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Ergonomics in product design: safety factor

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Abstract

The aim of this paper is to give a number of methodological and theoretical indicators concerning the contribution of ergonomists to the execution of design projects of new products. Within the context of a design project, the present work therefore describes the studies and ergonomic analyses that can be undertaken during each phase of the design process from a design model based on concurrent engineering. Encompassing the design of the driving cabin of the new generation of high-speed trains (TGV-NG), this paper, through the ergonomic study of a number of technical sub-systems of this product, illustrates the advisory role of the ergonomist who, within the collective design process, ensures that the specific nature of the “human factor” is fully integrated into the design approach. Thus, throughout the design process, the ergonomist is called upon both to advise the designer on the characteristics of the target users and, on the basis of a “desirable future activities” approach, to help him or her assess the consequences of the design choices made. Ergonomics is described consequently, as an innovation and safety factor.

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1. Introduction

Complaints, accidents even disasters, occupational diseases, drops in both productivity and quality, increased unit costs and a high number of breakdowns are just some of the consequences of the poor design of any product or system that does not take man and his role as a factor of reliability and safety into account.

In our view (Sagot, 1999), only a multidisciplinary approach combining social sciences and engineering sciences can respond to the challenge of the human factor being given greater consideration in the design of products. Ergonomics, although

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not being the only discipline concerned by this necessary change, can contribute greatly (Chapanis, 1995; Sagot et al., 1998). Closely linked to technological development, ergonomics looks at the compatibility of man and product when co-operating. To achieve this, ergonomics relies firstly on human capabilities and even their limits to design products adapted to **the characteristics of the human component**, and secondly on studying “**human activity**” in a reference situation, the aim being not only to take into account isolated functions as was previously the case but also behavioural patterns (gestures, glances, reasoning, etc.) such as those demonstrated in current situations or those being designed (de Montmollin, 1995).

To be efficient and less costly, the ergonomic approach must start at the initial design phases with a needs analysis and be applied throughout the design process; this is then termed **design ergonomics**. This contrasts with **corrective ergonomics** involving modifications to existing products, often in very restrictive limits, to overcome problems relating to safety, health, comfort, and the efficiency of the man-product system.

In practical terms, it has been observed that in every project, even if the ergonomics-design link is starting to be accepted in theory, dialogue between engineer-designer and ergonomist still remains difficult. The engineer often blames the ergonomist of being merely an observer and conversely the ergonomist regrets that many engineers still think that a perfect product is one that reduces man's role to a minimum.

Based on the study of the design of the driving cabin of the new generation of high-speed trains (TGV-NG), the aim of this paper is to highlight the link between ergonomics and design. We shall show that the design approach adopted has the advantage of associating several partners, namely designers, ergonomists, occupational physicians and, last but not least, the drivers who were able to express their views throughout the design process, detailed studies included, in other words up to the definition of the final design. By centring the co-operative design process around the train drivers, and in a more general way, around the Man, we shall show that the ergonomist can help the designer at the various phases of the project to evaluate the consequences of its design choices, in terms of safety, health, comfort and efficiency. Predicting the future desirable activities and **simulating some of them on design simulator** will be the two main aspects of the ergonomist action, which will improve the safety of the future situations.

2. Link between an ergonomic approach and the design process

Today, new forms of industrial organisation known as “concurrent, simultaneous or integrated engineering” are being employed not only to reduce design costs and deadlines, but also to improve the quality, the value of use and the safety of products (Ciccotelli, 1997). Hence, over the past few years, for reasons of competitiveness, firms have shifted from a sequential approach to the design process to a simultaneous approach emphasising a systematic, integrated and simultaneous design of products and associated processes encompassing manufacturing, logistic support and questions relative to recycling (Solehnius, 1992; Bocquet et al., 1996; Jeantet et al., 1996; Bossard et al., 1997). The traditional hierarchical-functional

organisation is therefore giving way to a matrix organisation that intermeshes professions and projects (Bossard, 1995).

