Democracy & Technological Change: Limits to Steering

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ABSTRACT

Participatory design can be read as a way of interest representation in the design of technical artifacts, be it computer systems or houses. Apart from participatory design, other strategies have been tried out in the past, to democratize the processes of technological change. In this paper we will evaluate several of these initiatives, and analyze them in terms of the factors that drive technological development. Possibilities for technology steering seem rather limited, and in the last section, we will discuss what still may be feasible.

Keywords

Technological change, technology assessment, democracy, participation, trade unions, science shop.

INTRODUCTION

As a tool for designers and managers, participatory design (PD) is a useful approach among others to achieve high quality systems. However, PD is also one of the efforts to democratize technical change. In this second reading, it is based on a rejection of *technological determinism,* which can be summarized as 1) technological development follows an internal logic of rationalization, and 2) technology determines its social consequences. As economic factors (the world market) play an important role in technical change, technological determinism comes very close to 'techno-economic' determinism. It underlies technology policy in developed countries, based on the idea that the better a country is adapted to the new technologies, the more prosperous the future will be (e.g., [3]). In other words, in high-tech societies, no room is left for social choice. The direction of technological development is taken as given, and adaptation of society to the new technologies is the task.

This view is criticized by science and technology studies, which have shown that social factors heavily influence the development of science & technology, and its effects on society (e.g., [11, 29]). At the same time, it has been shown that technological development is characterized by stable patterns, exhibiting an internal logic [13, 25, 26, 35]. This dialectics of social determination and internal logic of technological change suggest that, at least theoretically, it is possible to influence technological development and its integration into society, by influencing the crucial social variables. The program of democratizing technological development has been inspired by these insights: The trajectories of technological development can and should be influenced, because technology influences society, and the interests and positions of various social groups.[1]

Forms of strategic decision making about technological development can be found in (large) knowledge based companies since the end of the last century [36], and more recently in government: military, space, and nuclear technologies [15]. These institutional actors are able to influence direction and speed of technological development. In the political climate of the seventies and eighties, other social groups formulated a demand for access to decision-making about technology, and many initiatives have been undertaken to 'democratize' technological development. As technologies do have politics [57], the basic idea underlying these programs is to replace 'autonomous' and profit maximizing technologies by *human centred technologies.* This is based on the idea that technological development *may* result in social progress, but that it does not necessarily do so. Thus, combining technological change with social progress is a *problem* and a *task,* and not a-priori given, as has been the dominant view since the rise of *enlightenment.*

In this paper, several efforts to democratize technological development will be discussed: 'technology assessment', 'participatory design', 'trade union oriented technology

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[1] From a 'social constructivist' point of view, it has been argued that technology does not have effects by itself. In this perspective, technology and its effects have to be 'deconstructed' into various actors' intentions, strategies, and interests [4, 5, 19, 30, 58]. Although I agree that on an 'ontological' level, every artifact can be 'deconstructed' as social, this does not imply that technologies have no social effects. Constructed technologies have effects as soon as they are constructed, and construction is determined by constructions from the past.

policy', 'science shops', and 'strategic workers' plans'.[2] I will evaluate these initiatives, using insights from contemporary science and technology studies.

TECHNOLOGY ASSESSMENT

Technology assessment (TA) emerged in the 1970s, and the original idea was to provide the decision-makers and the public with a comprehensive overview of the possible economic, ecological, social, and cultural effects of new technologies [10]. In this way, TA was expected to become an 'early warning system', to improve decision making about technological development and about the conditions for implementation and use of these technologies. In various countries, TA has been institutionalized, and many TA-studies have been published on many aspects of technological development. However, the expectations have not been met, and the following problems have been formulated [50].

First, it has proved to be impossible to give a *complete* overview of possible future effects of new technologies. Every TA-study needs to select its focus, and this selection necessarily reflects normative viewpoints. Consequently, instead of being a neutral knowledge input into political decision-making, TA became itself subject of political and normative discussions. In fact, the underlying concept of political decision making was inaccurate. Politics is *not* technical optimization based on complete knowledge about goal-means relations. On the contrary, politics is about different views and interests, and technological development itself is embedded in and an expression of social processes and diverging interests.

Second, the accuracy of predictions of TA-studies generally is rather modest, which is not (only) an effect of lack of forecasting techniques, but also of the more fundamental issue of the 'counter-intuitive' nature of complex social systems. In general, one could argue that building 'good' artifacts (e.g., human centred systems [17, 43]) may have 'bad' effects. For example, 'sustainable technologies' may on the long run impoverish the physical environment even more than the less sustainable technologies, because 'clean' technologies may enable a continuation of unsustainable behavior, leading to a postponed, but more severe environmental crisis [14]. And, improving quality of work (e.g., autonomous workgroups) may result in an extreme stress at work [39].

Third, in the early phases of the development of new technologies, it is often difficult to say much about future consequences. Social implications only become clear when the technology matures and has started to diffuse on a larger scale. However, at that moment the technology is entrenched into society, through a process of co-evolution of social institutions and technological development [34], and the technology has become part of vested interests. As a consequence, it is rather difficult to influence an established technological trajectory. Lock-ins [1] have emerged, and despite the availability of potentially better technological paradigms, sub-optimal solutions remain dominant.

