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# Information Technology at Work

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## 1 Introduction: Experiencing the IT Productivity Paradox

There is a growing body of empirical evidence for widely unproductive use of IT systems. In many cases, the overall performance of the working processes in which these systems are used is far below the potential and the expectations as well. Performance and productivity of working processes obviously do not solely depend on the functions and properties of the IT systems in use. Performance and productivity rather largely depend on the intellegence and skill by which they are embedded in and appropriated through the organisation running these processes (for details and more material see Landauer 1995, Brödner 1997).

On the macro level of the economy, the phenomenum of the „IT productivity paradox“, i. e. the rather growing discrepancy between massive IT investments (which meanwhile exceed those in production technology) and poor productivity growth (stagnating in the manufacturing sectors while even dropping to zero in the non-manufacturing sectors), can be observed since the late seventies. After being studied in a large number of investigations there is growing evidence that, apart from unsolved measurement problems, the poor IT productivity is mainly rooted in the design und use practices on the level of organisations (Brynjolfsson 1993 and 1998). Organisations and their ways of implementing and using IT systems must, therefore, move into the center of attention.

The use of MRP systems may exemplify this. More than half of the organisations using this kind of IT systems experience almost no (or only very little) reduction in throughput time and inventory (being the most important objectives for implementing the systems). Other, more successful organisations nevertheless are able to achieve major improvements with this respect, although they use the same technology. They take a different approach to the design and implementation process: Instead of adapting the organisation to the functions and working logic of the system, they reorganise the working process to better achieve the objectives and search for ways how they can use the system's functions to accomplish the changed working tasks more efficiently. In other words: They jointly design and implement the organisational structures and procedures and the technical system in an integrated way.

Moreover, a German investigation of 400 medium-sized firms using CADCAM systems has revealed that in eight out of ten managers do not even care at all about the costs and benefits of these IT applications; they just believe in its potential advantage. And even the other two of the ten paying attention to cost-benefit aspects use very limited and inappropriate analysis and evaluation schemes not reflecting the complex interactions between technology and organisation and the resulting high learning efforts (Lay/Wengel 1994).

In order to develop a better understanding of the difficulties and problems organisations face in designing and implementing complex IT systems, a theoretical framework is first developed in the next chapter. It is based on an action-oriented view on the interactions between technology and organisation that helps to explain the underlying problems as well as to lay ground for promising solutions. It also forms the conceptual basis to analytically reconstruct the real development in the dynamics of design and use of MRP systems as a prominent example.

## 2 Computers in Context: An Action-Oriented Theory of Technology

An appropriate theoretical perspective of technological development has to consider the real working activities of humans, the active, intentional and purposeful change of their environment, in particular the accomplishment of a given working task by means of some working instruments available to them in their social practice. It, therefore, has to consider both the design of technical artifacts according to anticipated requirements in this context and the way how these artifacts are being appropriated and used in the working process (for more details of the theory outlined below see Brödner 1997).

It is a specific characteristic of human work that we – according to a functionally closed action circle – intentionally cause some changes in the environment through our acting. The intended actions may concern material objects (instrumental acting) or social interaction (communicative acting) as well. We experience the effects of our actions through the senses, but cannot disclose their meaning unless we interprete the effects in the light of our intentions. With these experiences and interpretations that etablish a meaningful context for further acting, we can generate new intentions and expectations to act even more effectively. Thus, meaning is created within this activity circle, i. e. meaning is not a property of the objects or processes in the environment, but an effect of our intentions and acting with them. This experience-based competence to act is called practical or tacit knowledge („knowing how“, Ryle 1969), and it is available at any time (no matter how far developed it is).

Under certain conditions, this intentional interaction with the environment allows us to form concepts and explicit knowledge about the world. Changing interactions create various experiences by which we can explore different aspects of the world. By specific efforts in our acting, e. g. by exploratory activities under controlled conditions or by experimenting, we are able to determine and identify recurring patterns in the diversity of activities. By laying hold of objects in the environment, by exploratory acting with them, we conceive their functions and comprehend how we can use them intentionally and purposefully. By remembering the action schemes and identifying recurring characteristics in these schemes we can form classes or concepts of objects or processes in the world.