It is clear that the introduction of concurrent engineering implies changing the approach to project execution, modifying design habits and, more generally, transforming the company as a whole (Bossard, 1997). As a new design method, concurrent engineering must be capable of integrating several dimensions including the technical, human, organisational, social and economic dimensions. The role of the project leader is to co-ordinate all these tasks in terms of quality, performance, cost, and deadlines. Within this context, the contribution of ergonomics to design can take place at several levels (Fadier, 1997; Sagot, 1999).

The first places the ergonomist in **an advisory and accompanying role**, the focus mainly being fixed on the activities of designers, both at an individual and collective level. This approach, which primarily falls within the scope of cognitive and social ergonomics, aims to identify and describe the activity of designers and the underlying cognitive processes (Darses and Falzon, 1996; Darses, 1997; Béguin and Darses, 1998).

The other level of contribution casts the ergonomist as **an actor** in the product design and development process. The ergonomist thereby integrates into the project group as **co-designer**, ensuring that the specificity of the “**human factor**” is incorporated into the design approach. Throughout the process, he contributes a clearer understanding and a better representation of the users of the product to be designed in addition to various ergonomic recommendations with justified prioritisation. This article focuses on this contribution, one which remains complementary to the preceding and which is based on a **co-operative design model** falling within the scope of concurrent engineering.

Fig. 1 below, stemming from the work carried out within ERCO (Sagot et al., 1998; Gomes, 1999), attempts to illustrate this co-operative approach to the concurrent engineering based design process, by placing all those involved in the design at its centre. This design process, constructed on the basis of numerous publications in the literature, particularly those of Duchamp (1988), Calvez (1991), Quarante (1994), Bocquet et al. (1996), Pahl and Beitz (1996) is meant to be **retroactive** and **co-operative**. It is **retroactive**, as it opens up the possibility of questioning the results of preceding phases at all levels, for example in the case of the solutions proposed not being compatible with the aims of the study (Quarante, 1994), and **co-operative** due to the special relationship existing between all those involved in the project.

It has recourse to the traditional design steps, in keeping with the work of numerous authors (Duchamp, 1988; Quarante, 1994; Bocquet et al., 1996):

- **feasibility study**: first step of the analysis following the identification of needs, this highlights the problems linked to the project and allows its chances of success or failure to be assessed,
- **preliminary studies**: this involves a situation analysis phase followed by an overview phase leading to precepts, in other words proposals of solutions that should be ranked in order of importance and optimised to arrive at the final concept,

