic competencies to the engineering designers. To be able to do so the ergonomic professional needs to develop competencies in how to run a

design process and get a broader insight into the different challenges of a project manager. The positive relationship with the engineering designers is crucial in relation to getting involved in design processes.

6. Conclusion

The objective of this paper was to uncover how different factors either promote or limit the integration of ergonomic knowledge into design processes.

A model illustrating these different factors was developed and presented along with different hypotheses about how the factors promote and/or limit the integration of ergonomics into design processes.

The model was based on a single case study and this paper calls for further investigations whereby the presented hypotheses can be confirmed or disconfirmed. In the further work with the model it is also interesting to focus on how the different categories are interrelated and to form hypotheses about these interrelations.

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