Fourth, TA overestimates the role of political decision making in technological development. Complex technological systems in particular do have many determinants, and many direct and indirect consequences. Various social actors with diverging interests and related strategies are involved. Complex social processes around technological development are only partially influenced by politics, and they cannot be 'rationalized' by TA. As stated earlier, TA always takes a normative stand, and becomes therefore part of the political struggle around technological change [32].

Last but not least, because of the speed and the scale of contemporary technological development, TA is always far behind.

These problems resulted in a different, more practical TA-conception, 'constructive technology assessment' or CTA ([56, 40]; related approaches are 'strategic TA' [50] and 'interactive TA' [18]). Whilst TA was aiming at influencing the *selection* between existing and expected technological options, CTA aims at *variation*, that is the creation of additional technological options. Technological development is a process of building, learning and managing, and the idea behind CTA is to include stakeholders of various views in this process. CTA consists of: 1) research and reflection on the possible impacts of new technologies, 2) strategic anticipation of future technological developments, 3) strategic decision making about technological development, by bringing the relevant stakeholders into the decision making process, 4) technology development based on business *and* social considerations. Thus, the program of CTA is to include possible future effects in design, development and implementation of new technologies, and to tackle the anticipated effects in advance. CTA focuses on social learning, producer-user relations, decision making, and on creating consensus through public debates. It is a strategic approach to technology, which combines learning, assessment and evaluation, with the stimulation of technological development and innovation. Including social considerations in the design may extend the set of technological options.

The CTA-program has been implemented in several countries, notably The Netherlands and Denmark. A successful example of CTA is the Dutch Prisma project, on including environmental considerations in the (re)design of factories. The project showed that *environmental engineering* of plants reduces pollution and at the same time may

[2] The paper does not pretend to give a complete overview of all initiatives to democratize technological development. Here, the focus is on trade union and work oriented grass roots activities. Also left wing governments have tried to establish socially oriented technology policy, e.g., in the UK and in the Netherlands in the seventies and in France in the early eighties. These policies were not very successful. I cannot go into detail here. However, an explanation would proceed along similar lines as presented in this paper.

improve profitability, by reducing pollution taxes, and by saving energy and materials. The project is paradigmatic for CTA. However, a main drawback is that the project focuses on the engineering aspect of redesign, and that it does not include fundamental changes of the technologies involved. Other CTA projects which were more oriented to 'basic technologies', like a hydrogen-based energy system for the Rotterdam harbor, did attract *interest* from companies, but no *commitment* to change the current technological system [38].

CTA implies a shift from politics to design. CTA is based on a better understanding of the dynamics of technological development, and relates the social dynamics of technological change to the complex integration of technology into society. It enables a more differentiated treatment of the relations between technological and social change, in terms of effects of technical change and in terms of strategies to influence it. At the same time, an understanding of the dynamics of technical change may explain why 'engineering' projects can be successful, while 'basic technology' projects generally fail. I will come back to this issue later.

PARTICIPATORY DESIGN

PD can be seen as an early version of CTA. After information technologies began to diffuse in the workplace, awareness grew about the implications the new technology was going to have for workers. Trade unions started to discuss the possible effects of information technology on the quality of working life and on employment, resulting in a demand for co-determination in the development of information systems in the workplace: PD. Clement & Van den Besselaar evaluated some fifteen 'best practice' PD-projects [9]. The projects differed in many respects. First, the early projects were more directed at acquiring knowledge about the technologies, and about their possible consequences for the workplace, whereas the later projects were based on the development of systems and software, and on the identification organizational changes related to the use of the new systems. We also noticed a shift from projects concentrated in the manufacturing industry to projects focusing on 'female' clerical and service jobs. This, of course, reflects social and economic changes that took place during the two decades. The projects were organized in various forms, and various participatory methods and techniques were used.

We also found some common characteristics. PD was based on industrial relations regulations (co-determination legislation) and on labor legislation (e.g., on quality of work). Generally, local unions, works councils, and researchers were the major actors. In most cases, the researchers brought in the resources needed for the projects. The concrete involvement and role of trade unions, however, was less clear. Another common characteristic was the absence of management from the projects. Finally, most projects focused on small stand-alone applications of IT, indicating a low organizational complexity of the projects.

A comparative analysis of the projects showed that the employees needed access to relevant information; that they must have the option of taking an independent position on the issues; and that they must in some way participate in the process of decision making. Additionally, the availability of special participatory development methods, and resources, is important. Finally, crucial for PD is the presence of technological and organizational flexibility: alternatives have to be available. The projects were relatively successful. Through participation, workers became skilled in formulating an independent vision of the implementation of information technology, and were able to formulate demands in terms of technical and organizational requirements. Often, the workers were able to succeed in developing and implementing the system and the organizational changes. The projects also suggested that PD does not necessarily lead to 'uneconomic' solutions. The main lesson of this retrospective evaluation was that workers (users) are perfectly able to influence the use of computers in their everyday working life, especially when they can be supported by computer specialists who are sensitive to the social and organizational aspects of the use of ICT. Increasingly, PD is accepted as a part of common knowledge in the field, and a large amount of scholarly literature is witnessing this. Nevertheless, some major limitations have to be mentioned.