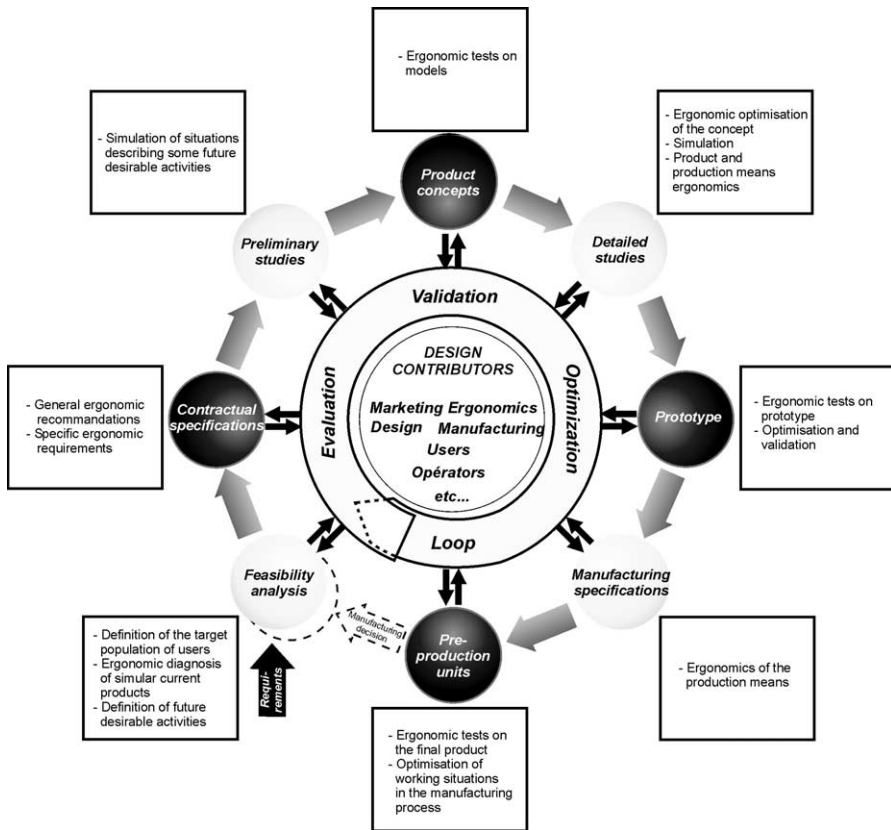


Fig. 1. Simplified illustration of the product development and design process, a process both co-operative and retroactive. The life cycle of the product intentionally finishes at the “product production” phase; in reality, this cycle continues, as illustrated by the present model, which represents the start of a spiral. This design model also describes the ergonomic activities that may be undertaken at each step (phase) of the design (according to Sagot et al., 1998).

- **detailed studies:** these consist in finalising the concept chosen for subsequent production from different points of view including technical (choice of materials, manufacturing, assembly, etc.), functional, and ergonomic,
- **industrialisation:** this step consolidates the project and marks the start of the existence of the product. It corresponds to the industrialisation phase through pilot production and mass production.

The model shown in Fig. 1 also aims to demonstrate that the development of the various tasks is gradual. For example, subsequent tasks employ some of the principle subjects of preceding tasks, but each time the level of detail or refinement is taken a stage further towards the final solution, namely “the solution that is not optimal but acceptable”. The following key steps have also been added to the figure:

- definition of the contractual specification,
- proposal of draft projects or preconcepts in our case,
- development of prototypes,

which mark and consolidate the upstream phases.

Finally, Fig. 1 shows how ergonomics and, in particular, the various ergonomic activities can be integrated into each phase of the design process. This model allowed us to describe the different ergonomic activities undertaken within the framework of the design of the driving cabin of the new generation of high-speed trains.

2.1. The need: the demand

The twenty first century is set to see the appearance of a European network of high-speed trains (TGV). These trains will travel at 350 km/h. For this kind of performance, the power, the aerodynamics, the comfort and the safety will all have to be improved. However, attaining these objectives also mean increasing number of trains, homogenisation of the driving and safety systems and a reduction in running costs. The design of the driving cabin of these trains (control desk, information devices, controls, etc.) therefore requires particular attention. It must indeed allow drivers to respond to the numerous requirements of their task in conditions that are not detrimental to **their health, their comfort, their safety and that of the passengers**.

The systemic approach to the project employed by the technical development department of Alstom Transport Division Belfort allowed the formation of a multidisciplinary working group comprising engineers, ergonomists, occupational physicians and drivers from SNCF, ergonomics and design researchers from the Université de Technologie de Belfort-Montbéliard, and researchers specialising in technical and human safety from the Université de Technologie de Compiègne (UTC). The collaboration could only involve French nationals for reasons of confidentiality, although the product is intended for a much wider geographical area than that of France, encompassing at least all the countries of the European Union.

To sum up, it was our job as ergonomists to participate in the design of a “new product”, namely a new driving cabin, the aim being to integrate the needs and requirements of the future drivers. Adequacy between the new product the future users represents for us, ergonomist, the “key to success” of technical progress, which allows to improve the safety of the future situations. The desired intervention, which falls within the framework of design ergonomics, therefore started at the feasibility study stage (Chapanis, 1995; Sagot et al., 1998), and this is described in the following section.

2.2. Feasibility studies: information search

The first step of the analysis is the information search, where the ergonomist, at an early stage in the design process when everything is possible, can help the designer, and in particular the owner, to develop the initial design orientation. To achieve

this, at needs analysis level, we propose that the ergonomist focus his activity on two complementary areas:

- definition of the target population of users,
- ergonomic diagnosis of similar existing products.

2.2.1. Definition of the target population of users

Characterising the population of future users is necessary at this early stage of the design process. The ergonomist, although not the only person involved in this approach, does play an important role. He participates in characterising both the sociocultural and biometric data of the target population not only on the basis of the work published in the literature in this field but also on that of his own measurements and assessments carried out on a sufficiently representative sample.