Concepts, therefore, are mental constructs created by the acting person; they are generalised entities derived from experience by means of action and interpretation schemes. Concepts form the core of explicit, propositional knowledge („knowing that“, Ryle 1969). They enable us to tentatively „act“ within our minds. On the other hand, concepts can also be externalised and objectified as symbols (language) or as tools (technology). Formation of symbols and construction of tools, thus, are closely related characteristics of human activity that both are rooted in mental concept formation and reflection.

In this way, technical artifacts emerge as objectified propositional knowledge about human work, as results of purposeful acting. They are, as such, used again as means for further acting. As „congealed knowledge“ they incorporate human practice, and as means of work to practical ends they set specific action requirements for effective use. Usefulness and usability of technical artifacts are, therefore, determined by appropriate form, i.e. by adapting their forms and functions to the acting context as well as by meeting their action requirements. Since they are derived from abstract, decontextualised knowledge, technical artifacts always contain empty „slots“ that have to be filled in use through interpretation and recontextualisation. As a consequence, their use value is constituted in the application which is, due to the scope of interpretation within the limits of the action requirements, open for diverse use. And users learn to express or to articulate their action plans in the technical language of the artifacts' forms and functions and to internalise them as new action patterns. The effective and efficient use of technical artifacts, therefore, requires both: that they are designed appropriately for the tasks at hand and that the users learn to use them skillfully for accomplishing the tasks in a process of appropriation (see Fig. 1).

According to this dialectics of form and process, technical acting, the interaction with technical artifacts to accomplish a given task, can be understood as a process of social construction of reality. Since the meaning of artifacts is created through interpretation in the process of acting with them, they can also be interpreted by others acting in the same action context. Successful and mutually confirmed acting thus leads to a shared understanding among the co-workers. Like practicing a language or organisational acting, technology, thus, is socially embedded. In all these activities conceptual knowledge is externalised or objectified as forms – technical artifacts, language terms or organisational structures – together with emerging rules how to interprete them and how to sensibly act with them mutually approved and shared by those working in the same context. The externalised forms, in turn, can be used as resources for further acting, they even enable or allow for new ways of acting, if interpreted differently. As far as the rules of acting with them are being appropriated and internalised, they establish, together with the objectified forms they refer to, a new practice. And as far as they are shared by others, they constitute a community of practice.

The resources and the rules of acting established in this way together form a social structure that enables and, at the same time, constrains collective acting. What the actors in such a community of practice can imagine and which opportunities to act they see in a given situation thus depends on the expressive forms they created as well as on the interpretative rules they developed with them in

