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The Ergonomist: a full design actor

Example of an ergonomic action

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Abstract

Activity-centered ergonomics has developed an approach to provide support for design projects which comprises ergonomics work analysis, participatory design and simulation of work. This approach leads us to appreciate the reality of work in order to design systems which are adapted to human's abilities and also to the tasks to be performed. However, beyond the technical recommendations, ergonomists may take part in project management. In fact, for some years now, they are no longer satisfied with merely providing the information and advice they have discovered through work analysis. In order to take into account functional requirements of work situations, they now try to influence the very way in which projects are managed and thus influence the design process itself. This perspective sheds a new light on the ergonomist's positioning as a full design actor or as a co-designer. This type of contribution is possible from the early phases of feasibility until the installation start-up. We will try to illustrate this perspective through the results of an ergonomic intervention in an industrial design project.

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Keywords: design project ; project management ; activity-centered ergonomics ; methodology of practice ;

1. Introduction

Designing workspaces have the power to open or close fields of possibilities to users' future activity. These design choices are sometimes essential resources or, contrariwise, strong constraints with consequences in terms of efficiency, reliability, health, life or work conditions, and quality of service. Still, design processes are rarely based

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on a deep analysis of users' real activity and functional needs. One of the reasons is that designers (architects, engineers, etc.) are not necessarily in direct link with work situations and users concerned by the project. Therefore, they may not have in mind all the diversity existing in these working situations. In this context, activity-centered ergonomics (ACE) has developed an approach to provide support for design projects which includes work analysis, participatory design and simulation of work. This approach gives an appreciation of work reality in order to design systems that would be adapted to human's abilities as well as to the tasks to be performed. But ergonomists do not purely influence the projects' content. Their contribution may also impact the way these projects are carried out. The aim of this paper is to underline that, beyond the technical recommendations; ergonomists may take part in project management. This perspective sheds a new light on ergonomist's positioning as a full design actor or as a co-designer. This paper aims to illustrate this perspective through the telling of an ergonomic intervention in an industrial design project. The ergonomists' contributions are discussed by analyzing the project in which the authors participated.

2. Context and demand

The intervention concerns an aeronautics workshop of fifteen workers. The main activity is to adjust, control and pack pieces of planes' engine. With the increase in production's rate, the management board decided to modernize this workshop and has invested in new machines. Initially the workspaces were designed for smaller production volumes. This resulting need of space has made it compulsory to run a redevelopment project. Few years before, two attempts had already been conducted in this sector and were unsuccessful. For this third project, the chief investment did not want to repeat the past mistakes and decided to appeal our services. Working with ergonomists in such a project was a new experience for the firm. In this context, design actors had a limited and vague representation of our field of expertise: "the ergonomist provides recommendations on physical conditions (acoustic, lighting, ventilation…) and on workstation arrangement (work surface height, furniture, etc.)". The initial claim for benefits reflected this representation. The request was to "improve existing workstations by taking into account the redevelopment project". However, we assumed that our contribution would go further than this one mission. This paper shows the methodology used to do so and the results obtained.

3. Project analysis

The first stage of the intervention was to understand the four dimensions of the project: 1. The strategic goals and objectives; 2. The stakeholders' organization; 3. The progression level of the project; 4. And experience feedbacks.

3.1. The strategic goals and objectives

Above all, it must be specified which strategic goals the project is supposed to meet, and what the objectives and the extent of the project are. Originally, the purpose of the project was to arrange the space in order to optimize the new investments and modernize the production equipment. With the increase in the number of produced pieces and the lack of space, the production line had become increasingly cluttered. The obtaining of a workshop adjacent surface triggered the emergence of the project. With the purchase plan and the extra space acquisition, the managers wanted to make the production flow more readable and efficient. Furthermore, the chief investment who was sensitive to health and safety issues wanted to take advantage of this relocation to integrate prevention at an early stage of the design. Very quickly, he talked about load handling problems, repetitive movements, noise, dust, lighting, etc. Besides the budget, his concerns focused on improving working conditions as well as on involving operators in the project. These were the original reasons why ergonomists had been asked to participate. In this context, and before any action, it was necessary to understand the key points of the project and the state of progress.