The sociocultural data relates to qualification and/or training, life style, cultural models, etc. Within the context of our design project, this data was examined in detail in conjunction with those of the project group concerned. Within the group, the views expressed by six high-speed trains drivers, all working in different regions of France and representing different levels of training, qualification, seniority, and experience, were particularly valuable.

As regards the biometric data of the future users, a project was undertaken to characterise the “human component” in terms of health condition, physiological characteristics and anthropometry. Thus, in close collaboration with the project group, our work as ergonomists consisted in making the designer fully aware of human capabilities and limits: physical capability, muscular strength, corporal dimensions, sight, hearing, potential means of receiving information, etc. in order to define the requirements of the task entrusted to man and to quantify the different factors that can influence the relationship between man and task. This knowledge relative to the human component, at the present time subject of numerous standards (AFNOR, 1999), can therefore help the project group to better predict the multiple effects resulting from the numerous mostly interactive relationships existing between the different components, namely man, task, product, and environment. This initial approach allows to design some **products adapted** to the “characteristics” of the future users. It also allows, very early in the design process, to integrate the specificity of the “human factor” in the new product development cycle, which improve safety and preserve health.

As an example, within the context of our project, the designer was given help in sizing the driving cabin (control desk, seat, etc.). The necessity of designing an international driving cab intended for a European and wider population for the years 2000–2030, representing the years of the product studied coming into the market and its expected life span respectively, led us to define predictive anthropometric standards. The latter had therefore to represent the 5th and 95th masculine predictive percentiles of the years in question, which came down to taking into account almost 90% of the target population. On this basis, we dismissed people either smaller or taller than our 5th and 95th predicted percentiles. To define the latter, we constructed our own anthropometric data base on the basis of international

work published over the past thirty years. This data base contains the main corporal dimensions, in particular the stature that was employed as our starting data to deduce and predict, using statistical tools, the other corporal dimensions such as leg length and arm length necessary to construct our anthropometrical standards. The models thus developed were then three-dimensionally modelled using the Computer Aided Design software package CATIA from Dassault Systems. It was then possible, by means of interfacing with the CATIA software, to animate the different corporal segments of our models at will, thereby enabling us to study postures and gestures interactively on the basis of ergonomic criteria.

Fig. 2 is a graphic representation where the volume of comfort defined from the upper limbs was constructed for our 5th and 95th percentiles, both comfortably seated and standing up, in order to optimise the seat adjustments in particular. Thus, the volume of comfort represented is common to the 5th percentile both seated and standing up and to the 95th percentile seated only (heights of 1.56 and 1.92 m, respectively with no shoes on). This figure clearly shows, according to Das and Sengupta (1995), how we were able, in conjunction with the project group, to optimise the posture of the driver at his control desk, the shape of the latter and the layout of the various controls. The position of the head and the angles of sight, the latter being expressed by solid angles, were of course taken into account so that the target and foreseen population could easily observe the track and signals as well as the information devices and controls present in the cabin while carrying out their driving task.

Naturally, knowledge of the “**future desirable activities**”, described later on in the article, was coupled to this dimensional approach so that we could draw up a series

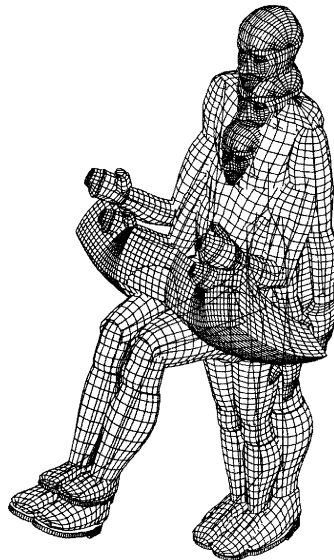


Fig. 2. Optimal volume of gripping: volume common to the 5th percentile seated and standing and to the 95th percentile in the seated position (according to Sagot et al., 1994).

of recommendations that subsequently became the subject of a conceptual ergonomic specification. This is also gone into later.

