A cognitive analysis of collective decision-making in the participatory design process

Françoise Darses
Laboratoire d'Ergonomie, Projet EIFFEL
CNAM–INRIA
41 rue Gay Lussac
75005 Paris, France
darses@cnam.fr
(33) 1 44 10 78 07

ABSTRACT

In this paper, we examine, from a cognitive standpoint, the issue of collective decision-making in participatory design groups. These multi-occupational group (manufacturing operators, foremen, maintenance mechanics, the method agent, the shop foreman, draftsmen, etc.) are asked to redesign the equipment of a production line in a factory manufacturing steel tubes.

Our analysis is focused on the cognitive side of the redesign activity, and especially on the collective evaluation processes. From the transcripts of the meetings, we have examined how the co-designers come to an agreement about the redesigned equipment. We show that the criteria sponteneously used for the evaluation of the solutions are far wider (quantitatively and qualitatively) than the list of functional criteria prescribed to the co-designers for the decision-making process. This study has led to the development of an evaluation method, named CRITERIA, which is briefly described.

Key words

collective design process, cooperation, collective decision-making, evaluation, criterion

Acknowledgements

We would like to thank Catherine Sauvagnac for the many fruitful discussions we had about the study, as well as for her contribution to some parts of the analysis reported in this paper.

In *PDC 02 Proceedings of the Participatory Design Conference,* T.Binder, J.Gregory, I.Wagner (Eds.) Malmö, Sweden, 23-25 June 2002. CPSR, P.O. Box 717, Palo Alto, CA 94302 cpsr@cpsr.org
ISBN 0-9667818-2-1.

INTRODUCTION

In this paper, we examine, from a cognitive standpoint, the issue of *collective decision-making* in participatory design groups. This issue arises when the degree of participation is the highest (Jensen, 1997), that is, when all concerned partners are joint to the decision-making process. In these participatory groups, the stakeholders are not only requested to give opinions and suggestions about the future work displays: they are asked to play a role of *co-designer* in the design process.

In our case, the participatory design project aims at *redesigning the equipment of a production line.* The equipment is redesigned by a multi-occupational group (manufacturing operators, foremen, maintenance mechanics, the method agent, the shop foreman, draftsmen, etc.). These people are asked to provide insights for improvements that could be made towards redesigning equipment, in order to increase production quality, product maintenance, product cost, possible transfer to other machines, reusing equipment designed for other uses, etc.

We have analyzed how this redesign process is performed by the group. Do the methods adopted to support the design process meet the co-designers' objectives? Are all viewpoints really taken into account when selecting the solution? How is the collective evaluation of the new equipment performed?

The results presented in this paper go beyond the field of manufacturing industry. They can be applied to any collective design activity (such as concurent engineering or integrated team design), where stakeholders representating various expertises are gathered together in order to design an artefact.

COLLECTIVE DECISION-MAKING IN THE PARTICIPATORY DESIGN PROCESS

(Re)designing does not mean finding the best solution to a given problem, but finding an optimal and acceptable solution with respect to many different criteria (Simon, 1973; Goel & Pirolli, 1989; Darses, 1991; Darses et al., 1996). A single best solution to a design problem does not exist. Alternative solutions can be proposed and compared, but they can hardly be ranged, because one solution will always be better than another regarding a given criteria. Thus, the selection of one solution from the set of the proposed solutions is based on a multi-criteria assessment. This means considering all the fields related to the object to be redesigned, not only the technical aspects but also the social and organisational ones.

This systemic analysis of a problem is at the core of the decision-making process, and is indeed one of the crucial stages of the collective design process (Rasmussen et al., 1991). During this stage, the evaluation of the various solutions is essentially supported by the comparison of the *evaluation criteria* that are put forward by the participants of the design groups during their discussions. The definition and the weighting of these criteria is built and modified through the participants' interactions. The design process requires the integration of all the parameters of the artefact, whether they be technical, social or organisational. Through this comparison of different parameters of the design situation, the co-designers' viewpoints are broadened and enriched.

All these cognitive activities do contribute to the decision-making process. Non-participatory design processes – that is to say, design processes including only "designers by trade" – do have a number of tools to support the decision-making: design methodologies such as functional analysis, CAD simulation or prototype development are the traditional resources of designers to support the solution development cycle, to evaluate the various solution proposals and to make the right design choices.