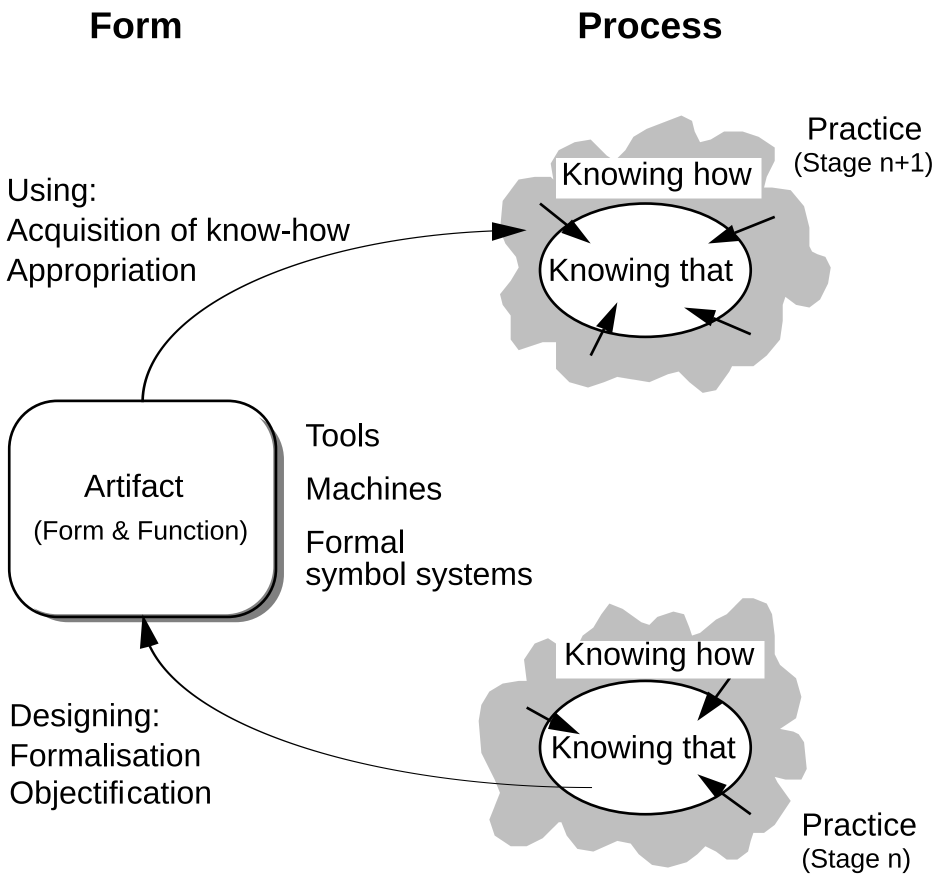


*Fig.1: Development of technical artifacts: dialectics of form and process*

previous acting. The better the forms are adjusted to the action context and the more appropriate they are interpreted, the more effective their social practice can develop.

In sum, the social structure being reproduced as interacting resources and rules in a social practice turns out to be a result and media for collective acting at the same time. This has been called the „duality of structure" (Giddens 1984). It constitutes the opportunities as well as the constraints to act in a given situation. The actors thus are socially constructing their reality, not of their own free will, however, but as prisoners of the conditions they have created by their own acting. By making sense of the artifacts they deal with based on grown interpretative schemes, by forming power relations through authoritative or allocative resources they use, and by sanctioning or legitimating actions according to norms they established, the actors in any case reproduce the social structure that marks out the scope for future action and negotiation (Giddens 1984, Ortmann 1995; see Fig. 2). It is worth noting that Orlikowski (1992) has, although starting from a different approach, developed a similar perspective of interpreting design and use of IT in the light of Giddens' basic theory of structuration.

Consequently, the social structure brings stability to collective acting enabling the actors to perform a continuous flow of action taken for granted, even over time and space and even across organisational borders. In particular, designers and users of IT systems (and maybe other actors involved) are frequently working in different organisations, with different roles, perspectives and interests. They, therefore, need a basis for communication or a media of understanding that, in a way, allows them to develop shared views and knowledge about the meaning, usefulness and usability of the systems in question and of their functions for the working process. This bridging function between the different actors is performed by shared *visions* that bring orientation and stability to the complex process of interaction. Visions relate the technically feasible to the socially desirable which the actors involved can agree on and accept. Visions provide the actors with shared *guidelines* how to productively relate and bundle their different views and roles and how to determine what is making sense. Visions also provide the actors with *images* that stimulate creative problem solving competence as well as commitment thus stabilising their social relations (making them feel „to be on the same boat").

