Lisl Klein

On the Collaboration Between Social Scientists and Engineers[1]

Dynamics and Models

The Dynamics

The very term "socio-technical," used to characterize work systems, implies that there has been a process of splitting which needs to be rectified. Splitting is a process of psychic economy whereby people tend to simplify a complex situation by attributing all its X characteristics to one of a pair and all its Y characteristics to the other. The goodies are all-good and wear white hats, and the baddies are all-bad and wear black hats and possibly also black moustaches. Splitting means that one is most unlikely to be presented with a black moustache under a white hat.

Splitting is very pervasive. In its simplest form people identify one football team, one political party, one nation as all-good and others as all-bad; scientists are supposed to be all-rational; artists all-intuitive; industrialists concerned with money and nothing else; academics with knowledge and nothing else; etc. Although many people know with a part of their mind that things are really not like that, once splitting is established and becomes institutionalized,

(1) Adapted from Chapter 6 in *Designing Human Centred Technology A Cross-Disciplinary Project in Computer-Aided Manufacturing*, edited by H.H. Rosenbrook. London: Springer-Verlag, 1989.

those involved get caught up in it, and it becomes very hard to break out of. Companies seem obliged to encapsulate their "soft" aspects in personnel departments or donations to ballet companies in order to maintain their required "toughness" intact. Politicians are unable to say anything good about the policies of their opponents. In turn, people and institutions begin to live up to what is apparently expected of them.

Something like this has happened in relation to technology and its human inputs and outputs. Clearly, they are interdependent: on the one hand, the inputs to design decisions in manufacturing systems are not only knowledge about the properties of materials and the dynamics of machining. They are also, first, factors affecting the individual designer, such as values and assumptions about how people function and about what is really economic and, second, organizational factors affecting design processes such as pressures on a team from outside, status differences when alternatives have to be selected, career development issues, etc.

On the other hand, the outputs from design decisions in manufacturing systems include effects on the perceptions, attitudes, skill repertoire and behavior of individuals, on organization and therefore also on society. The consequences for the people who work with and around the technology are, in turn, that technology is often not operated in the ways in which its designers--from a split position which blanks out the human and social aspects--intended. A split position would lead one to conclude from this that people should be eliminated from the system, not that they should be taken into account more realistically.

The most important aspect of all this is that the social and technical aspects of technology are split off. This splitting, against which are attempts to work in an integrated way is deeply institutionalized. It permeates professional institutions and their literature. There are populations whose horizons are dominated by the one and populations whose horizons are dominated by the other. Social scientists read what social scientists have written; engineers read what engineers have written.

The perpetuation of splitting by institutionalization is illustrated by my experience as a member of the steering committee of a project concerned with designing a flexible manufacturing system such that the operator would stay in control (Rosenbrock, 1989). I considered that I was not being as useful as I might because I did not understand the technology well enough. I asked for some teaching about metal cutting. Among other things, I was shown a video used in teaching first-year engineering students. It was an excellent teaching aid, but within the first five minutes two factors emerged:

> The operator was referred to as a constraint--a cost. He was never mentioned again.

> The content itself--the engineering --was very fascinating and absorbing.

These two things together would, of course, help to set a student's attitudes for life and be very difficult to counteract later.

Engineers and social scientists in the present age are to a considerable extent products of this deeply institutionalized splitting. So powerful is it that large parts of both professions see no relevance in collaborating with the other at all. Some social scientists are afraid of technology, and some engineers are afraid of getting into the human area.[1] These fears are difficult to acknowledge and, from such fears, the human aspect may take on a pseudo-mechanical form such as "the Man-Machine-Interface" or "the Human Factor."

There is also a substantial history of mutual criticism. On the side of the social sciences, more precisely of sociology, criticism has its roots in studies of the human and social consequences of production technology and was originally not directed at engineering design but at the economic framework within which it was taking place. Marx's original analysis of the societal consequences of trends in manufacturing technology contained much of what a present-day social scientist would call socio-technical understanding, i.e., understanding of the interplay between human and technical aspects of technology. The following is an example from Marx (1887):

> In the English letter-press printing trade, for example, there existed formerly a system, corresponding to that in manufactures and handicrafts, of advancing the apprentices from easy to more and more difficult work. They went through a course of teaching till they were finished printers. To be able to read and write was for every one of them a requirement of their trade. All this was changed by the printing machine. It employs two sorts of labourers, one grown up, tenters, the other, boys mostly from 11 to 17 years of age whose sole business is either to spread the sheets of paper under the machine, or to take from it the printed

[1]The term "socio-technical" has recently acquired some popularity, but activities going on under that label are frequently still confined to working only with the social system. "We are not here to discuss technology," said a consultant introducing a training course on socio-technical systems.