First, although some of the results were durable, in most cases they were fragile. When the project ended, and the researchers who facilitated the project left, the active participation of workers generally ended. In other words, also in these best-practice cases, the PD did not become part of company culture. A lesson is, therefore, that participation in technical change is a project that permanently needs support and active stimulation, like the innovative activities of management.

Second, most PD-projects are stand alone projects, small scale and not of high strategic value for the organization involved. The question has to be asked whether the PD approach can be extended in a meaningful way to large, strategic and infrastructural ITC applications.

Third, although PD started as an effort to allow workers to democratically influence the quality of working life and technological change, the question of democracy has been removed from the agenda. 'Workers participation' is now replaced by 'user (including management) involvement'. Sociological analysis of interests is replaced by 'ethnographic analysis' of the use of technology. Emphasis on 'interests' is replaced by a focus on micro-social characteristics of the workplace. Technology is increasingly seen as 'neutral', and many PD researchers moved to the field of CSCW, which is seen as a 'better' technological trajectory. Finally, influencing the development and use of information technologies no longer has a place within union strategies.

Clearly, the larger agenda of emancipation and democracy has been abandoned in favor of a narrower one of improving systems for users. Starting as political grassroots movement to empower workers and enable them to represent their interests in technological change at the shop floor, PD now is more and more a tool to improve the design and implementation of information technology, for users and for management. The point is, however, "that by looking exclusively at the problems of designing and implementing user-friendly systems, one is ignoring, or at the very least, minimizing, some real problems that even the best user friendly systems will generate". [33]

TRADE UNION TECHNOLOGY POLICY

The awareness that 'traditional' PD projects were restricted to the design and implementation of small-scale systems grew in the early 1980's. After many PD projects within the tradition of socio-technical design, and later within a trade union context, Scandinavian researchers in particular found that the dominant technological trajectories were too constraining. As early as 1983, Sandberg formulated this clearly, when he stated that: "What is needed is an offensive, long term and far reaching strategy, coordinated by national unions - not simply reactions to local changes and crisis. This will require both trade union cooperation on an international level and union cooperation with engineers, physical scientists, and social scientists. Through such efforts one might test the possibilities and limits of *a positive and offensive trade union policy of technology*." [45]

Based on this program, the well known Utopia-project on developing graphical tools to support skills and product quality was formulated. This project is one of the few examples of a pro-active and 'democratic' technology policy, based on cooperation between researchers and unions, and funded by the government. Cooperation was organized with a trade union owned newspaper (for implementation and testing), and with a producer of graphical equipment (for marketing). Unfortunately, implementation as well as marketing failed, despite relatively positive conditions: legislation that forced employers to use the most 'human-centred' technology available, a large public sector, and strong trade unions and a stable social democratic government. Nevertheless, the first implementation went wrong, because of diverging interests between graphical workers (and their union) and journalists (and their union). Additionally, the graphical equipment producer had problems in commercializing the Utopia tools, because it could not manage nor afford to produce and market the Utopia tools *and* mainstream graphical equipment.

These problems do teach us an important lesson. Unions appear to have an ongoing problem with the formulation of a pro-active technology strategy, because every strategy also defines the future victims. Empowering graphical workers affects the interests of journalists and typists. Propagating Utopia tools affects other producers (and workers) of graphic tools. This is true in a sectoral activity, like Utopia, but even more at the company level. There, works councils and local unions are as constrained by competition as management is. Consequently, unions are generally reluctant to associate themselves with strategic management decisions. They prefer to keep 'clean hands', to be able to negotiate with management the social plan for the victims of reorganizations and technical change. If unions become responsible for (technological) change, they will get into trouble with parts of their membership. This may be a relatively small problem in periods of full employment (as in Sweden during the peak-years of PD), but it is completely different during crises. Therefore, company level and sectoral technology policy of trade unions is only possible within the context of economic and social policy at the macro-level. As a PD project, Utopia was successful. It indicated that workers are able to specify systems requirements, based on their interests and goals. As a democratic technology development process, however, it failed.[3]

WORKERS' PLANS

Another strategy of workers and their organizations to cope with the effects of technological change were *workers' plans*, which were first practiced at Lucas Aerospace (the 'alternative corporate plan') and by the Greater London Council. In 1976, a combined shop steward committee at Lucas Aerospace presented an elaborate plan as an alternative to drastic job reductions envisaged by the management. Because the company was highly knowledge-intensive (devices for military airplanes), the plan implied alternative diversification strategies and alternative technologies. An impressive list of proposals was presented. Labor's industrial policy, initiated by Tony Benn and Stuart Holland, was the original setting for the Lucas Aerospace Alternative Corporate Plan [51]. However, by the time the 'alternative corporate plan' was ready, the policy had already been abandoned, and Tony Benn was no longer minister for industry. Although the plan was never realized, it inspired many trade union members to make their own proposals about what to do with new technologies, and to confront these options with the proposals put forth by management. The plan implied labor's cooperation with an institute of higher education. The combined efforts of workers and intellectuals would produce new technologies, which – since they did not have capitalist aims - could at the one and same time be socially useful, less polluting, and create new jobs [27]. Both in Britain and in the Netherlands many such plans were put forward. We were able to detect some 37

[3] Another technology development project within this tradition is an ESPRIT funded project on 'human centred machine tools', run by Howard Rosenbrock, and Mike Cooley [43]. The lessons are similar. As in the Utopia case, it resulted in new technological ideas, which then did not diffuse. In Germany, a large-scale research program on technological change and quality of work ('Humanisiering des Arbeitslebens', was launched. In [23] we discuss this program, and it became clear that its impact was on social and organizational issues only, and not on technology and technological change.

workers' plans from papers, and from trade union informants. In 27 cases, we had access to the relevant written material, and we were able to interview various people involved, workers, union officials and managers.