But in the participatory design processes, most of the participants of the group are *not designers by trade*. The involvement in the design process of stakeholders such as manufacturing operators, foremen, maintenance mechanics, the method agent, the shop foreman, draftsmen, etc., reinforces the difficulties arising during the decision-making stage, since these co-designers have to create their own methodological tools to generate and evaluate the solution proposals.

What are these tools? What are the specificities of such collective evaluation processes, in which the stakeholders' viewpoints are not of the same nature of the traditional technical ones? What is going to differ in the decision-making process? Will the criteria be different? Will the evaluation modes change? This study is aimed at answering some of these questions.

DESCRIPTION OF THE PARTICIPATORY DESIGN ORGANIZATION FOR THE REDESIGN OF MANUFACTURING LINE EQUIPMENT

The factory in which we conducted our study is a subsidiary of a large steel consortium. It manufactures welded stainless-steel tubes for the automobile, chemical, food processing, medical equipment and building construction sectors. Participatory redesign took place in the *manufacturing* department, which had approximately 60 employees, including approximately 40 manufacturing operators, several foremen, a shop foreman, two method agents and several maintenance mechanics, as well as tool and die makers.

Tube Manufacturing

The manufacturing of steel tubes is conducted on TIG lines, so called because of the welding process used. The forming of the tube is done by shaping a sheet of steel with various shaped rollers, which are large pieces of bronze set on axles. The joint is welded, then hammered and polished. The tube is annealed and sawn off at the end of the line, at the length required by the client. It is then packed, ready for shipment.

The production of tubes of different diameters requires the dismantling and assembling of such line equipment as rollers, straightening and hammering tools, support saddles, axles, etc. These operations have become increasingly frequent (due to smaller batches which are specific to each client), quite long (at least 8 hours for a complete equipment change) and physically demanding (the equipment is very heavy). It is shift work (3x8 hours) and each team is responsible for a specific line. The adjustments made during the assembly process and later on when the work is underway determine production quality. It is this activity that demands all of the operators' knowledge.

The Collective Redesign of Equipment in SMED Groups: a Participatory Design Organisation

Description of the SMED Groups

The ergonomic study (for a full report, see Darses, 2002) began with a request made by the production engineer in charge of the manufacturing department. He wanted to have the opportunity to evaluate the benefits and limitations of the participatory redesign groups in charge of redesigning equipment so as to reduce dismantling/assembly time. These groups were assigned numerous objectives, in accordance with the quality policy: to increase production, to standardise procedures, to improve quality and to improve safety. To reach these objectives, two participatory redesign groups were settled, which brought together 5 to 7 people per group depending on the work rotation, for two years in bimonthly meetings. The profiles of the participants varied according to their position, status and seniority in the company. They included manufacturing operators, foremen, maintenance mechanics, the method agent, the shop foreman and draftsmen.

The Redesign Process Followed by the SMED Groups

The groups were asked to apply the SMED methodology - Single Minute Exchange Die - developed by Shingo (1985) to redesign the equipment. Starting with an approximately 8-hour-long video filmed during an equipment change, the group began by isolating the problems involved in dismantling/assembling by measuring the time required for each operation, i.e. the dismantling/assembling of anchor plates, the drop hammer, etc. These problems were dealt with one by one during the bimonthly meetings of each group.

Since the participants of these groups were *not designers by trade,* they had to create their own methodological tools to support the solution development cycle. Here, these tools took the form of a problem-solving methodology. It was made up of three sequential stages:

- The first stage is dedicated to an ***analysis of the problem***, by applying a frame called WWWWHHM. The method prescribes to answer the following questions in order: *Who? What? Where? When? How? How Much?*
- The second stage consists in finding a ***solution to the problem***: various solutions are put forward and written down on a board and, in principle, none are immediately rejected.
- The last stage consists of an ***individual vote.*** The solutions are judged on the basis of eight criteria that had been pre-established by the production engineer. These are: *cost, efficiency, safety, accessibility, reliability, simplicity of the system, creation time, installation time*. Each participant gives a score for each of the criteria related to the proposed solutions. The solution with the highest global score is chosen.