> sheets... A great part of them cannot read, and they are, as a rule, utter savages and very extraordinary creatures. To qualify them for the work they have to do, they require no intellectual training; there is little room in it for skill, and less for judgement; their wages, though rather high for boys, do not increase proportionately as they grow up, and the majority of them cannot look for advancement to the better paid and more responsible post of machine minder, because while each machine has but one minder, it has at least two, and often four boys attached to it. As soon as they get too old for such child's work, that is about 17 at the latest, they are discharged from the printing establishments. They become recruits of crime. Several attempts to procure them employment elsewhere were rendered of no avail by their ignorance and brutality.

However, Marx did not draw socio-technical conclusions, i.e., he did not conclude that social aspects should therefore feature in engineering design. He attributed the problems he saw to the ownership of private capital and to the drive to create surplus value. He did not take seriously, as an independent contributing factor, the human need to reduce complexity that results in splitting and allows for these models of man in the minds of engineering designers. Since designers were generally working for the owners of capital, the omission is understandable. But we know today that trends in design do not automatically change when ownership changes, as in nationalized industries or in socialist societies, or when the need for economy abates, e.g., during phases of subsidy. Splitting and its consequences are powerful independent contributing factors.

In the 1920s, 1930s and 1950s in Britain, a range of researches and other activities of social scientists began to elucidate specific rather than global problems. For example, empirical research showed that, given the opportunity, people varied their working pace in the course of the day without loss of output (Harding, 1931). This fact has never found its way into the kind of "knowledge" that is explicitly used in design. (In a recent project, the managing director of a company in the domestic electrical appliance industry commented that he was "amazed" at how miraculously their industrial relations improved when they took the mechanical drive off their assembly line.) What happened instead was a split development. Production engineers continued to work on the assumption that controllability and predictability required evenly spaced, i.e., mechanical, pacing. Then, in the 1950s, when basic standards of living were regained after the war, the motor industry began to suffer from waves of strikes, most of which were unofficial and short. It was not recognized that the main function of a short strike is simply to create a break, an interruption from work, and that the strikes were taking place in situations where work was machine-paced.

Again, research showed that, if the work system did not provide feedback (knowledge of results), people would insert a way to get such feedback informally (Wyatt and Fraser, 1928). And again empirical research showed that, if people's actions were closely controlled, as in work study systems, they would react by inserting controls of their own. "Fiddling" in work-studied incentive schemes had the function of exercising creativity and regaining control over one's work situation, which the formal system did not permit (Klein, 1964).

The coal-mining studies of the Tavistock Institute conceptualized much of this in a cumulative way. They showed that, given experience of a job and some flexibility, people would find the optimum way of doing th job for themselves. Conversely, if a new technology did not take account of their experience, its productivity potential was not realized. The technical system and the social system were truly interdependent (Trist et al., 1963).

In the 1960s, some engineers and their institutions began to be interested in the findings of empirical social research. With increasing frequency, social scientists were invited to take part in the conferences of engineering institutions. However, before a move toward integration in design could get very far, a second trend within the social sciences was making itself felt. The expansion of social science teaching and writing in the 1960s brought with it the reemergence of critique as the dominant mode. This time it tended to be <u>mere</u> critique, on the basis of a preexisting formal theoretical framework, rather than empirical and grounded investigation as had been the case before and was, indeed, the case with Marx. Given that the frame of reference for critique was well established and that frames of reference for synthesis and contribution were only beginning to be worked out, critique was simply an easier option and many social scientists chose it. The two trends, sociological critique and socio-technical design, to some extent came into conflict. The difference between them is a fundamental one.

At that time, public awareness of a need to bring social science and engineering together was growing. But it has turned out that, where arrangements were made for social scientists to make a contribution to the education of engineers, they tended to do it from a split position, i.e., they tended to teach elements of social or psychological theory, not to help engineers incorporate human and social factors into their engineering.