Table 1: Characteristics of workers' plans*

Total number of workers' plans	27
Factory is part of large company (of which Philips Electronics: 10) (of which RSV Shipbuilders: 9)	27
Factory is under threat of far reaching reorganizations (of which a threat of closure: 2)	26
Plan contains ideas for new products	10
Consultation of external specialists	7
Result with respect to employment**	3
Result with respect to quality of work	1
Results in technological innovation	3

* The Netherlands, early 1980s.
** In two cases fewer jobs were lost than planned by management. In the third case, the impact of the plan was small compared to other factors. For details: [55].

First, all but one of the workers' plans were a reaction to the threat of closure of the plant (8%), or to a far reaching reorganization (88%). Only in one case the plan was more proactive. In this case, the plant had severe problems with the quality of work. Second, all cases were in local plants of large corporations, reflecting that larger corporations are more 'technology intensive', and characterized by the strong presence of trade unions. Third, a large number of the plans (39%) contained ideas for new products, indicating that there are many innovative ideas among workers. The development of such ideas into R&D projects, however, is a different story.

In 60% of the plans with product ideas, external expertise was consulted. However, only in three cases was this cooperation successful. In two of these cases, parts of the plan were incorporated into the company's strategy, and developed further. One product was designed to burn heavily polluted earth; the other was related to packing products. In the third case, a new way to produce alcohol (from maize) was developed, as an alternative for motor fuel. This was inspired by environmental considerations. However, the market was not attractive for further development: petrol was (and still is) less expensive.

Although the three cases noted above constitute remarkable results, the general picture is completely different. In nearly all cases analyzed, it was the decline of the plant by purposeful planning of top management (and probably the lack of technological development), which gave rise to the plan. The general conclusion here is that the workers' plans were defensive weapons to counter planned dismissals by top-management. The thesis that these plans offer workers an offensive instrument to influence management strategies on new technologies is, therefore, not supported by our results. Only in two out of about thirty cases, an interface with R&D was established. Usually, there was little idea of how to develop such an interface.

SCIENCE SHOPS

In the seventies, the awareness grew that science and technology were becoming a major 'productive force', with a pervasive ideological power, changing the dialectics of 'structure and superstructure' of society. Progressive students and academic researchers linked up with trade unions, but soon the lack of cognitive content in such cooperation was perceived as a problem. This problem then was solved by the proposal to create 'science shops': university-based institutes that would take the questions of their clients (trade unions, social movements, and individual citizens) as an external demand for the university research system. The first Science Shop was established at the University of Amsterdam in 1977, and mediated between social actors and researchers on many issues. However, as far as science based technologies are concerned, we soon realized that demands put forward by trade unions were nearly always technical (and not scientific or technological) and generally required service and not research. A scientific or technological question 'behind the problem' was never obvious. Therefore we tried to find situations in which trade union issues were more directly related to the effects of technological change. Two long-term projects resulted, one in the chemical industry, and another in banking. These two sectors were going through a period of fast technological development, and the concern existed that this would impact on workers and unions. Elsewhere, we have analyzed the possibilities and problems of influencing technological strategies of large knowledge intensive companies [24]. Here I summarize the conclusions.

In chemical industry and in banking, we found that power relations prevented unions from influencing strategic decision making. The chemical firm had placed all strategic decisions in the international parts of the company, and in the banking case, decision making was transferred to the sectoral level. Under the prevailing Dutch co-determination laws, strategic decision making remained outside the influence of works councils and trade unions. At the same time, it proved to be difficult to formulate an alternative technology strategy from a labor point of view. In the banking case, unions and works councils did have a strategy on quality of working life, and on employment, but no strategic view on information technology and the future of banking: electronic fund transfer systems. The workers' perspective was too much oriented to micro-issues (quality of work) or too general (e.g., employment) to create an interface with corporate (or sectoral) technology policy.

These – relatively pessimistic – results indicate at the same time the limits of the Science Shop as an instrument to influence technological development from a grass roots point of view, and support the lessons drawn from the analysis of workers' plans.

PARTICIPATION IN CONTEXT

While PD was developing mainly in the Scandinavian countries, workers' plans were more based in Britain and the Netherlands. This can easily be explained: during the seventies and eighties, the Scandinavian countries were economically doing well, and the main problem with information technology was seen in the potentially deskilling effects. In Britain and in the Netherlands, unemployment was rising sharply, and information technology was seen as one of the main causes of unemployment.

Participatory design was inspired by Braverman's analysis of 'taylorism' and 'capitalist technology'. Division of labor and deskilling (transfer of knowledge and skills from the shop floor into machinery) were interpreted as management instruments to control labor and the labor process. [6, 37] Information technologies were seen as an extension of 'taylorizing' to parts of the economy that had not been affected before: office work, services, and knowledge work. As Noble argued [37], workers had to counteract the technological strategies of management, and struggle for technologies that retained skills and quality of working life, without being less 'economic'. PD emerged as such a counter strategy.