The SMED redesign groups adopted a strictly democratic decision-making process. Decision-making authority was not attributed to a specific trade or actor chosen in advance. The method officer ran the meeting, saw to it that the methodology was applied, wrote down the problems and the proposed solutions and tallied the vote, but had no preponderant decision-making role. Likewise, the shop foreman had no official privilege in decision-making, although his position gave him a say in the follow-up to decisions made during meetings. As for the manufacturing operators, though they were seen to be expert about the operational modes and about the process, they had no more decision-making authority than the others.

The method officer was likewise responsible for the technical implementation of the solution adopted. Depending on their complexity, these solutions were either submitted for study to the methods office, or sent directly to the new works department or executed by the method agents themselves in the case of the simplest problems. Prototypes were submitted to tests and definitive solutions were then installed on the lines.

METHODOLOGY DEVELOPED FOR THE ERGONOMIC STUDY

A six-month pre-study led us to establish two levels of complementary analysis which were required to draw up the collective redesign processes: a macro-analysis of the organisational context, and an in-depth analysis of the SMED group meetings.

Juxtaposing Two Complementary Levels of Analysis

The macro-analysis focused on the requirements of the organisational context in which collective redesign was implemented. It was conducted through a regular assessment of the group's work, on collective and individual interviews and on a study of the minutes of the meetings, as well as on the test sessions of the proposed prototypes. This level of analysis stresses the communication paths and inter-department relations, the links with other continuous design endeavours, the role of the actors involved in the process, etc. But we had to go deeper into the functioning of the SMED groups in order to identify the collective redesign processes. This in-depth analysis focused on a cognitive approach of the meetings held by the groups, and especially on the debates related to the evaluation of a proposed equipment.

The analysis presented in this paper was conducted on the transcripts of *five* meetings of one SMED group, each of which lasted two hours. These meetings were chosen because: (i) they focused on important equipment problems and (ii) the issues of these meetings were dealt with within the time scale. They focused on the redesign of two pieces of line equipment, namely the *drop hammer* (which flattens the welding line on the tube), and the *straightening head* (which straightens the tube into a precise horizontal line). With the participants' consent, the five meetings were tape-recorded. The participants to the meetings could vary, according to the rotation of work. The method agent who ran the meetings and the shop foreman were always present. The other participants included at least one manufacturing operator out of the three in charge of the line, and depending on the production requirements, one or two foremen, and one or two maintenance mechanics.

Method of Cognitive Analysis of the Meetings

The cognitive analysis is based on the rationale that the collective decision-making is at the core of the redesign processes and is essentially supported by the comparison of the *evaluation criteria* of the new equipment that are put forward by the participants of the SMED groups during their discussions (Mac Lean et al., 1991; Cross et al., 1996; Bonnardel & Sumner, 1996). These evaluation criteria were extracted from the transcripts of the meetings and were examined.

A *criterion* is defined as any judgement of a solution that is supported by an argument. For example, in the sentence *"it doesn't* ***cost*** *too much to make* ***adjustment screws****"*, the artefact *"adjustment screw"* is considered to be evaluated by the criterion *"cost"*. Other examples of criteria are reported in bold in the protocol excerpt shown below.

Method agent	That means ... changing the axle and the support saddle, doesn't it?
Manufacturing operator	What's more, it'll **always have to be supported [CR 1].**
Shop foreman	You're right, but there'll be **nothing to target [CR 2].** As it is now, we have to target the braces, bearings, everything.
Manufacturing operator	Yeah, but it'll **have to be supported [CR 3].**
Shop foreman	Ok, **support it and put in a bolt [CR 4].**
Method agent	But is there a chance of running into a problem if ... ?
Shop foreman	Well, we can build in a tiny bit of play **so we can assemble it [CR 5].**

Figure 1 Excerpt from a SMED group discussion

We have extracted 444 occurrences of evaluation criteria expressed during the meetings. For the qualitative analysis, these occurrences have been characterized, according to the object being evaluated and according to their level of formulation. The quantitative results take into account the possible repetitions. For example, in figure 1, we will not count twice the occurrences **[CR 1]** and **[CR 3]**, since they are formulated in the same way by the same person. But we will count two different occurrences for **[CR 3]** and **[CR 4]** because the formulation differs, and the locutor as well.