Engineers, in turn, insofar as they have been aware at all of what social scientists were doing, have resented being forever criticized. They notice that social scientists are not given to studying the ways in which human life has been made easier by the products of engineering. They consider the social sciences to offer little in the way of positive contribution and find social scientists unwilling to dig in and help instead of criticizing. And, if they experience resentment, engineers can get their own back. It is easy to trap a social scientist with questions that are not only unanswerable but that serve to block the contribution that might be made. The following are two examples from experience:

> The first concerned the design of a new plant. "We want to design this plant so that the operators will be happy. What we need from you is advice on what colour to paint the walls to achieve this."

> The second concerned the design of equipment.
> Social scientist: "We need to keep options open for the operator."
> Engineer (after doing a quick calculation): "I reckon there are about four billion options. Which ones do you mean?"

This combination of recognizing the value of the other and resentment of the other is the dynamic of ambivalence. Both the habit of critique and the habit of resentment are sufficiently well established to have some of the characteristics of cultures, affecting to some extent even those, in both professions, who do wish to collaborate. It is against this background that attempts to work together take place.

Models of Science

This discussion of the practical aspects of collaboration will now be confined to the concepts, methods and experience of those social scientists and those engineers who do wish to engage in collaborative work. For even where there is a wish to collaborate, there are still considerable handicaps. The phrase "multidisciplinary work" trips from the tongue more easily than it is realized in practice.

It is possible to postulate two models of science in approaching the topic of job design and work organization. In one model, a high value is placed on measurement and quantification in the search for precise guidelines. The other model accepts ambiguity and conflict of interest as part of the reality being dealt with. It is salutary to remember that "scientific management" was to a large extent motivated by a wish to take conflict out of the situation by developing "objective" standards that would be self-evidently correct and that would therefore be accepted by both management and workers. It has been one of the main causes of conflict ever since.

It would certainly not be true to say that engineers necessarily adhere to the first model and social scientists to the second. Much of engineering is still empirical (though that "still" shows the power of the stereotype), and there is much room for debate among engineers. On the other hand, a good deal of social science research is conducted within the natural science model.

There are also cultural influences at work. In Germany, for example, a clause in the Company Law of 1972 requires that "proven scientific findings about the workplace must be applied." This sounds strange to British ears. In Britain research involving people at work has been very context-specific, and the emphasis on application has been on cases and experiments rather than on the broad application of generalized "knowledge." The clause in Company Law has, in turn, had considerable influence both on the sponsorship and on the nature of research carried out since it was passed. For example, a piece of social science research was used to test what level of buffer stock on an assembly line would be optimal in freeing the operator from machine pacing. As part of a complex research program, a "job satisfaction index" was compiled from the views operators expressed about a range of things connected with their work. This index was then correlated with the buffers related to particular workplaces, and it was found that the bigger the buffer, the greater (for whatever reason) was the job satisfaction. Far from indicating an optimal level to which the law might then be applied, this brought the issue back into the arena of negotiation, and the social scientists, no less than the engineers, were disconcerted.

The Disciplines in Relation to Outputs

As a group of professionals, engineers have, of course, been evolving their methods and developing their products for much longer than have the social scientists. Social reflection about the output of technology is as old as technology itself. (Certainly the authors of Genesis had a view about the condition of man once he had to labor, and saw even God as needing a rest.) But as disciplines that attempt to aggregate the outputs at a societal level or to study them systematically at the individual level, and thus to verify social reflection empirically and systematically, the social sciences are young by comparison. And as professions which attempt to contribute the resulting knowledge and methods to a variety of spheres and to the design of plants and equipment, the social sciences are very much younger still. The very process of studying and commenting, by bringing gaps to light, has led social scientists into the habit of critique and has contributed to splitting, and has thus hindered the development of their contribution.

Nor do the social sciences have much to show in the way of products, at least as products are understood by engineers. By definition, where an idea or a finding in social science is accepted as valid, it becomes incorporated into the general body of common sense. Mothers are encouraged to stay in the hospital with their small children as a matter of common sense, not as a consequence of the research (Bowlby et al., 1952) that demonstrated the effects of this not being allowed. Thus, the useful products of social science are likely to be in the form of understandings, methods, practices and institutions. Sometimes they may be standards, but where standards are applied, the processes of developing them, which social scientists may sometimes consider more valuable than the outcomes because of the learning involved, will have been bypassed. Engineers, on the other hand, are likely to want outputs in engineering terms, i.e., at least in the form of standards.