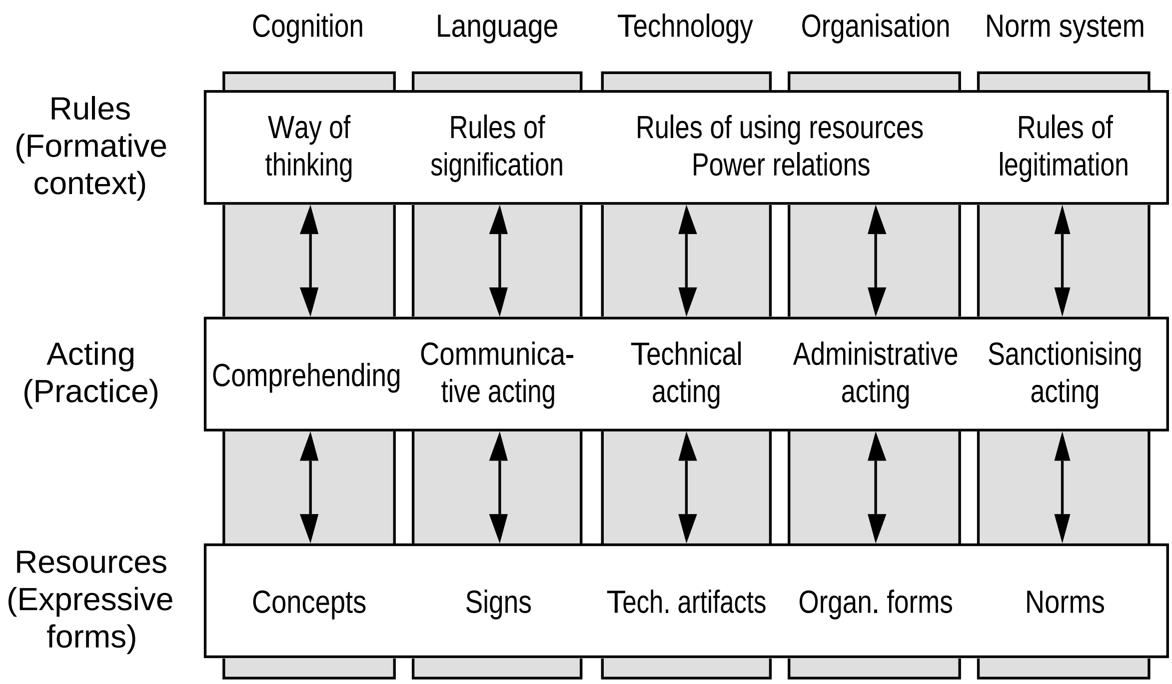


*Fig. 2: Recursive constitution of action and social structure*

The development of technical artifacts (and of software in particular) so far has predominantly concentrated on design according to functional requirements and almost neglected the reverse process of appropriation. However, the skill to make sense of the artifacts, to find adequate interpretations for accomplishing the working tasks is of equal importance and requires creativity as well. Consequently, the design and use of technical artifacts have to be regarded as integral part of organisational development.

## 3 „The Times They Are A-Changin' ": MRP Systems in Use

Development, implementation and use of MRP systems (Manufacturing Resources Planning) are a good case to demonstrate how technology is socially embedded, in particular to illustrate the relevance of interaction between suppliers and users of technology and the mediating function of shared visions between the actors in the field. Based on a recent investigation carried out by the Institute for Work and Technology (Maucher 1998), this chapter presents how MRP systems and their use developed over time in the area of conflicting views and interests of suppliers and users and which strategic orientation they had. It also underlines the value and effectiveness of participatory implementation processes that deliberately takes into consideration the manifold interactions between organisation and technology.

Production planning and control is a set of operational activities being established to enact the principles of rationalisation, i. e. to achieve the highest possible economic effect with the least effort under given conditions. In particular, these activities aim at manufacturing products, subassemblies and parts just in time they are needed which means to simultaneously meet the partially conflicting objectives of maintaining due dates, of reducing throughput times, of reducing in-process inventories and of increasing machine capacity use. This very much looks like a formal problem of optimisation and, in fact, it drew the attention of operations research experts. At the same time, it seemed to be made for the use of computers to practically solve the underlying planning and control problems, since huge masses of data had to be handled and processes appeared to be easily modelled in algorithmic procedures.

Concentrating at first on material resources planning, on resolving bills of material, and on calculating net demands for parts' supply, this actually was one of earliest fields of commercial computer use. It soon expanded towards the control of material flow throughout the manufacturing process. The underlying optimisation problem was attacked by a variety of heuristic algorithms. This was about the state of the art in the fifties and the starting point of a rapid multi-step development process for MRP methods and systems, which can clearly be characterised as a reflexive process of design and use. It is driven by the ongoing interaction between system suppliers and users searching for appropriate solutions. Within the interaction, the functional requirements for design become closely linked to the views and expectations for use and, on the basis of these links, shared visions of appropriate design and use conceptions emerge.

The social dynamics of this interaction and the dialectics of form and process it produces can be demonstrated by characterising the prevailing practice with its dominating problems on each step, by identifying the paramount shared visions of the actors and by reflecting the new use problems the systems produce on the next step. These new problems then produce modified guidelines in the process of interaction that lead to improved engineering methods and systems and again establish a new practice of production planning and control. In this way, at least four major development steps can be identified which normally are referred to as „systems generations", although much more is changed than just the IT system: The whole complex of operational rules and procedures, their organisational and technical implementation and the underlying visions shared by the actors involved are subject to change (see Fig. 3).