Workers' plans on the other hand, mainly focused on the employment problem. The focus was not on the deskilling effects of new technology, but on the rationalizing effects. Workers' plans responded to techno-economic change, which forced companies to change strategies. Where management in the companies decided for strategies that implied downsizing or closing plants, workers tried to formulate alternative corporate plans that could give new options. Not Braverman, but Schumpeter (focusing on the long wave in economic development and on the role of technological development as a force behind it [48]) can be used to understand the emergence of workers' plans. The relationship between workers, unions, and technological change becomes completely different in these different contexts. It is not the *process innovation* that is central in workers' plans, but *product innovations*, strategic choices for new markets and the preservation of jobs.

These differences between PD and workers' plans reflect the economic changes that have taken place since the first oil crisis in 1973. PD projects are a reflection of the boom period, in which the focus was on quality of working life, skills, and autonomy. Workers' plans, on the other hand, reflect the recession period, in which a structural economic and technological transition was taking place. In this transition, problems changed. The analysis of Braverman may have been adequate for the prosperity phase after World War II, which was based on productivity enhancing taylorist production concepts. Research shows deskilling tendencies during this period, which was perceived as a problem for workers. Although Braverman probably was right in that this deskilling is a consequence from the maturing of dominant (capitalist) technologies during the post World War II prosperity phase, this, however, cannot be generalized to technological development as such. More recent empirical research suggests that after a period of deskilling, upskilling seems to be dominant, possibly as a consequence of the transition from one technological regime to another [2, 53]. New production concepts seem to require more skills, and at least for the core workers the 'end of taylorism' may become reality.

These socio-economic changes are reflected within the PD-movement, which continued to focus on skills and quality of work, and became increasingly a-political (which does not mean irrelevant). As society is in a transitional phase, the arena in which technological development is contested changes too. New techno-political issues arise, requiring a shift in the focus of a PD-approach that aims at democratizing technological development.

THE DYNAMICS OF TECHNOLOGICAL CHANGE

Above, I have analyzed the problems of PD and related efforts to influence technological development. In the past 25 years, significant research has been done to understand technological change and its integration into society. This growing body of knowledge may inform us about structural problems and strategic possibilities for democratizing technological development. We lack space to discuss this literature here, and restrict ourselves to what we see as a general result (for overviews e.g., [12, 15]).

Technological development is an evolutionary process, guided by heuristics [35], dominant designs [44], or paradigms [13]. Learning by doing and by using [42], and step by step improvements [21, 41] play important roles in technological development. Social and political factors [5, 8, 21], economic expectations [47, 31, 42], and finally the organization of user-producer relations [28] are important contextual variables influencing technological change. The generation of new technological possibilities, in evolutionary terms 'variation', takes place within a social environment that influences the variation, and at the same time 'selects'. This may result in a 'stabilization' of technological development in trajectories or regimes. Studies have focused on the various levels at which technology can be defined.

Technology is a multi-faceted and multi-level phenomenon, that can be defined as an artifact, as a process, as knowledge, methods and skills, and as a 'socio-technical system of production and use', which includes artifacts, infrastructures and institutions [22]. Without a consequent differentiation between these levels, it is impossible to study and discuss the social determinants and the social consequences of technological development in a rigorous way. More specifically, conclusions that are valid on one level cannot be generalized to other levels.

A layered concept of technology requires a similar concept of *technological change.* Freeman and Perez [16] suggest a useful classification.

- *Minor innovations,* the regular improvements of products and processes, which are not very influential individually, but together have an enormous impact on performance.

- *Radical innovations,* important innovations, but only in a restricted field.
- *New technological systems*, consisting of many related innovations, and resulting in a new technology for an existing function (e.g., nuclear energy).
- *Technological revolutions*, which change the complete techno-economic structure of society (e.g., information and communication technology).

On the lower levels, technical change takes the form of processes of innovation and diffusion of new artifacts. If, however, we conceptualize technological development as the dynamics of large technical systems, we have to distinguish between different phases of system evolution, like the ones suggested by Hughes [21]. In the various phases, different factors are important, not only technological and economic, but also social, institutional and political factors. On this level, system evolution can be described as a complex and layered management problem [20, 21].

On an even higher level, technological development can be analyzed as a sequence of 'techno-economic paradigms', with an economic, but also social and institutional dynamics. A new techno-economic paradigm implies a fundamental restructuring of the economy based on the new technological factor. In periods in which the old techno-economic paradigm is substituted by a new one, the role of social and institutional change becomes very important [16]. Long-term technological change is related to changes in the organization of society. Social innovation is required, which accompanies technological innovation. In other words, on this level technological change is a process of *co-evolution of technology, markets, and institutions.*

Only when all social and technical components of a socio-technical system fit together, the system will function [8, 21]. Evolutionarily, one expects these complex dependencies to develop into a *hypercycle*, which stabilizes and reproduces itself, even when they are under the influence of disturbance [26]. This implies that efforts to influence the development of socio-technical systems are generally not very effective. Complex systems are by nature very difficult to influence, and exhibit self-organizational behavior. Recently, technology studies have developed models of *self-organization*, using concepts like *lock-in* and *path dependency.*

Brian Arthur [1] distinguished between diffusion of new technologies in terms of increasing and diminishing returns of adoption of innovations. Where the latter used to be the general pattern in the industrial society, the former is more relevant in the knowledge economy. Increasing returns from adoption means that as soon as one of the technical options passes a certain threshold, it will take the whole market and push the alternatives out – even if they are better. This means that diffusion is path-dependent, and the result is a lock-in situation where the dominant technology may be sub-optimal. Using relatively simple simulations, it can be shown that the preferences of the early adopters are decisive. Well-known examples of lock-in are VHS versus Betamax, and the PC. As soon as a lock-in occurs, the situation has become stable.[4] The selection environment is too coercive for new technological options to be able to mature. In evolutionary terms, only when a 'niche' exists, outside the influence of the dominant paradigm, new technologies may be able develop. Eventually, the new technology may start to compete with the dominant one.