2.2.2. *Ergonomic diagnosis of existing products*

The design of a product rarely consists in the creation of an entirely new product, but rather in modifying an existing product to a greater or lesser extent. Thus, the ergonomist is well aware that it is vital at this phase of the design to carry out a complete ergonomic diagnosis of existing products, particular attention being paid to analysing utilisation activities. Here, it is the behaviour (gestures, glances, speech, reasoning, etc.) as it occurs in reference situations (de Montmollin, 1995) that is taken into account rather than isolated functions as previously.

Regarding the study of the driving cabin of the TGV-NG, the detailed analysis of the driving activity on existing TGVs was a determining factor. It was determining, according to others authors about others situations (Benyon, 1992; O'Hare et al., 1998), in that it formed the **true basis of the ergonomic initiative** aimed at developing and even transforming existing driving situations.

Thus, to be able to analyse the driving activity, three very complementary methods and analyses were used (Sagot et al., 1997):

- observations and analyses using video recordings taken in the cabin,
- verbalizations from these same films,
- verbalization with scenarios and questionnaires

The observations were obtained from 12 accompanied trips recorded on video tape; 6 drivers [three for the TGV Paris Sud Est (PSE) and three for the TGV Atlantique (A)] accepted to be recorded during two journeys. During these journeys, four cameras were laid out in the driver's cabin to allow simultaneous recording of the external environment (track and signalling), the tachometer and surrounding areas, the postures and gestures of the driver (side view), and finally his face (appreciation of the direction of glances). Processing the data concerning the description of human behaviour in the driving situation was facilitated by "compressing" the four video recordings into one and the use of the "KRONOS" software package, a product to assist in the gathering and analysis of systematic observation data (Kerguelen, 1986). The statistical results obtained allowed inter/intra individual and inter TGV comparisons of driver activity.

The verbalizations obtained from the films were primarily intended to analyse the processing modes employed by the drivers (knowledge, representation formats, inferential processing, etc.). Finally, the use of scenario and questionnaire based verbalizations, an approach complementary to the preceding, had a dual aim. First, the emphasis was not on establishing an exhaustive list of the different parameters likely to engender incidents but rather on highlighting the different categories of elements interacting with the driver-machine system and then identifying those that tend to reduce the overall level of safety. Our final aim was to focus on the driving activity in terms of both speed regulation and future desirable development.

In particular, the results showed the fundamental role of line knowledge for the drivers, thus highlighting the advantage of a tool to assist representation, memorisation and anticipation (Sagot et al., 1997).

These results stemming from the detailed analysis of driving activity on existing TGVs allowed source elements of variability likely to generate incidents to be clearly identified, typical actions to be listed (Pinsky and Theureau, 1985), theoretical shortcomings to be highlighted (De Keyser, 1987), and the unsuitability of certain tools, potential malfunctions, and their causes and consequences to be determined.

On the basis of this knowledge, and in conjunction with the project group, it was possible to progress towards what we have termed (Sagot, 1999), on the basis of the work of Daniellou (1992), the “**field of future desirable activities**”, namely activities desirable in terms of safety, health, comfort and efficiency. This definition indeed became the basis of the discussions that took place with the project group on the driving activity of future drivers. These discussions encompassed a number of essential points including the place allocated to man in the future Man–machine system, the distribution of tasks between man and machine, the help to be provided to the driving activity in terms of information assistance, and the modifications to be made to the main speed regulation system.

It should be pointed out that this description of future activities, which provided all those involved with a better overall assessment of the consequences of their design choices (Daniellou, 1992), was continually added to and refined as the project progressed on account of the various participants contributing ongoing information regarding the successive definition states of the future product. Finally, it should also be noted that the definition of the future desirable activities did not allow for all the aspects to be formalised, and rightly so. Indeed, as Daniellou (1992) also suggested, room for manoeuvre had to be left to the users who must play a determining role in taking into account aspects that are difficult and even impossible to formalise (Huguet et al., 1996). That is this room for manoeuvre of the users which will guarantee the adaptation flexibility of the future product to the environment. We identify here the concept of **ecological security** described by Amalberti (1996). This ecological security results from the protection mechanisms developed by the drivers in order to help them to manage incidental situations, and also correct their own errors. It is indeed the drivers expertise (example of the line knowledge) which allows an efficient regulation of the activity. The new systems must integrate this dimension according to Parasuraman (2000), in order to generate a positive transfer of knowledge from a system to another and thus, to ensure the maintenance and optimisation of the ecological security. If at the beginning, the majority of the designers thought that the driver was the weak link of the Man–machine system, in terms of reliability, safety, etc., they understood the importance of defining the design of sure complex systems around the Man (operator/user), by considering its operating modes, its behaviors, etc. Thus, in the control of risky systems (nuclear power stations, chemical industries, etc.), Man cannot be considered as a factor of limiting the safety and the performance, but as a strong link of any system, if of course he has been integrated very early in the design process.