In the beginning of development and use of MRP systems, the paramount problem was to cope with the growing diversity of parts and sub-assemblies as well as with the more and more frequent time delays in the manufacturing processes. A large number of „part chasers“ was needed to keep track with the rather untransparent and complex operations. In this situation, the guiding idea of detailed planning procedures for prescribing and controlling the flow of material in the manufacturing process, based on algorithms for the resolution of bills of material, for inventory control procedures, and for flow control, was a promising approach to get over these problems. This appeared to be in line with the use of computers to process the high volumes of data. The procedures were individually implemented creating large monolithic software packages and making the programmers irreplaceable experts (as the „germ cell“ of the later IT department). Their skills were especially challenged by the lack of established software engineering methods and the rigid hardware constraints.

It is no surprise, of course, that the problems of using these systems, turned up immediately. In the perception of the actors they were traced back, however, to insufficiencies in the planning and controlling procedures leading to frequent changes of the computer programs which in turn, caused tremendous deficiencies in the reliability of the software, since new undetected errors came along with every change. Time and cost budgets, therefore, were regularly overdrawn as just another manifestation of the „software crisis“ being discussed since then. This gave rise to new paradigms in software development that subsequently put much emphasis on software development process models organised in strongly controlled sequential phases of requirements analysis, specification, design, implementation and test as suggested by older engineering disciplines. They promised to get better control of efficiency, correctness, and changeability of programs and to keep costs within reasonable limits. The underlying logic of optimising material flows remained untouched, however, while, as a consequence of improved software engineering, the systems were shaped in a more functionally structured and modulised form.

These redesigned systems could not, of course, really solve the use problems rooted in their insufficient usefulness and usability with respect to a meaningful interactive planning and control process incorporating human experts doing this job since ever. Progressive actors became increasingly aware of the absolutely indispensible experience and tacit-knowledge needed for effective and efficient production planning and control. This insight directed the paradigmatic perspective towards seeing the computer as a means of work and media for cooperation whereby the planning and controlling experts could improve their decision making being based now on more complete, more detailed and more up-to-date data from the manufacturing process. Moreover, the understanding grew that an IT system, being as inseparably interwoven with organisational structures and procedures as it is the case with MRP systems, cannot be totally specified in advance and without the participation of end users. Therefore, new paradigms emerged as a