Efforts to realize technological alternatives need to be based on knowledge about conditions that lead to monopoly, knowledge about the competition between technologies, and knowledge about the dynamics of 'niche creation'. It has been shown that timing is the crucial factor if one wants to counteract [1]. However, research in evolutionary economics and simulations suggest that existing technologies create serious thresholds, which make the diffusion of alternatives rather difficult ([7], for an overview [25]).

CONCLUSIONS AND DISCUSSION

In the fist part of this paper, various efforts to democratize technological development have been analyzed, resulting in several interesting findings.

First, participation in small-scale and micro-level technical development projects is relatively successful, whereas intervening in large-scale projects at company level or sectoral level generally is unsuccessful. And, operating within a dominant technological paradigm (e.g., environmental engineering within existing plants) is easier, but also has less radical effects, in comparison with a move to a new technological trajectory (e.g., the development of hydrogen based power systems).

Second, structural constraints and an uneven distribution of resources explain why certain social actors can have success, while others fail in their role of technological system-builders. Various structural barriers were identified, like unequal power relations, inadequate codetermination laws, insufficient knowledge and resources to translate innovative ideas into R&D programs and company

[4] Lock-in results from various mechanisms, reflecting the complex nature of technical change. *Learning by using*, resulting in faster improvements of the dominant technology. *Network externalities*: factors in the environment of a technology reinforce the diffusion. *Economies of scale*: leading technologies profit from economies of scale, whereas newly emerging technologies do not, and consequently remain more expensive. *Informational advantages*: well known technologies diffuse faster than others, which consequently remain relatively unknown (and unused). *Technological dependencies*: dominant technologies rest upon a developed infrastructure of supporting technologies. New technologies are lacking this, and are therefore less attractive.

strategies, diverging interests of the workforce and the complexity of interest representation.

Third, various plans and projects have shown that at the level of *generating* innovative ideas and alternative designs, democratic PD initiatives can be successful, whereas the efforts to realize *adoption* of the new technologies by society generally failed. In other words, the focus has been too much on design and the generation of new technological options. However, the impact of the social and economic factors that determine the diffusion of new technological options has been overlooked.

Fourth, the agenda of PD has not kept up with the changes that have taken place in society and in the changing opportunities and risks of technological development.

In the second part of the paper, we briefly discussed some literature on the dynamics of technological development. Various issues arose that are relevant for a program of democratic PD. It has been argued that technology is a multi-level phenomenon; influencing technological development means different things on the different levels of increasing complexity. On the micro-level of local systems and innovations, the social environment of technology consists of arenas, in which various interest groups try to shape technology and related organizational forms. On the level of large technological systems, and on the level of techno-economic paradigms, technological development takes place in a more complex environment. This has considerable implications for the possibility of democratizing technological development. The distinction of various levels at which technology 'exists' enables us to specify various levels of institutional conditions for influencing technological development.

On the level of individual innovations, 'leading edge consumer' arrangements and relations between producers and users/consumers are important, and open up possibilities for influencing the production and use of new technological artifacts and information systems. Basically, Participatory Design, and Human Centred Systems Design are strategies useful only *within* existing technological trajectories. The effectiveness of these strategies depends on an actor's ability to translate objectives into input for technology development processes and for the integration of the technology into society. The more general objectives are (equality, employment, sustainability), the more difficult this seems to be within the context of existing technological trajectories and regimes.

Complex technological systems consist of a set mutual interdependent technological trajectories and socio-political elements. If one wants to influence the development of large technological systems, one needs resources and instruments to manage complex transitions. The question remains of which actors can successfully construct systems, given an existing socio-technical constellation. Which actors are able to handle the problem of 'multi level management' of large technological systems? We find successful and unsuccessful 'system builders' [21] and 'translators' [5]. The evaluation of the various programs illustrated that the chances for democratization of technological development have been rather small on this level.

The dependency between changes of the techno-economic paradigm and changes in the socio-institutional structure suggests possibilities to influence the development and stabilization of new technological regimes through a program of social innovations. However, whether this can be a democratic process, remains an open question: Which social actors are able to carry these processes? Which institutional arrangements are required for this kind of transitions?

At the same moment, our knowledge of 'path dependency', 'lock in', and 'thresholds' in the competition between technologies, teaches us that in many situations serious barriers hinder a steering of technological development. Where 'positive returns from adoption' exists, path-dependency and lock-in occurs even at the level of the diffusion of individual innovations [1]. At the higher levels of complex technological systems and techno-economic paradigms, mechanisms of self-organization work even stronger. Technological development on this level is relatively autonomous, which does not imply that human agency has no influence at all. However, the relation between goals and outcomes generally is rather weak on this level. The links between agency and effects have become indirect, resulting in important secondary effects and unintended consequences. When systems exhibit self-organizational behavior, the concept of *steering* needs to be redefined.