RESULTS: IDENTIFYING THE COGNITIVE PROCESSES PERFORMED DURING COLLECTIVE EVALUATION

The results of the study are presented in the following sections. They show that the restricted set of prescribed criteria which was established by the chief engineer do not allow a full assessment of the solutions. These problems with the prescribed criteria used by the group for the evaluation of the new equipment lead us to analyze the whole set of criteria spontaneously formulated during the debates.

The Solution Cannot Be Assessed Through a Restricted Set of Pre-Established Criteria

Before our ergonomic analysis could be undertaken, the decisions of the redesign groups were based on a list of 8 functional criteria that had been pre-established by the management, namely *cost, efficiency, safety, accessibility, reliability, simplicity of the system, creation time, installation time.* We call them " prescribed criteria ". These criteria, previously set up by the chief engineer, were the basis for a decision-making grid, from which the solutions were compared and selected, according to their ranking position. For instance, co-designer X will give *n* points to the *efficiency* criterion for solution A, because in this case, it is said that " *the efficiency of the ball-bearings, it will not be so good* ".

As explained in the next sub-sessions, two types of problems occurred with these pre-established criteria: they are polysemic and they provide a narrow view of the process.

Problems with the polysemy of the prescribed criteria

We observed many problems when using the prescribed criteria list. First, the way in which these criteria were formulated was itself open to various interpretations. The participants found it difficult to agree on the meaning of such a criteria when it was time to rank the solutions and to select one of them. For example, *efficiency* could mean (i) *suitability of the solution* with respect to the process or (ii) *ease of installation* of the new equipment. This polysemy in the criteria led to some dissension and misunderstanding during the decision-making stage.

Problems with the restricted view of the process provided by the prescribed criteria

Another problem is that these prescribed criteria did not cover the set of criteria that were spontaneously debated during group meetings. Only 146 of the 444 occurrences of the criteria spontaneously expressed during the meetings (that is to say 30% only) belonged to the set of prescribed criteria. Some of the criteria spontaneously formulated were, among many others: *time, easiness, acoustics, ease of assembly, gestural easiness, strain, assembling frequency, handling, hardness, weight, posture, SMED rationale, quality, rapidity, task suppression, time savings.*

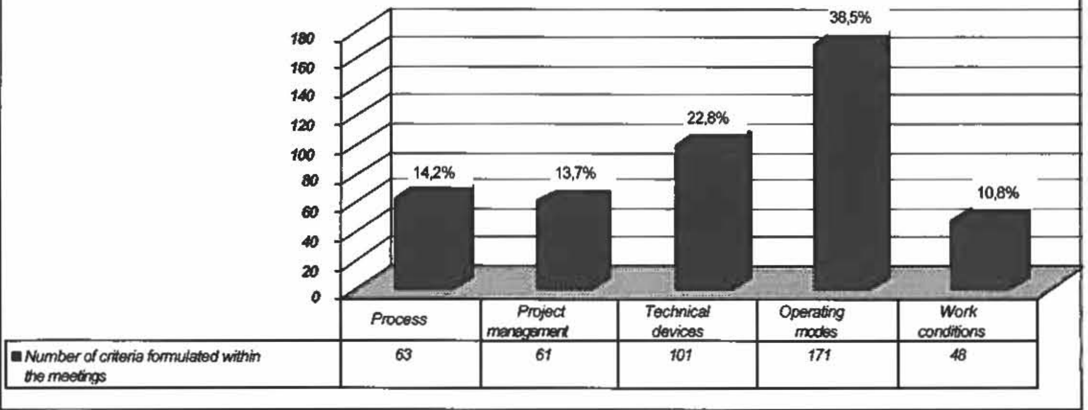
The "Spontaneous" Evaluation Process Is Based on Five Criteria Registers of Reference

These problems with the prescribed criteria used by the group for the evaluation of the new equipement lead us to analyze the whole set of criteria spontaneously formulated during the debates. The analysis of the transcripts reveals that the participants in the meetings were led, through the debates, to explore five different fields in which each solution would be applied. We call these " registers of reference " to stress the fact that the assessment of the solution refers to a set of complementary viewpoints from which the problems are analyzed and the solutions are thus judged (Garrigou et al., 1995; Blanco et al., 1996; Darses & Sauvagnac, 1997; Martin et al., 2000; Darses 2002). These registers of reference are:

- *Effect on the process* (eg, a solution would be rejected if the tubes are not straight);
- *Operating modes* (eg, a solution is deemed interesting because it eliminated the need for the adjustments and centring of rings);
- *Work conditions* (eg, the redesigning of equipment must lead to lighter physical loads);
- *Technical devices* (eg, the technical limits of solutions are judged);
- *The management of the SMED project* (eg, solutions were judged in terms of the cost and the return on the investment).

We have categorised and sorted all the criteria according to these reference registers, as shown in figure 2 below. This shows how each reference registers contributes to the assessment of the solutions.

Figure 2 Proportion of criteria used for the evaluation of the solution (all meetings taken together according to the five different reference registers.



We see that the register of reference *operating modes* is strongly represented, (i) due to the objective of the design group (the redesigned equipment is to be handled during dismantling/assembly of the production line), and also (ii) due to the fact that the future users of the redesigned equipment (the manufacturing operators) are involved in the team. These two reasons explain why the operating modes are of crucial importance in judging the solution.

It is worth noting that all of the reference registers are used, although some of them only concern the participants in the meetings indirectly. For example, the register "*Project management*" is much used to assess the solution, although it mainly concerns the production chief engineer (who does not belong to the redesign group). We thus observe that all of the fields in which potential solutions could be applied are explored through evaluations, even those not closely related to participant's concerns.

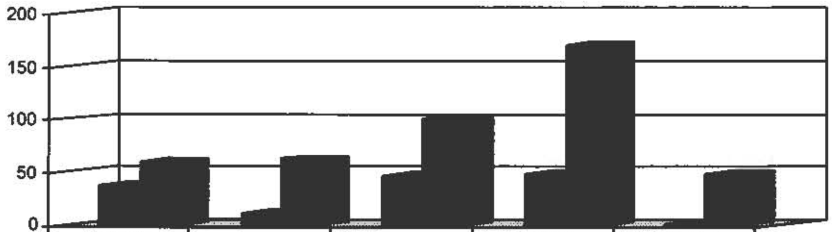
These results show that the participatory meetings foster the examination of the various registers of reference from which the solution is assessed. Individual viewpoints are enlarged and a systemic view of the problems is built when redesigning the equipment. Such a participatory situation brings together various viewpoints, for the purpose of recreating the system in which the continuous design objects take their meaning.

Comparison of the Use of Prescribed Criteria/All Criteria According to the Registers of Reference

We made a comparison of the use of *prescribed criteria* versus *all criteria* which were formulated during the meetings, according to the registers of reference they belong to.

The results, as shown in figure 3, point out that the decision-making process is implicitly performed on the basis of a much larger set of criteria than the pre-established ones. The proposed solutions, if evaluated only through the set of prescribed criteria, are thus assessed in a restrictive fashion. Moreover, the prescribed criteria list favors the evaluation of the solution regarding some reference registers rather than are others: *operating modes* are under-evaluated by the prescribed criteria, as are the *working conditions* and *process criteria*.

Figure 3 Use of prescribed criteria when evaluating the solution, compared with all the criteria formulated during the debates (all meetings taken together), according to the five different reference registers.



	Project management	Process	Solution	Operating mode	Working conditions
■ Prescribed Criteria	38	11	46	49	2
■ All criteria	61	63	101	171	48

Using Complementary Levels of Representation of the Solution

The analysis of the meeting transcripts has also highlighted that the decision-making process is far to be performed on the only basis of a functional representation of the problem. A *functional representation* is very close to the functional analysis formulation. It is supported by functional criteria, as for instance, *easiness, efficiency, reliability*, etc. It is worth noting that all the prescribed criteria are formulated on a functional level.