Standards which social scientists can formulate with confidence and without an empirical "research loop," are likely to concern processes, not outcomes; for example, "no installation without a transitional system involving prototyping," rather than "no cycle time less than X seconds"; "operators should have some say in shaping their environment," rather than "the walls should be blue." This kind of advice may be experienced by engineers as especially unhelpful at the design stage of plant or equipment when the particular population of operators does not yet exist. To interpret and operationalize the general principle of "minimum critical specification" (Herbst, 1974/Vol. II, "Designing With Minimal Critical Specifications") demands a great deal of work in particular situations.

The Disciplines in Relation to Methods

The social sciences may be weak on products, but they are strong on methods. First, it is possible to make values explicit, to get members of organizations to express them in terms of design criteria and to prioritize these and make them operational by getting them incorporated in design (Klein and Eason, 1990). But splitting affects preferences and expectations about methods, and such a systematic approach to design may not be what engineers look to social scientists for. The element that has been split off not only gets projected onto the other, it exists in oneself in an unintegrated way. I have been surprised in more than one situation when people who would not dream of making decisions about materials, or temperatures or surface finishes, without some kind of systematic trials, insist on either making, or asking for, decisions about people by some kind of inspired guesswork. For example,

> In a shipping organisation, a number of policies including 'integrated crewing' were introduced, designed to encourage seafarers to identify with the particular employer rather than with seafaring as a whole. It seemed at least possible that people who go to sea do not want to identify with a particular organisation; but when questioned why he was so sure that they would want to if given the opportunity, the manager concerned put his hand on his heart and said, "because I feel it here" (Klein, 1976).

One is somehow reminded of how Italians describe the behavior of foreign tourists in the face of Rome traffic. It is said that some foreigners, no doubt otherwise quite rational people, faced with the need to cross a busy street, put up one hand to stop the traffic, hold the other tightly over their eyes, and plunge. Like manufacturing design, it quite often works.

Secondly, the social sciences have a methodological concern for the links between process and outcomes. The dynamics at the input end of design have direct consequences for the output end; in fact, that is often where the origins of poor design decisions are to be found. If design decisions are made for reasons other than design needs, the outcome is bound to be problematic.

> A fierce argument about which of two layouts to adopt in a new plant was conducted on cost grounds (which were considered acceptable grounds for debate). It was in fact about the competition between the company's and its parent company's engineering departments (which was not acceptable). The costs could not be assessed in their own right unless the dynamics could be worked through (Klein and Eason, 1990).

Operational Issues and Institutionalization

Considering how long the concept of socio-technical interdependence has been around, critical mass for these ideas remains a very long way off. One of the reasons for this seems likely to be that discussion and development have focused too exclusively on the values and paradigms, to the neglect of the operational issues involved in turning them into practice, and to the neglect of institutionalization.

The joining of the two perspectives can take many forms. Engineers may internalize the concepts. In one such case, the project engineer began to write job descriptions in terms of the experiences and relationships involved as well as the activities to be carried out. Human aspects which are predictable, such as selection and training, may be incorporated in planning systems such as Critical Path Methods. But many issues cannot be anticipated in such a structured way. The design of transitional systems such as prototyping, simulations and the systematic testing of alternatives may be a particularly fruitful area for collaboration.

The following are some of the issues that arise in the course of operationalizing integrated work.

Phasing

When engineers and social scientists work together, many of the issues may be thought of as differences in values and often emerge operationally as problems of phasing. Putting the disciplines and their concerns together does not automatically lead to integration; the consequences of the original splitting still have to be worked though. Otherwise, if a project or development process has been designed with the assumptions of one discipline, the contributions of the other may appear as things that will hold it up. (There are, of course, differences within the two perspectives as well as between them: within social science approaches, strategies which rely wholly on the participation of those affected can perforce only involve those who are immediately present.) Representation of the two perspectives generally does not start at the same time or equally influence time estimates. The social perspective may be represented by philosophy statements for a long time before it is turned into implementation strategies; decision sequences may be seen as linear rather than cyclical, etc. The following are some illustrations of problems of phasing.

<u>Company A</u> was an oil company engaged in building a new fuel-oil pipeline from one of its refineries to a major distribution terminal. Fuel-oil facilities would need to be built at the terminal that until then had been engaged in the storage and distribution of other products.