CTA, PD, Workers' plans, Science shops, and HCS-design represent too much an engineering perspective on the high-tech society. We cannot engineer society, and PD therefore has to be complemented with social innovation, but uncertain about the effects remains. Where uncertainty dominates, a reflexive position is required. In a *knowledge-based information society*, also grass roots initiatives have to become knowledge-based. The following suggestions may add some reflexive elements to the PD-agenda.

1. Technological change influences the distribution of power and income, and generally in an unequal way. Where we cannot steer technological development and its social impacts, policies and institutional arrangements are needed to redistribute benefits and costs of technological development more equally.

2. Despite its stabilization, the existing socio-technical system is not the only one possible, nor will it last forever. Which 'functionally equivalent' systems can be envisaged, and under which conditions could they operate? What are the normative dimensions of these possible futures? Can we enlarge our 'possibility space', and our scope of thinking about the future of society? Of course, ideas about alternative options may stimulate participatory experiments.

3. Even if we can identify possible alternatives, we cannot create socio-technical system purposefully. Social and technological developments are characterized by a counter-intuitive logic. Therefore, knowledge of 'transitory dynamics' (evolutionary jumps, niche management, social innovation) is a next step in the increase of reflexivity, which may inform our acting.

4. The early PD-movement was based on a diagnosis of society. However, as society, economy, and technology have changed, an updated analysis of the current area is needed, to renew the agenda of participatory design. Within the context of this paper, I cannot present an analysis of the 'rise of the network society' [59]. But I have the feeling that issues like *technology, unemployment and inequality* [52], and the development and use of *communityware and community networks* [54] will be important topics for such a renewed agenda.

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REFERENCES

1. Arthur, W.B, *Increasing returns and path dependency in the economy*, Ann Arbor: MUP, 1995
2. Attewell, P., The deskilling controversy. In: *Work & Occupations* **14** (1987) pp. 333-346.
3. Bangemann Commission, *Europe and the global information society*. Cordis Focus, supplement 2, 15-7-'94.
4. Bijker, W.E., Hughes, T.P., Pinch, T.J., *The social construction of technological systems; new directions in the sociology and history of technology*, Cambridge, Mass.: MIT Press, 1987.
5. Bijker, W. & J. Law, *Shaping technology, Building society*. Cambridge: MIT Press, 1992.
6. Braverman, H., *Labor and Monopoly Capitalism*. New York: Monthly Review Press, 1974.
7. Brückner, E., W. Ebeling, M.A. Jimenez Montano & A. Scharnhorst, Hyperselection and innovation described by a stochastic model of technological evolution. In: Leydesdorff & Van den Besselaar 1994.
8. Callon, M., The sociology of an actor-network: the case of the electric vehicle, in: M. Callon, J. Law, A. Rip (eds.), *Mapping the dynamics of science and technology*, Houndsmill: MacMillan Press, 1986.
9. Clement, A. & P. van den Besselaar, A retrospective look at PD projects. *Communications of the ACM* **36** (1993) 6 (June) pp. 29-37.
10. Coates, V., *Readings in technology assessment.* Washington: George Washington University, 1975.
11. Collins, H.M., The sociology of scientific knowledge: studies of contemporary science. In: *Annual Review of Sociology* **9** (1983) pp.265-285.
12. Coombs, R., Saviotti, P., Walsh, V. (eds.), *Economics and technological change*, Houndsmill/London: MacMillan Education Ltd., 1987.
13. Dosi, G., Technological paradigms and technological trajectories, *Research Policy* **11** (1982), pp. 142-167.
14. Forrester, J.W., Counterintuitive behavior of social systems. In: D.L. Meadows & D.H. Meadows, *Toward global equilibrium: collected papers*. Cambridge: Wright-Allen, 1973. pp. 3-30.
15. Freeman, C., & L. Soete, *The Economics of industrial innovation*, 3rd edition. Cambridge (MA): MIT, 1997.
16. Freeman, C. & C. Perez, Structural crises of adjustment: business cycles and investment behaviour. In: Dosi et al. (eds.), *Technical change and economic theory*, London/New York: Pinter Publishers 1988.
17. Gill, K.S., *Human-machine symbiosis, the foundations of human-centred design*. London: Springer, 1996.
18. Grin, J. & H. van de Graaf, Technology assessment as learning. In: *Science, Technology and Human Values*, **21** (1996) 1, pp. 72-99.
19. Grint, K. & S. Woolgar, Computers, guns, and roses: what's being social about being shot. In: *Science, Technology and Human Values* **17** (1992) pp366-380.
20. Hughes, T.P., *Networks of power: electrification of western society 1880-1930*, Baltimore: John Hopkins University Press, 1983.
21. Hughes, T.P., The evolution of large technological systems, in: Bijker, W., et. al., 1987.
22. Kline, S.J., What is technology. In: *Bulletin Science, Technology & Society*, 1985
23. Leydesdorff, L. & P. Van den Besselaar, Queezed between capital and technology; on the participation of labour in the knowledge society. In: *Acta Sociologica* **30** (1987) pp. 339-353.
24. Leydesdorff, L. & P. Van den Besselaar, What we learned from the Amsterdam Science shop. In: S. Blume, J. Bunders, L. Leydesdorff, R. Whitley (eds.), *The social direction of the public sciences; sociology of the sciences yearbook XI*. Dordrecht: Reidel 1987 pp. 135-160.
25. Leydesdorff, L., & P. Van den Besselaar (eds.), *Evolutionary economics and chaos theory: New directions in technology studies*. London: Frances Pinter Publishers 1994.
26. Leydesdorff, L., & P. Van den Besselaar (1998), Technological change and factor substitution in a non-

linear model. *Journal of Social and Evolutionary Systems*, forthcoming.