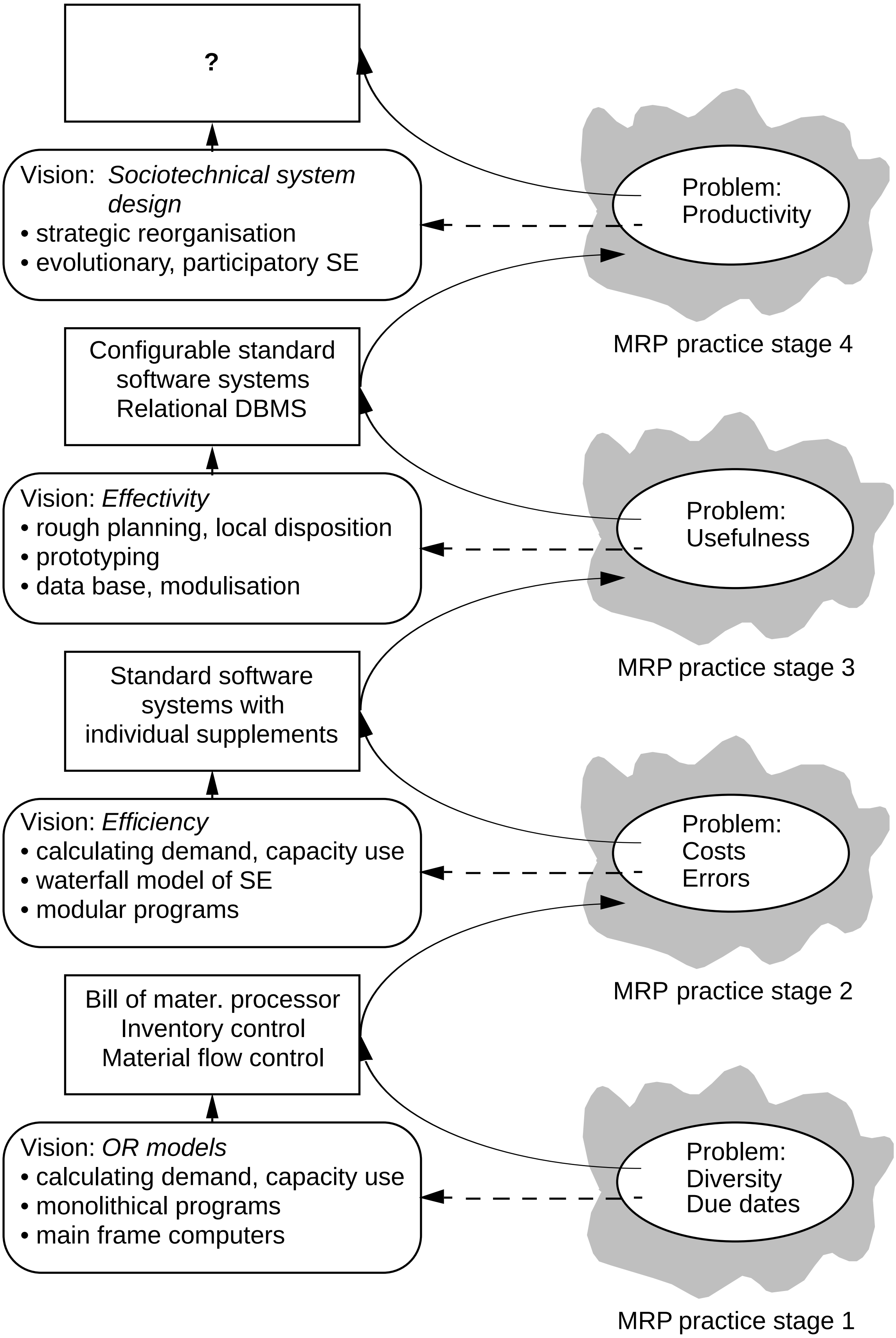


*Fig 3: MRP development as a reflexive process*

shared understanding that, firstly, the rigid and detailed palnning and controlling procedures should be abandoned in favour of rather wide-meshed central planning prescriptions leaving room to manoeuvre to local actors. Secondly, the system development should be more closely linked to the experience and feedback of pilot users and make use of prototyping techniques to this end. Thirdly, in order to be more easily adaptable to different organisational and work oriented requirements, the system's architecture should be based on a relational data base as a core component and on widely independent functional modules being combined and configurated according to specific organisational needs.

This resulted in configurable standard software packages on the basis of relational data bases that could be, within relatively wide limits, adapted to diverse organisational requirements and allowed for stepwise implementation with end user participation, iteratively considering organisational and work-related requirements coming up within the implementation and organisational change process. Thus, the reflexive development process of MRP systems has finally, after almost fourty years, autonomously achieved a state that corresponds with the conception of evolutionary and participatory system design as theoretically founded above.

With the existence of such modern MRP systems and their participatory implementation the real problems of effective production planning and control are still not solved, however. This would need a rather fundamental rethinking of the users and their decision makers whose still dominant method and technology-centred perspective prevents them from seeing the division of labour in their functionally specialised organisations as the real causes for long throughput times, high in-process inventories and insufficient reliability of due dates. Consequently, those organisational deficiencies could best be overcome by organisational measures such as the introduction of Kanban systems reducing in-process inventories (even without any computer support), the implementation of load-oriented order release procedures releasing orders to manufacturing only, if they are urgent and processing capacities are available, or the complete object-oriented restructuring of the manufacturing process with production islands where separated tasks are reintegrated. All these organisational measures can reduce throughput times and in-process inventories substantially, and they simplify the planning and controlling procedures considerably while creating fundamentally new requirements for computer support.

This indicates again how organisational structures and procedures depend on a firm's strategic goals, how they are interwoven with supporting IT systems and the way they are used, and how all this is related with the mental models the relevant actors share. It is the core of the present struggles for appropriate organisational and technical solutions within the frame of sociotechnical systems design where organisation and technology are seen as a unity. Accordingly, the detailed case studies of the investigation reveal two main streams in present production planning and control that can be characterised as follows.