One decision which had to be taken concerned the site of the control room. One alternative was to build a new control center at the entrance to the site so that truck drivers would be given instructions as they drove out and could lhand in documents as they drove in. This would also have the effect of geographically separating the control of loading from the physical operation of loading. The alternative was to extend the present loading and transport control room at the center of the site. The engineer in charge of the construction asked what the difference would be in terms of the social organization and attitudes of the drivers. It was a very perceptive question; getting an answer would involve doing some work with the drivers.

An answer could be available within three weeks but the engineer could not wait. Major consequences for work roles and group relations were, of course, implied in the decision and the engineer realized this. But he was locked into a schedule for linking the design and construction of the new building with the opening of the pipeline and could not create a three-week delay. He had assumed that there might be a ready-made answer (Klein, 1976).

<u>Company B</u> was engaged in building a new high-speed canning plant. It was to be built on a site where the company already had some other operations so that, while the operators who would be staffing the plant were not yet available, there was a trade union organization. A

Job Design Committee was established for a time to consider the nature of the jobs being created in the canner.

Two control systems engineers were involved in the planning of the cannery. They became interested in the idea of job design and, after some preliminary induction to the topic, one of them gave a presentation to the Job Design Committee. He said that, at that stage, the control systems could still be designed in almost any way the Committee wanted. He liked the idea of working as a service to the operators who would later be doing the jobs. But once the floors were laid, with channels for the cables, it would be very difficult to change. The trade union representatives at that stage did not have enough knowledge of the process to be able to be very specific about what they would want. The technology was very new and advanced and the engineers had about two years' start on them in thinking and learning (Klein and Eason, 1990).

The problem of participants, or social science professionals, being out of phase with engineering designers in their absorption of the necessary know-how is very general (Eason, 1982). Unless arrangements can be made to deal with this discrepancy, contributions from social scientists are likely to be limited to general statements and "participation" is likely to be superficial and unreal.

<u>Company C</u> was also building a new plant, this time for the manufacture of confectionery. Much of the production machinery was to be transferred from an existing older building, and the job design contribution concerned the organization of work around existing equipment rather than the design of new equipment.

The prospect of an entirely new factory, an opportunity which people have only very rarely, was acting as a focus for a powerful vein of idealism in the company. Not only did the company want the jobs in the new factory to be satisfying for the people working there; they wanted the architecture to be innovative, to be human in scale and to make a distinct contribution to the built environment. This position had involved a good deal of discussion about company philosophy. At the time I joined the group, two concepts for the new factory were being debated: on the one hand, the concept of a large, hangarlike structure, within which there would be freedom and flexibility to arrange and rearrange things; and, on the other, something like a village street with small production units as well as social facilities such as a tea bar, a bank, possibly one or two stores. The result would give the as"feel" of a varied and small-scale, village-like environment where people moving from one unit to another would inevitably meet each other. This would be far removed from the conventional idea of a factory.

Within a few minutes of joining the group, I was confronted with the question, "What do you think--large hangar or village street?" I had, of course, no basis for an opinion and realized the dilemma they were in. The company felt that they could not even begin to talk to architects until they had some idea of the basic shape of the building they wanted; one could not sensibly discuss the shape of the building without some idea of the production layout; and I could not contribute to discussion about the layout from the job design point of view without some socio-technical analysis of the production process, which required time. At that stage I had not even seen the production process.

Two meetings and some familiarization later, we achieved a breakthrough. The first of the products to be manufactured on the new site consisted almost entirely of crushed sugar with some additives, which was then compressed into a tablet and packaged. Groping for a more detailed understanding, I said, "Look, I still haven't understood the process properly.

Suppose I'm a piece of sugar. I've just been delivered. What happens to me?" Somebody said, "Well, the first thing that happens to you is that you get blown along a tube. But there is a physical limit to how far you can be blown." I said, "OK, what happens next?" And somebody said, "Next, you get crushed into a powder." In this way I talked my way through the process in very great detail, role-playing the product. For example, I heard myself saying,

"All right, so now I'm a granule. What happens next?"

"Next, we drop mint oil on your head."

"Might you miss?"

"Yes, we might."

"How would that be discovered?" And so on.

The product was a fairly simple one which the company had been making for a long time, and ways of thinking about it had become rather set. In the transitional system established through role-playing the product, these ways of thinking began to unfreeze, and the participants began to discover alternatives and to say to each other, "It doesn't have to be like that. It could be like this if such-and-such conditions are met." In particular, some things which they had been used to thinking of in sequence could, it was found, be done in parallel. That meant that the logic of the production process was not necessarily a straight line, and this, in turn, meant that one could think in terms of a short, squat building. This was the eventual shape of the "product house" which emerged from this process.