27. Low Beer, P., *Industrie und Glück*, Berlin: Klaus Wagenbach, 1981.
28. Lundvall, B.A., Innovation as an interactive process: from user-producer interaction to the national system of innovation. In: Dosi et al., (eds.), 1988.
29. Mackenzie, D., Wajcman J. (eds.), *The social shaping of technology*, Milton Keynes: Open University Press 1985.
30. Misa, T., How machines make history and historians help them to do so. In: *Science, Technology and Human Values* **12** (1987).
31. Mowery, D., Rosenberg, N., The influence of market demand upon innovation: a critical review of some recent empirical studies, *Research Policy* **8** (1979), 102-153.
32. Mowshowitz, A., On approaches of the study of social issues in computing. In: *Communications of the ACM* **24** (1981) 3, pp. 146-155.
33. Mowshowitz, A., The bias of computing. In Hoffman & Moore (eds.), *Ethics and the management of computer technology*. Cambridge (Mass): Oelgeschlager 1982.
34. Nelson, R., Economic growth via the co-evolution of technology and institutions. In: Leydesdorff, L., & P. Van den Besselaar, 1994.
35. Nelson, R.R., Winter, S.D., *An evolutionary theory of economic change*, Cambridge, Mass./London: Belknap Press, 1982.
36. Noble, D.F., *America by design; science, technology and the rise of corporate imperialism*, New York: Knopf, 1977.
37. Noble, D.F., Social choice in machine design, *Politics and Society* **8** (1978), 313- 347.
38. Rathenau Instituut, *The Rathenau Institute and the debate: Annual report 1994.* (Dutch)
39. Rhodes, E., & R. Carter, The impact of emerging forms of corporate or private organization. In A. Clement et. al. (eds.), *Ethics and Systems Design, The Politics of Social Responsibility*. IFIP WG9.1 Workshop, Havana, 1994.
40. Rip, A., T. Misa & J. Schot (eds.), *Managing technology in society*. London: Pinter 1995.
41. Rosenberg, N., *Perspectives on technology*, Cambridge: Cambridge University Press. 1976.
42. Rosenberg, N., *Inside the black box: technology and economics*, Cambridge: Cambridge University Press, 1982.
43. Rosenbrock, H.H. (ed.), *Designing human-centred technology*. London: Springer Verlag, 1989.
44. Sahal, D., Technological guidepost and innovation avenues, *Research Policy* **14** (1985), 61-82
45. Sandberg, A., Trade union oriented research for democratization of planning in working life - problems and potentials. *Journal of Occupational Behavior* **4** (1983), 57-71.
46. Sandberg, A., G. Broms, A. Grip, L. Sundstrom, J. Steen, P. Ullmark, *Technological change and codetermination in Sweden*. Philadelphia, Temple U.P., 1992.
47. Schmookler, J, Economic sources of inventive activity, *Journal of Economic History*, March 1962, 1-20.
48. Schumpeter, J.A., *Capitalism, socialism and democracy*, New York, 1942.
49. Sclove, R.E., *Democracy and Technology*. New York: Guilford, 1995.
50. Smits, R. & J. Leyten, *Technology assessement: watchdog or tracker dog*? Zeist: Kerckebosch, 1991. (Dutch)
51. Steward, F., Lucas Aerospace, the politics of the corporate plan. In *Marxism Today* **23** (1979) pp. 70-75.
52. Van den Besselaar, P., The future of employment in the information society, a comparative and multilevel study. *Journal of Information Science* **23** (1997) pp. 373-392.
53. Van den Besselaar, P., Technology and skills. In: Vink & Volkers (eds.), *Organisatieverandering en technologie*. Utrecht, Lemma, 1996. (Dutch)
54. Van den Besselaar, P. & D. Beckers, Demographics and sociographics of the Digital City. In T. Ishida (ed.), *Community computing and support systems*. Springer Lecture Notes Computer Science, 1998. (forthcoming)
55. Van den Besselaar, P. & P. Ossenblok, Workers' plans and technological change. *Wetenschap & Samenleving* (1994) 5, pp. 6-13. (Dutch)
56. Van den Besselaar, P. & A. Rip, *Research program Technology Assessment*. Amsterdam: SWI, 1987. (Dutch)
57. Winner, L., Do artifacts have politics? In: *Daedalus* **109** (1980) pp.121-136.
58. Woolgar, S. & K. Grint, Computers and the transformation of social analysis. In: *Science, Technology and Human Values* **16** (1991) pp.368-396.
59. Castells, M., *The rise of the network society*. Oxford: Blackwell, 1996.