We show that the assessment of the solution is rather performed through *low level* criteria, these being *structural* and *operational*, as figured below (see figure 4). Most of the criteria (47,7%) are expressed at a *structural* level, focusing on the structure of the equipment being debated, i.e. the materials, forms, volumes, etc. For instance, the co-designers said "*the problem that we have with that is that bearings might give*" or "*that's going to leave marks on the tubes*", "*the crankcase must be soundproofed*", "*make sure that the height of the tank be adjusted*". The co-designers also use a large number of *operational* criteria, such as "*the problem with that is that you have to support the roller with your hand in an uncomfortable position*" or "*what's more, it'll need a nut*", "*it'll still have to be carried*". These criteria refer directly to the user's actions when using the equipment.

One of the most surprising results of this study is that the *functional criteria* which were expressed during the debates only represent a small proportion of the total criteria spontaneously expressed to evaluate the solution (27,5%).

This result stresses that the decision-making process relies much more on a concrete and instanciated view of the solution, than on an abstract and functional representation of the object to be redesigned. We could assume that this phenomena is linked to the fact that the members of the redesign team are not designers by trade, and do not master the "right" technique for design. But this result is in keeping with a number of studies (Visser, 1990; Nicolas, 1996) which have shown that designers, even during the functional phase, will tend to use a concrete representation of the object rather than a functional one.

Thus, the assessment of the problem and of the solution requires the use of complementary levels of criteria, with a clear preference for the use of "low" and concrete levels of representation, as the structural and operatinal ones. This must be taken into account when conceiving participatory decision-making tools or methods.

Synthesis: Performing the Collective Evaluation Process on the Basis of an Expanded Set of Criteria

The cognitive analysis of how the evaluation is performed in the participatory design groups highlights that:the restricted set of prescribed criteria established by the chief engineer does not allow a full assessment of the solutions because of:

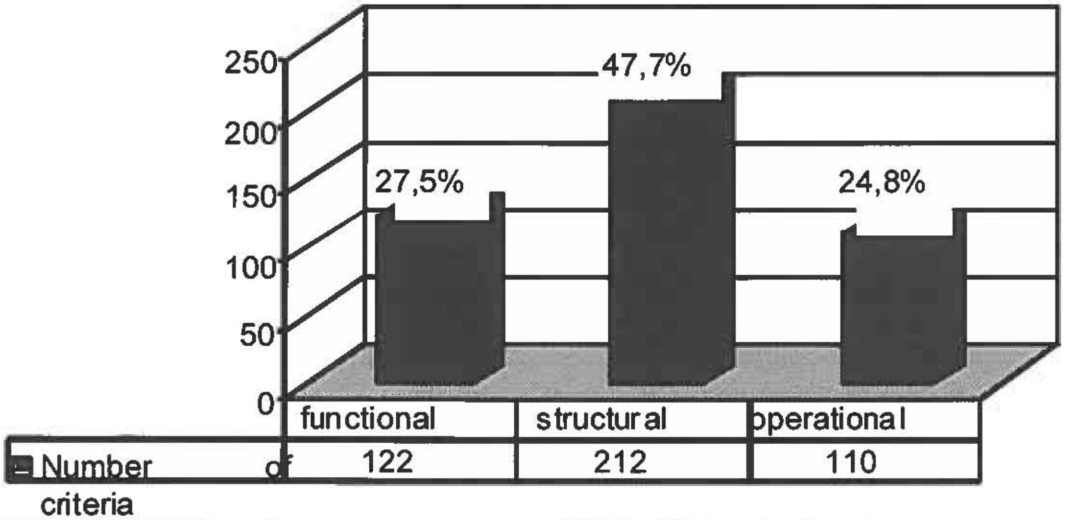
- the polysemy of the criteria
- an insuffisant coverage of the parameters to be evaluated.

The analysis of the whole set of criteria spontaneously formulated during the debates show that:

- The solution is assessed by the way of criteria which belong to complementary registers of reference, which are not equally represented within the set of prescribed criteria. This introduces a bias in the evaluation process, some of the registers of reference being under-evaluated (especially here, operating modes, process and working conditions).
- The evaluation criteria are not homogenously formulated at an abstract level of representation (called functional level). This level is the one adopted by the prescribed criteria, whereas two complementary levels (structural and operational) do represent many other criteria.
- The solution is poorly assessed with the functional criteria, since these are very weak in accounting for the designers' representations: the co-designers mainly base their decision on concrete and operative criteria. Accordingly, the decision-making process, as based on a set of functional criteria, does not integrate all design parameters and restricts the decision sphere.