In terms of work design, I realized afterward that my strategy had been about leaving options open. Once the factory was staffed and experience of the work system was beginning to accumulate, there was more chance of reviewing and revising the work design in a short, squat building than in one where the logic of the layout led to long, straight lines. In these, more things would be irrevocably fixed. From the socio-technical point of view, the short, square product house should have three functions: the opportunity to identify with the product; the opportunity for people to relate to each other; and the opportunity to keep design and organizational options open.

Architecturally, the product house turned out to be a kind of compromise between the aircraft hangar and the village street ideas--smaller than a hanger but larger than the cottages envisaged along the village street. With this concept the company then went in search of architects.

Systems Boundaries--the Meaning of "Human-Centered"

This set of issues is particularly relevant in the design of new technology. Within the human and social sciences there is a longstanding debate about how criteria that make a piece of equipment easy to use relate to criteria that make the work being done meaningful and that are conducive to the development of the person. In some instances they are simply different. For instance, the operator's autonomy does not generally feature among the usability criteria which "Human Factors" professionals apply. But in some instances the criteria can be in opposition. The usability criteria of Human Factors specialists usually include short learning times, while developmental criteria give a high value to opportunities for learning.

These differences are, then, sometimes debated as differences in values. They may also be seen as differences about systems boundaries, i.e., what is considered to be within the system and susceptible to design and change; and what is outside the system and part of the environment, i.e., to be taken as given. It is an issue that is likely to crop up within multidisciplinary design teams.

It may be useful to think of this problem in terms of a typology of products. In equipment design there is a crucial boundary between design decisions that are within the design project and those that are in the hands of the purchaser of the resulting product. Where a product is a tool, a means of doing something else, or where it creates a task which is only a part of a role so that the configuration of the role itself is out of the hands of the product designer, the aims of good integrated design may properly be in the direction of "usable." Where a product or system creates roles, and where the configuration of the role itself is therefore in the hands of the product or system designer, usability should be a minimum baseline, and the aim of good integrated design must be more in the direction of "developmental." At any rate, in such a situation the issue cannot be ignored. Product or systems designers cannot help influencing long-term consequences such as future organization or industrial relations, whether they want to or not.

There are, in fact, several scales, and the boundary will not be in the same place on all of them. It may be useful to draw a profile across them for a particular project (below)

From	To
affects task	affects role
tool	system

The nearer a product profile is to the left-hand column, the more appropriate are usability criteria by themselves. The nearer it is to the right, the more do developmental criteria need to feature as well. This approach would by no means eliminate value-based debates, for instance on the question of safety and responsibility, but it should help to clarify them.

Institutionalization

Where the idea of the collaboration between social scientists and engineers is new to people, they are likely to become preoccupied with what this will actually mean in practice and how to set about it; they are much less likely to worry about longer-term considerations. However, this kind of work has now been going on long enough for some long-term issues to become clear--not so much how to make it start as how to make it stick!

The issue is institutionalization. To institutionalize something is to build it in, and it has already been pointed out how the problem is not so much that the technical and social aspects of engineering design have become split off from each other as that the split is deeply institutionalized. This means, for example, that every time membership of a design team or steering committee changes, the socio-technical perspective may need to be reasserted.

To make something stick requires a surprising range of interacting and mutually supporting institutions. This may be illustrated by the institutions supporting the simple decision to restrict driving to one side of the road. The assumption that it will happen is built in to the <u>design</u> of vehicles. It is built in to the <u>training</u> of drivers as well as in to their <u>legitimization</u>. It is built in to the formulation of <u>codes</u> and <u>standards</u> (the Highway Code, standards about the width and layout of roads, etc.). Then there is the <u>continual reinforcement</u> of seeing that others do it and, finally, <u>sanctions</u> if it does not happen. These institutions, in turn, are supported by <u>funds</u>, <u>training establishments</u>, <u>staffing</u> and <u>monitoring</u> (traffic police). It is the combination that makes these institutions, together, powerful and effective. In addition, a breach of the decision is generally clearly visible and unambiguous. As a result, the decision is mostly carried out; drivers are not continually deciding on which side of the road to drive.