A series of particularly valuable results that helped the designer draft the initial design orientations stemmed from these analyses, which were carried out very early in the process. These orientations resulted in the drafting of the contractual specification where, as ergonomists, and in conjunction with the project group, we were able to make a series of recommendations and requirements which, for the sake of simplicity, were at two levels:

- **general recommendations:** these were primarily based on ergonomic norms and standards, account taken of the assessment we were able to make;
- **project specific ergonomic requirements;** in this context this meant integrating and clarifying the functional needs of the future users which mainly stemmed from analysing the activity on existing products and was based on the description of the future desirable activities.

2.3. Preliminary studies

Dedicated to seeking solutions, this preliminary design phase allows the development of pilot studies or preconcepts that take into account the contractual specifications and the validated definition of the field of future desirable activities. It allows initial responses to identified needs to be expressed.

The ergonomist now plays an advisory role, traditionally the domain of designers, at this stage of the design and as such participates in the definition of preconcepts by communicating his analyses of the “utilisation” function of the various preconcepts being studied. His analysis is partly based at this stage of the design on **developing scenarios** aimed at recreating **fictitious but realistic activity situations** (Maline, 1994) in keeping with the definition of the field of the future desirable activities. Staging scenarios from simulation allows the ergonomist to guide the designer in his technical choices. This **theoretical simulation** remains a **very effective prospective method** (Maline, 1994; Zwolinski et al., 1998; Sagot, 1999). It indeed allows an understanding of the future situations of the users and therefore identification of **the probable impact on their safety**, health and comfort resulting from the technical and organisational choices made.

As an example, during the initial design phase, several Man-machine interface (MMI) preconcepts linked to speed regulation were proposed by the project group on the basis of the contractual specifications and the definition of the field of future desirable activities. This MMI comprises two parts, namely **a hardware part** for the traction/pulling-braking command and a **software part** corresponding to the associated information. Several of these preconcepts were firstly the subject of virtual models on which theoretical simulations were conducted to allow the staging of scenarios recreating certain conditions of carrying out the future desirable activities. These virtual models genuinely facilitated dialogue between all those involved. Two MMI preconcepts were retained by the project group. These were later the subject of interactive physical models using rapid prototyping software including the VAPS software (rapid interface prototyping software). One of its strong points is that once

the interface has been created in the environment, it is possible to generate the corresponding operational prototype on any type of machine. We were thus able to construct an assessment system which grouped all the devices relating to speed regulation (traction-braking control associated to the driving assistance visual interface, audible alarms, etc.), the visual environment of the track (videodisk), the cabin noise environment, etc. This assessment system (Plate 1) was equipped with several computers that reproduced the real behaviour of a real TGV train. This allowed us to carry out simulations in the presence of the drivers to assess and validate the two MMI preconcepts proposed.

Six SNCF drivers, experts in driving high speed trains, took part in these assessment tests. During these tests, we simulated **imposed driving scenarios** supplemented with **scenarios reproducing certain conditions of carrying out the future desirable activities**. The imposed driving scenarios were intended to assess the preconcepts in extreme cases of utilisation (emergency stop, very high acceleration, etc.). This simulation allowed us **to propose modifications to the preconcepts** tested as the results came in. The feasibility and the level of integration of the solution were able to be validated in successive steps in relation to their functional and operational aspects (Zwolinski et al., 1998).