Accordingly, all criteria can be characterized along two complementary lines (figure 5). One line describes the register of reference to which

Figure 4 Level of formulation of the criteria used for evaluating the solution



the criteria belongs, and the other line describes the level of abstraction in which the criteria is formulated.

These results have led us to build a new methodology for decision-making, which is presented in the next section.

		Level of Abstraction		
Register of Reference		**Functional**	**Structural**	**Operational**
	Project management	It'll take a long time	That'll lead to a lot of work	
	Process	The efficiency of ht eball bearings, it is not so good	If we do this, it'll leave marks on the tube	
	Operating modes	The point is the speed of taking it down	The screws have to remain accessible	What's more, it'll need a nut
	Working conditions		You'll have to work on soundproofing at the same time	It'll still have to be carried
	Solution	It's just too costly to keep a straightening head like that	You'll need to make sure the height can be reduced	

Figure 5 All criteria are classified along two complementary dimensions : (i) register of reference and (ii) level of abstraction

CRITERIA: A DECISION-MAKING METHOD TO SUPPORT THE PARTICIPATORY DECISION-MAKING PROCESS

The results presented above have led us to develop a participory design method called CRITERIA, which aims at helping collective decision-making. The rationale of CRITERIA is to foster the explicitation of the numerous criteria spontaneously expressed in the course of the design meeting.

CRITERIA's first goal is to scrutinize a wide range of reference registers. This forces to evaluate the solution on the basis of a comprehensive set of application fields. Thus, a systemic view of the design problem can be built and shared by all participants. In keeping with spontaneously expressed evaluations, the second goal of CRITERIA is to allow the explicit formulation of *complementary levels of criteria*, in order to avoid, as far as possible, functional judgements in favour of structural or operational judgements. The structural and operational criteria (eg. " guiding a piece, no aiming required, can be adjusted "), were grouped together with a related functional criteria (eg " system simplicity ").

As shown in figure 6 below, a grid was provided to the co-designers to be used during the voting phase of the participatory process. The issue is not to impose a tool or methodology that would serve to lay down the criteria at the beginning of the design process, but rather to provide the designers with one which would help them (i) to formulate the full set of criteria related to the solution and (ii) to negotiate their weighting during the development of the solution.

CRITERIA recommended three main successive stages[1], namely: (i) evaluate the problems encountered with the current equipment; (ii) propose solutions and justify them; (iii) choose the solution using the vote grid. Thus, by using CRITERIA, co-designers can assess the solution from a realistic point of view which is closer to their own comprehension of the process. At the end, CRITERIA improves the decision-making process, not only by increasing the *number* of criteria, but also by expanding the qualities of the criteria referred to. The collective decision has a better foundation simply because the arguments have been better and more widely scrutinized.

CRITERIA was produced to respond to specific problems in a specific industrial context. The participants in the redesign groups enjoyed using CRITERIA to select their solutions because it was a powerful tool for a systematic ranging of judgements. However, it appears that CRITERIA suffers some faults, which are the other side of its qualities. The maintainability of the method is problematic: the criteria, as soon as they are of low, concrete and detailed levels, are very much linked to the case and it is hard to use them in a generic sense. Thus, the adaptation of the grid to problems other than the redesign of tube production line equipment is quite costly. The second shortcoming of the

---

[1] The full CRITÉRIA method is presented in Darses & Sauvagnac (1998)

method lies in the weighting process of the criteria. These criteria, since they play a role of "design arguments", are negociated during the choice of the solution. This negociation was implicitely carried on by the participants, without solving the issue of participant's status in the process of argumentation. On this point, the improvement of the method could benefit of recent work being conducted in design rationale research (Moran & Carroll, 1996).

Evaluation of New Equipment from a Process Point of View

Reliability	**Quality Risks**	**System Simplicity**	**Efficiency**
Can be corrected	Leaves marks on the tube	Equipment homogeneity	Adjustable pieces
Tolerance	Blackened plates	Guiding a piece, no aiming required	Detachable pieces
Does not impede production	Etc.	Can be adjusted	Less cumbersome pieces
			Losable pieces
Etc.		Etc.	Etc.