3.2. Project progress

The project had reached the basic studies, and a draft plan was developed by the investment chief (Fig. 1).

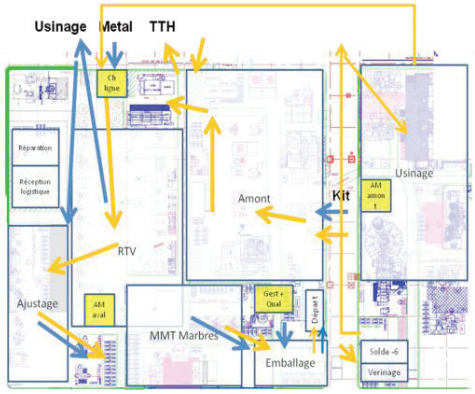

Fig. 1. Initial target plan for the relocation project.

This plan had been developed from a set of very brief oral specifications from the director and the production manager, namely: to optimize the flows (yellow and blue arrows) and to insert the technicians' offices in the production line (yellow squares). We noted that only one direction of flows had been proposed and was the current one. Other alternatives were possible but not investigated. This layout to be achieved seemed to be a response to an ill-formulated problem and was certainly not built (Martin, 2000). Why can this be stated? The investment project was poorly defined in terms of political (wishes concerning the future), strategic (intended improvements, new product development) and organizational orientations (types of work organization, personnel job evolution, training). Apart from machines specifications, there were no quantitative and qualitative specifications for the overall project. Furthermore, the project objectives were expressed verbally and didn't really take into consideration work situations and the resulting functional requirement. It is admitted that design problems cannot be fully defined in advance neither in terms of objectives, outcomes, nor actors. Uncertainty is an inherent feature of design activities. Different authors have attempted to better define the characteristics of design problems [8]. However the designers need to gradually build a representation of the problem. Some authors have shown that searching a solution to a design problem is partly deciding the problem's wording [8]. Indeed, the more project objectives are vague, inexplicit and indefinite, the more the processing of the project in design solutions will be critical and approximate. In this context, the first possible contribution of ergonomists in a design project can rely on the ability of the stakeholders to make decisions on project's orientations. Therefore, before being engaged for good in the project, the opportunity to revisit this first plan according to the results of work analysis was negotiated.

3.3. Stakeholders' organization

- Contracting authority and project management.
  In France, projects are structured in two relatively separate teams whose missions are complementary. Contracting authority (CA) (or contractor) that finance, structure the project and gives it directions concerning all aspects (political, strategic and technical) and project management (PM) that designs, interprets, draws, and technically specifies the demands of the contractor. In the project described in this paper, the contractor (here the director) had not developed any program. Moreover, there was no real separation between CA and PM because everything was done internally. Therefore, CA and PM roles and decision-making scope seemed blurred. For example the chief investment defined the requirements and set the budget but he was also the one who designed the implementation and monitored the progression of the project. He prepared the solution (block diagram), validated it by the group project and operators and forwarded it to the internal "Executing project manager" who only had to convert this solution into technical plans in order to implement the project. The initial design task was therefore carried by a single person who had other duties and responsibilities to fulfill.

- The team project: When we got into the project, a small team project was merely composed of the director, the line manager, his assistants and the chief investment who was also responsible for safety aspects. Thus, economics, technics and security were the main stakes represented. After several interviews with managers and operators, we quickly understood that a large number of actors were involved in the project and were working on it by themselves. Strategic analysis of these actors, their roles, and their positioning in the project was a key element in the intervention's social building. This stressed new issues that didn't appear in the project objectives.

3.4. Experience feedbacks

As mentioned above, two relocations had already been conducted in the workshop. During an interview with the chief investment, he revealed that, in both cases, the appropriation of the new facility by the operators was tricky despite their involvement in the project. It is indeed now well known that user participation doesn't guarantee a successful design. In the two cases, the participatory approach was a consultation method for determining the operators' wishes for the future. However, this method of "consultation" does not raise the daily constraints operators have to face and their regulations to cope with them. Indeed in their daily work, they use knowledge about materials, production process, work environment, upstream / downstream conditions, etc. But in most cases, workers may not be aware of having such knowledge. Therefore, in a participative design process, the approach of future work activity may not be a mere consultation of operator's opinion, but should be based on a precise analysis and formalization of their real previous activity and their skills.