The drivers were very much involved, thereby leading to the definition of a MMI concept linked to speed regulation that was not the only solution but the solution acceptable to the project group that would be studied in greater detail during the following design phase.



Plate 1. Assessment system to study and validate the different MMI preconcepts retained.

2.4. Detailed studies

This design phase involves moving from a model that demonstrates feasibility, as mentioned above, to a **prototype product**. This prototype product validates the requirements of the contractual specification, which for us, are all the ergonomic recommendations, both general and specific.

The prototype product also has the correct geometry, the final materials, etc., in keeping with the requirements of the contractual specifications.

During this design phase, the project group focuses on optimising the concept retained in order to create a prototype that integrates all the criteria linked to its production (technical principles, choice of materials, manufacturing, assembly, etc.). (Sagot et al., 1998).

The ergonomist continues to support the designer by carrying on with his ergonomic tests. This time, these are conducted on the prototype, still with representative potential users. These assessments and validations, which take place in an environment as close as possible to reality (Maline, 1994), are again based on scenarios simulating certain conditions of carrying out the future desirable activities. These experiments, which let the potential user “converse” with the new product, contribute a great deal of information to the project group and allow, in particular, verification of certain forecasts and correction of certain problems, which can affect the people safety and health, that had not appeared during the previous phases.

As regards the detailed studies, a “study and design simulator” was set up (Plates 2 and 3), to assess, amongst others, the MMI concept linked to the previously mentioned speed regulation.

To sum up, this simulator represents the interior of the future TGV cabin, with real dimensions and a full scale driving position where the various prototype driving



Plate 2. Exterior view of the study and design simulator for train driving.



Plate 3. View of the interior of the study and design simulator for train driving.

controls are laid out in the required positions. The visual environment of the track is reproduced by means of a videodisk, and the noise environment is simulated by judiciously placed loud speakers connected to a computer which reproduces the different sounds of a TVG locomotive. As for the test system, the simulator reproduces the real behaviour of a set of high-speed train.

The rapid prototyping tools mentioned previously allowed us to design the speed regulation MMI prototype in conjunction with the project group. This MMI comprises a pulse-driven traction-braking controller associated with a driving assistance visual interface. The prototype controller supplied by Alstom Transport, combined the three speed regulation functions which at the present time are separate: electric braking and traction force control, pneumatic force control and emergency braking. At the present time, these three functions are dissociated and distributed between three different controllers. This represents a significant modification compared to the existing devices which, despite their shape and lay out changing over the years, have always been separated. The new driving philosophy, validated by the project group which of course included drivers and ergonomists, is thus very different from that existing at present. Finally, it should be pointed out that this MMI represented only a sub-technical system of the driving position.

Twelve drivers in total took part in the three-stage assessments on the “study and design simulator”:

- **preliminary experimentation**, which both served as a familiarisation phase and allowed adjustment of the simulation system,
- **verification of the correlation between the task and the means to carry out the task** during which the drivers re-enacted imposed type scenarios,
- **overall assessment in a simulated driving context** where, this time, the drivers

re-enacted scenarios termed “free driving”, whilst respecting the instructions normally given to them in the field.

Several modifications were made to the MMI prototype on the basis of all the results obtained and the resulting discussions that took place within the project group. These validation tests carried out on the product prototype using an investigation tool (simulator), the aim being to produce **iterative design-assessment-validation loops** in conjunction with the project group, indeed allowed a number of forecasts to be verified with all the members of the project group. A number of problems that had not shown up during the preceding phases were identified and corrected by integrating the various professional points of view. It should be pointed out that the approach was meant to be global, participative and iterative. In particular, it was founded on a problem solving methodology where the ergonomist played an advisory and accompanying role during the search for the acceptable solutions which emerged from the design team.

A prototype speed regulation MMI was thus able to be validated and optimised in laboratory conditions (realistic and non real conditions), constituting the acceptable solution in technical, ergonomic and economic terms.