In the technology-centred main stream, actors still are locked-in in traditional rationalistic ways of thinking putting the main emphasis on sophisticated planning methods built into the MRP systems. Decision making for system implementation is mostly centralised in the planning department following such abstract criteria of rationality as the use of company-wide uniform standard software (in the expectation of avoiding interface problems), the reduction of IT costs or the use of traditional controlling techniques. Questions about usefulness and usabilitiy of the systems are, if at all, poorly considered only, and manufacturing experts are seldom involved. This has a number of undesirable consequences: in order to get the system running, manufacturing procedures have to be adjusted to system requirements (instead of the reverse way), rooms for maneuver in disposing resources needed for greater flexibility are being cut back (without really improving the planning results), while the system sometimes turns out to be an obstacle for quick reactions (driving the users to skillfully circumvent its procedures).

In the second, much more sophisticated main stream, although followed by considerably fewer companies, users concentrate first of all on the customer-oriented restructuring of their organisation. MRP systems are chosen and configurated such that they can be adapted to and support the new organisational reqirements. They are seen, implemented and used as an IT infrastructure to support human decision making, as a media for cooperation and coordination rather than a detailed planning procedure. Accordingly, those systems are preferred that have clearly defined and configurable functional modules and interfaces and that allow for work and process-oriented views on the data base. This also allows for stepwise implementation in the course of organisational development and fine tuning with the participation of relevant pilot end users from the very beginning. System configuration and human-computer interaction can thus be adapted to the needs of work and decision making, while rooms to move can be maintained for flexibility. A central activity troughout the implementation process is the participatory design of a shared data model reflecting the organisational procedures (and clearing up old data „inventories“). Much emphasis is put on early qualification of the end users for coping with decision making and coordination problems in the new organisation, not only on mere system interaction. Longer implementation phases are consciously accepted, since much higher economic benefits can be expected from this way of implementation.

This second approach to implementation und use of MRP systems in fact turns out to be the much more effective and economicly beneficious (in terms of throughput time and inventory reduction and higher flexibility) than the technology-centred way still followed by most companies. We not only can conclude this from the theoretical considerations outlined above, but can in particular also empiricly observe this in comparing highly successful firms with those of lower performance (with respect to reduction of throughput time and inventory, to increase of delivery date reliability and flexibility). Studying and comparing their implementation and use processes in detail reveals that successful firms realise the relevance of organisational change and of the social embeddedness of information technology in the organisation and, accordingly, practice many of the core elements that charactarise the second approach (Maucher 1998). Very similar findings from a study of the implementation and use of ERP systems in US firms have been reported by Davenport (1998). And Salzman/Rosenthal (1994), who made case studies on the use of IT systems in financial and health services, could equally trace back the use problems to unsufficient regard to the social shaping of technology perspective.

## 4 Concluding Remarks: Beyond End User Participation

The action-oriented theory of technology outlined in this paper not only provides us with a useful understanding of how information technology interacts with the organisation, how its implementation is and has to be regarded as part of an organisational development process and why poor performance is rooted in a misperception and misinterpretation of these relations. It thus gives an explanation for the existence of the IT productivity paradox. IT systems of the order of complexity of MRP systems are not only, like liana in a rainwood forest, functionally interwoven with organisational structures and procedures, but also socially embedded in the interaction process, in which knowledgeable actors make sense of the artifacts and functions they deal with while doing their work.

Moreover, it also provides us with clear orientation and directives how to develop more effective IT systems and how to use them more efficiently. The basic guideline is to organise a collective learning process in the organisation where the design perspective of shaping artifacts and organisational structures is combined with the process perspective of organising learning to sensibly use them.

A number of methods and procedures have been developed and probed to support this kind of collective learning in a process of integrated organisation development and IT system implementation:

- future workshops (Jungk/Müllert 1989), applied in early phases of the reorganisation process, can create a shared strategic orientation and framework for further more detailed development work;
- design scenarios (Carroll 1994) support the actors (using of mock-ups and prototypes) in finding a good fit between the system's functions and the action context and in exploring new ways of doing the work with the system;
- social simulation (Haho/Smeds 1996) brings the actors in realistic working situations where they can explore and experience social relations of cooperation in the new working procedures being created.

Applying these methods and procedures in a coordinated way with respect to a firm's strategic objectives goes beyond end user participation in system design and implementation. In rebalancing interests and power relations, in exploring the use of the new artifacts and in changing the norm system, this approach rather constitutes an organisational learning process where members of the organisation consistently and cooperatively learn to make sense of the artifacts they are designing and implementing.

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