In summary, owing to a rigorous analysis of the project several assumptions were made: 1. The project content had not taken into account users' functional needs. Operators' future working situations were not anticipated when rearranging workspaces; 2. Beyond the content, the project management had deficiencies: The incomplete definition of project objectives, the lack of differentiation between CA and PM missions, the lack of mediums for the collective and participatory dimension, and the insufficient articulation of the points of view to gather. Therefore, we had a role to play to help structure and enrich the project management.

4. Structuring and enhancing project management

4.1. Coordination of actors and viewpoints

The first step was to designate an operational pilot (OP) to relieve the chief investment of the project implementation for him to refocus on its missions as contractor. This new pilot primary missions were the monitoring of the project as well as the organization and the planning of group project meetings. A supervisor finally accepted this temporary role. Being both a field actor and a manager, he was able to create link between designers and operators. Following his assignment, a new team project was constituted. The pre-established team was expanded to other key players in the process: the quality and safety officials, all engineers working on the new machines, staff representatives, logistic managers, etc. The objectives of this group were to foster the coordination of various actors, enrich the problem (the objectives) and to create links between heterogeneous opinions [13]. The approach articulated three aspects. 1. Mobilizing actors with different knowledge and promoting information exchange, 2. Giving players a common communication, negotiation and deliberation framework; and 3. Supplying the group with data from the work analysis to revisit the project guidelines and design choices

The work realized in this group has highlighted new challenges in the project (quality of pieces, storage, distribution of tasks, subcontracting, and distribution of resources). Throughout the process, these meetings were crucial because they had truly been guidance moments for design. New constraints emerged along the way (e.g. by the confrontation of the will with the feasibility) and required adjustments. Those weekly meetings were opportunities to redefine the needs and constraints and to reframe decisions in order to make the project move forward. These orientations choices corresponded to "management situations" of design process [5]. In these situations, the idea is to develop "provisional compromise updated by the confrontation of a variety of the points of view needed for the company's survival" [9]. As ergonomists our target during those meetings was to shift the compromise productions and decision-making mechanisms from the perspective of the work. Then a work analysis was necessary to achieve this objective.

4.2. Work analysis

Operators' working activity must be analyzed as early as possible during the project. Observations and interviews were conducted in the existing workshop as the redevelopment project is not starting from scratch. Indeed, the project consisted in re-implementing existing work stations and new means whose purpose was similar to the previous ones, but which were more efficient and responsive. This analysis led to an understanding of the workshop's process, operators' activities, incidents encountered, but also strategies and regulations established by the collective to solve these problems. The analysis has generated several effects. On the one hand, it brought a description of a large panel of current working situations that will exist in the future. This is called "the library of Typical Action Situations" [10, 4, 9]. Moreover, understanding the work in all its dimensions enlarges the set of technical, functional and organizational requirements to consider. This systemic vision feeds the project management and decision making process. For instance:

- Observations highlighted the additional needs for space on some workstations (storage and handling areas, maintenance access, movement and circulation around the post, etc). These needs were initially not taken into account in the project. A diagnosis of the surfaces showed that despite the area enlargement, the problem of space would continue in the future workshop. The diagnosis has been formalized in a table (Table 1) in order to debate with the group project about the detected functional needs. Based on these new data, it was decided to prioritize the items to relocate and to re-evaluate the needs of surfaces.

Table 1. Surfaces diagnosis.