It should be stressed that the “realistic conditions” of the ergonomic tests carried out in the detailed studies can in no way be a substitute for real conditions where new difficulties may arise and new functional needs of users may come to light. Thus, as regards the MMI prototype studied, it is vital that it is tested in real situations in order to carry out the final validations, a fact accepted by the project leader who validated the principle of an ergonomic assessment being carried out on the prototype driver’s cabin to be installed on the test train. Also worthy of note is that at this stage of the project, the driving cabin will be completely finalised in technical, ergonomic and aesthetic terms, and will therefore integrate all the driving systems, including the controller and associated interface, described in this paper.

2.5. Industrialisation

In a logic of concurrent engineering, the industrialisation of the product currently being developed, and in particular the ergonomics of its future means of production, begins very early in the design process during the detailed studies, as mentioned in Fig. 1, and even earlier depending on the design projects. This paper primarily focuses on the ergonomics of the product, and therefore does not go into the ergonomics of the associated production facilities in any detail. However, the importance of the role of the ergonomist within the project group should be pointed out, in particular his advisory role, as his task is to monitor, verify, assess and validate the realisation and start up of the means of production by ensuring that the specificity of the human factor, in other word a safety factor, is indeed integrated into the design approach. It should also be mentioned, in keeping with our work (Sagot et al., 1998; Sagot, 1999), that the ergonomist can employ the same approach as that described in the feasibility studies. Here, however, the studies and analyses focus on the manufacturing population and the future desirable activities of the operators as well

as the workload factors linked to the means of producing the product. In the same way, on the basis of the definition of the field of future desirable activities, the ergonomist can therefore draw up recommendations concerning work organisation, work station ergonomics, the ergonomics of buildings, etc. (Sagot and Zwolinski, 1996).

3. Conclusion

The aim of this paper was to give a number of methodological and theoretical indicators concerning the contribution of ergonomists to the execution of design projects of new products. The aim was never to present a ready-made and fixed procedure regarding ergonomic intervention, bearing in mind the question raised by Falzon (1993) and more recently by Grosjean and Neboit (2000), namely “will it ever really be possible to arrive at a procedural activity”.

From a design model based on concurrent engineering, we place the contribution of the ergonomist as an actor in the product design process. From a design model based on concurrent engineering, the role of the ergonomist is one of an active participant in the process.

The ergonomist thus integrates into the project group as an advisor who ensures that the specificity of the “human factor” is incorporated into the design approach. His analyses, which are based on knowledge, methods and tools, allow him to:

- advise the designer on who the user is, in order to design products adapted to his or her ways of working, expectations and needs,
- help the designer assess the consequences of the design choices made in terms of safety, health, comfort and efficiency.

As Roussel and Lecoq (1997) pointed out, the ergonomist will not stop, as is often the case, at an ergonomic diagnosis of existing products conducted within the framework of feasibility studies, but will carry on advising the designer on his or her choices, based on:

ergonomic standards (Sanders and McCormick, 1992), which are strict rules regarding the design, assessment and use of products, as they are based on knowledge of man, his capabilities and even his limits, ergonomic tests, which the ergonomist carries out throughout the design process, based on **staging scenarios simulating certain conditions of carrying out future desirable activities** (in terms of safety, health, comfort and efficiency) on **interactive models** (virtual and physical) and **prototypes** (Sagot et al., 1997, 1998). These supports, also termed “intermediate design objects” (Jeantet, 1998), are real “co-operation and design assistance tools”.

By considering the knowledge on the human characteristics, the real activity and the future desirable activities, the ergonomist will be able to help the designer to define adapted and adaptable products. We highlight the importance of the simulation of future desirable activities, which helps the ergonomist, integrated in the project team, to project himself in the situations in which the users will be. Thus it

will be possible to specify the probable consequences of technical and organisational choices on the users security, health and comfort.

The ergonomist plays a vital role within the collective design process and is therefore a true **partner**. He has been described as a real **co-designer**, being very efficient in assessing and organising into a hierarchy the proposed solutions.

Finally, within the framework of this project, we can mention that the concurrent engineering as new design organisation, crossing trades and projects, was not very easy to apply if we consider the various trades involved (aerodynamics, electricity, mechanics, etc.). However, in this new organisation, in spite of the differences of culture among the various actors, the human factors and safety dimensions have federated all the points of view not only around the product technical performance but around the Man as agent of safety and reliability of the system.

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