Social aspects of work systems are, of course, not often so unambiguous. But it must be remembered that this is partly a matter of local tradition. In Germany, as has been stated, it is the law, with its accompanying sanctions, that says that "scientific findings about the workplace must be applied." In Germany, also, Human Factors methods and findings form part of the substance of some trade union agreements.

Where something can be formulated as a standard, that is a form of institutionalization. Where it can be integrated into the technology, such as dialogues that provide genuine options, or indicators on a machine that provide feedback or buffers that mitigate pacing, that is a more powerful form.

But to ensure that such structural influences are taken seriously in the first place, and for situations that cannot be formulated in these ways, the need is to achieve a degree of culture change. To attain this, it is not a matter of one or more social scientists joining a team; the socio-technical viewpoint must be represented powerfully enough, early enough and consistently enough, as a matter of routine. It must feature in the syllabuses of engineering students, in the appropriation for capital investments, in R&D budgets, in the qualifications and experience required of systems designers and in the assessment and emoluments of technical directors.

Collaboration between individual professionals is not enough. First, social scientists working as individual members of an engineering activity are likely to be exposed to projections of all the ambivalence, the hopes, anxieties and resentments that have accumulated in relation to the social sciences. If the things social scientists say are unwelcome, these may be seen as personal rather than professional contributions. Secondly, they will not have at their fingertips all the substantive and methodological contributions of all the social sciences. And thirdly, the number of things they have time to deal with will be very limited.

This is so even within a small team working on the development of a piece of equipment. It is much more so in the design and development of a large-scale plant, where there are so many things going on at the same time that it is hopelessly optimistic to see them all as consistent and rational tributaries of the mainstream. In the confectionery factory cited earlier, for example, it was not possible to keep alive the idea of keeping options open for three turbulent years between the decision concerning the shape of the building and the start of production in the new plant.

Some of many uncontrollable events may be

Market changes during the design and building process that influence the production capacity that is needed, leading to decisions outside the design teams.

The purchase of off-the-shelf equipment that cannot be influenced unless this influence is exerted long before actual orders are placed, i.e., unless the culture of the equipment manufacturers can be influenced as well.

Management development moves, which may not coincide with project needs, in which members of design teams as well as key people in the organizational context are moved around.

All these instances illustrate that the system which is carrying the design and development processes is an open and not a closed one. In these circumstances, mere collaboration between social scientists and engineers as professionals is not enough. Mere collaboration, however well it may be working, is too weak a mechanism to cope with open systems characteristics. On the other hand, mere infrastructure is not enough either, and formal guidelines circumvent the necessary processes of development and mutual learning. What is needed is collaboration supported by institutions and infrastructure.

References

Bowlby, J., J. Robertson and D. Rosenbluth. 1952. "A Two-Year Old Goes to Hospital." Psychoanalytic Study of the Child, 7:82-94.

Eason, K. 1982. "The Process of Introducing Information Technology." Behaviour and Information Technology, I:197-213.

Harding, D.W. 1931. "A Note on the Sub-Division of Assembly Work." Journal of the National Institute of Industrial Psychology, 5:261-64.

Herbst, P.G. 1974. Socio-Technical Design: Strategies in Multi-Disciplinary Design.

London: Tavistock Publications.

Klein, L. 1964. Multiproducts Ltd.: A Case Study on the Social Effects of Rationalised Production. London: Her Majesty's Stationery Office.

-----. 1976. A Social Scientist in Industry. London: Gower Press.

Klein, L. and K. Eason. 1990. Social Science in Practice. Cambridge: Cambridge University Press. (In press.)

Marx, K. 1887. Capital. (English translation 1958. London: Lawrence and Wishart.)

Rosenbrock, H.H. (Editor). 1989. Designing Human-Centred Technology: A Cross-Disciplinary Project in Computer-Aided Manufacturing. London: Springer-Verlag.

Trist, E.L., G.W. Higgin, H. Murray and A.B. Pollock. 1963. Organizational Choice: Capabilities of Groups at the Coal Face under Changing Technologies: The Loss, Rediscovery and Transformation of a Work Tradition. London: Tavistock Publications.

Wyatt, S. and J.A. Fraser, assisted by F.G.L. Stock. 1928. The Comparative Effects of Variety and Uniformity in Work. London: Her Majesty's Stationery Office, Industrial Fatigue Research Board Report No. 52.