Figure 6 Excerpt from Criteria: Grid for Voting on Solutions at Different Analysis Levels

CONCLUSION

The research reported in this paper had two main objectives, namely (i) to understand and model, from a cognitive point of view, how evaluation and decision-making are performed during participatory design; (ii) to develop a collective decision-making method better adapted to the participatory context of the design process. However, the results highlighted in this study can be applied to any collective design evaluation process, even "non participatory", such as concurrent engineering or integrated team design.

The major role of concrete levels of representation of the redesigned artefact (structural and operational levels) is a point to developing collective design methodologies which would go beyond the traditionnal "functional analysis". Greater assistance must be provided to the co-designers for building a shared view of the problem and its context. These tools should foster the explicitation of implicit design arguments, and should support the negociation upon these arguments.

REFERENCES

Blanco, E., Garro, O.,Brissaud, D. & Jeantet, A. (1996) Intermediary object in the context of Distributed Design. *Proceedings of CESA'96 Colloque IEEE-SMC*, Lille, July 96.

Bonnardel, N. & Sumner, T. (1996) Supporting evaluation in design, *Acta Psychologica, 91*, 221-244.

Cross, N. Christiaans, H. & Dorst, K. (eds) 1996, *Analysing design activity* (N.Y.: J.Wiley and Sons).

Darses, F. (1991) An assessment of the constraint satisfaction approach for design : a psychological investigation. *Acta Psychologica 78*, 307-325.

Darses, F. (2002) A framework for continuous design of production systems and its application in collective redesign of production line equipment. *Human Factors and Ergonomics in Manufacturing, 12 (1)*, 55-74.

Darses, F. & Sauvagnac, C. (1997) Représentations cognitives de l'objet à concevoir: construction collective dans une situation de conception continue. *Actes de 01 Design 97, Cinquième table ronde sur la conception*, Théoule-sur-Mer, 24-26 Septembre (EUROPIA: Paris).

Darses, F. & Sauvagnac, C. (1998) *Conception continue du système de production : enjeux et mise en oeuvre*. Final Report, July, Projet CNAM-UGINE (Paris : CNAM).

Darses, F., Falzon, P. & Béguin, P. (1996) Collective design processes. *Proceedings of COOP 96, Second International Conference on the Design of Cooperative Systems*, Juan-les-Pins, France, 12-14 juin (Sophia-Antipolis: INRIA).

Garrigou, A., Daniellou, F., Carballeda, G. & Ruaud, S. (1995) Activity analysis in participatory design and analysis of participatory design activity. *International Journal of Industrial Ergonomics, 15*, 311-327.

Goel, V. & Pirolli, P. (1989) Motivating the notion of generic design within information-processing theory: the design problem space.

AI Magazine, Spring, 18-36.

Jensen, P. (1997) Can participatory ergonomics become "the way we do things in this firm"? *Ergonomics, 40 (10),* 1078-1087.

Mac Lean, A., Young, R., Bellotti, V. & Moran, T. (1991) Questions, options and criteria : Elements of design space analysis. *Human-Computer Interaction, 6,* 201-250.

Moran, T.P. & Carroll, J.M. (1996) *Design Rationale. Concepts, Techniques and Use.* Hillsdale, N.J., USA: Erlbaum.

Martin, G., Détienne, F. & Lavigne, E. (2000) Negotiation in collaborative assessment of design solutions: an empirical study on a concurrent engineering process. *Proceedings of CE'2000, International Conference on Concurrent Engineering*, July, 17-20, Lyon, France.

Nicolas, L. (1996) *Etude de la phase d'analyse fonctionnelle en conception.* DEA d'Ergonomie, (CNAM: Paris).

Rasmussen, J., Brehmer, B. & Leplat, J. (Eds) (1991) *Distributed Decision-Making: Cognitive Models for Cooperative Work* (Chichester: Wiley and Sons).

Shingo, S. (1985) Revolution in Manufacturing: The SMED System. The Western Library: University of Western Ontario.

Simon, H. (1973) The structure of ill-structured problems. *Artificial Intelligence, 4,* 181-201.

Visser, W. (1990) More or less following a plan during design: opportunistic deviations in specification. *International Journal of Man-Machine Studies, Special Issue: What programmers know, 33,* 247-278.