Workshop	Available surfaces	Occupied surfaces (Equipment, machines, work stations)	Occupation ratio
Existing	591,9m^2	308,4m^2	0, 52
Futur	866,1m^2	522,2m^2	0,60

- Optimizing the flow was the guiding principle of the project. The analysis of flows and pathways was then required. To model the circuits of different pieces, but also carts, vehicles and pedestrians was judicious. This stressed the significant diversity of flows and pathways (pieces manufactured, containing important anomalies, needing to be retouched, etc.) as well as a circuits' crossover problematic and a lack of definition of storage areas. The observed negative impacts were 1. A security risk for operators and the disruption of their work (i.e circulation of pieces near their work station); 2. A risk to quality and production delays related to a lack of clarity concerning the origin and the destination of the pieces (static pieces, production delays, interchange of good quality pieces with faulty pieces, customer returns, etc.). The results of this analysis led to a reflection on the distribution, identification and sizing of storage areas.
- Regarding work organization, some gaps between field reality and some strategic managerial directions existed. For instance, one of the desired changes was to extend the FIFO (First In, First Out) production mode to make flows more readable and to decrease pieces' storage. Concrete aspects of work as time for adjustment on equipment or operators skills have shown that it was not possible.

In summary, each time the ergonomic analysis has highlighted new issues, it has been debated within the steering committees (project group or select management committees) in order to enrich the decision making process. The formalization of knowledge about the work was aiming decision makers, who are likely to change the project's objectives and to designers-prescribers. It was provided in the form of design guidelines helping for design solutions elaboration [7].

4.3. Design guidelines

On the basis of work analysis, prescribers and designers can be given "design guidelines". In the present case, there were three types of guidelines. 1. General guidelines related to the workshop planning (proximity or remoteness needs, visibility on other workstations); 2. Detailed guidelines on work stations layout; 3. And reflections on work organization (resources' allocation, tasks, etc.). The educational and visual formalization (on plans and photos of the workshop) has fostered their validation by operators. Then these guidelines were gathered in specifications which have been submitted to the team project. This led to an evolution of the project content. The original plan was a response to an ill-posed problem and had to be rebuilt by the team. The new project went far beyond a simple extension and reorganization of the workflow. The operational and functional specifications were a safe and clear working basis. Throughout the process, they were used as means for monitoring and comparing the objectives asked and the answer made. The guidelines were taken into account thanks to design process change. Two steps were suggested: One that determines the direction of flow and the general layout by the group project validation ; Another step in which operators were involved to define the arrangement of workstations in detail. Finally, a simulation approach was developed, in order to feed these two design phases.

4.4. Simulations of future work activity

Simulations play an integral part of the ergonomic intervention approach in industrial and architectural design projects. It is a projective method [11] contributing to anticipate future working conditions. Such simulations can be instrumented in various ways. Here we built a mock-up (Fig. 2a). This media depicts the entire workshop with a sufficient level of detail for simulating (through avatars) operators or pieces moves and flows, the collection of information, human or technical interventions on machines, visual communications, etc. Different solutions or evolutions were tested thanks to this tool. During the first stage of design, this model was used for facilitating the exploration of feasible implantation. The chief investment and the project pilot had a role to play. The aim of their participation was to bring out several solutions with providing technical knowledge and using the guidelines stemming from the diagnosis. Concerning ergonomists, the contribution lied on the consideration of work reality as well as on their abilities to innovate by dint of their outside view. This opened up the field of possibilities. An adding flow direction to the one initially chosen was raised. Some alternative implantations were presented and discussed with the group project. The target plan was finally abandoned. However, it had been decided not to fix the chosen solution in order to leave the possibility for operators to make changes. This crucial principle fostered an active and effective participation of operators during the second phase of simulation. The suggested implementation had been tested through the screen of their work expertise and operational knowledge. After several iteration, the session of simulation provided the following results: 1. The progression of the general solution (Fig 2b); 2. The definition of detailed arrangements of workstations; 3. The facilitation of operators' anticipation and projection into their future work situations.

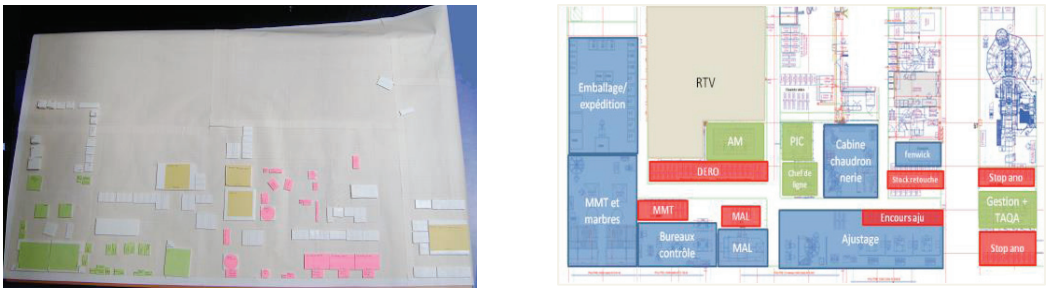

Fig. 2. (a) Simulations model; (b) General implantation.

5. Results

The final result of our intervention was an implantation proposal that met 82% of the design guidelines elaborated from work analysis (Fig. 3). Ultimately, "it is the very DNA of the project" that have evolved [3]. The new implementation had arisen from a reflection that went far beyond the mere reorganization of the workflow.

Among these developments it can be mentioned: the identification, distribution and sizing of storage areas in order to optimize flows and unclog workstations. Good quality pieces and faulty pieces were physically separated by creating areas that are suitable, materialized and visible from the controllers' offices to avoid errors. Traffic corridors were defined outside working areas to avoid activity disruption. Offices and the meeting area were far from noisy zones in order to facilitate communication between operators and with supervisors.

Conversely, the adjustment area and the control area were close together to promote exchanges between the two categories of workers. The current implementation of the new machines considers the required access for maintenance and the pieces handling by the mean of hoists.

The packing area has been completely redesigned in order to reduce the manual handling of pieces after the control operation and to facilitate shipping. Some functional areas have also been added: a parking for forklifts, a soundproof booth for boiler making operations, some functional storage spaces for offices, some extra spaces for facilitating cleaning work around the post and for machine settings.

Finally, beyond the impacts on design, the intervention had educational effects at different levels. Firstly, at the decision-makers level the intervention has encouraged the development of a contractor function and of its "decision making activity" [1]. This experience shows the benefit of helping the CA to "build the problem" posed by the investment project rather than settling it without any preliminary construction. The team management achieved a collective development of effective compromises and trade-offs by taking into account various point of views despite their contradictions.

Furthermore, work analysis has opened up new opportunities for improvements and future developments which were not included in the initial objectives of CA (i.e. on work organization and on quality for example).

Finally, the simulation sessions with operators and field managers showed that many mistakes can be avoided through their involvement in the project. Employee participation mode has evolved within the workshop. The way they are involved is no longer to collect operators' opinion but it is now to get information on their experience and know-how through scenarios of future actions. This approach has contributed to avoid malfunctions before the implementation of the project. Malfunctions could have resulted in adverse consequences for health, safety and performance of the operators in the workshop. The benefits at designers' level are the evolution of their view about work activity. The designers have learned to regard human labor as a resource to the design process instead of as a constraint. Being confronted with work situations has been a source of innovation for them in the search for solutions. Similarly, the evaluation criteria of the solution were no longer only related to the technical coherence of the system but were supplemented by functional requirements for effective work activity, quality and for preserving the health of employees.

6. Discussion

To conclude, the experiment presented here shows that an ergonomist can be a full participant in the design process. This co-designer role is possible both on the content of the project with directing its objectives and on solutions through design guidelines and simulations. But its contribution also deals with the way the project is conducted.

The method displayed underlines the importance of preliminary project analysis in order to influence the project management. After this diagnosis, the ergonomist is able to enrich and structure the project management, by building favorable conditions for efficient cooperation, consultation and collaboration, having a systemic vision of the project, integrating the different facets and making the final users participate in an efficient way.

Of course this type of intervention necessitates several conditions to be gathered to reach this result. The ergonomist must have the opportunity to start the consulting at an early stage of the project as it provides an essential flexibility. Furthermore spending much time within the company is required to understand the project

progress, to do a deep work analysis but also for social building. Indeed, to gain the confidence of both the operators and the group project can be a long process but is necessary for being considered as a full member and as an expert in the group project.

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