The social construction of technological artefacts

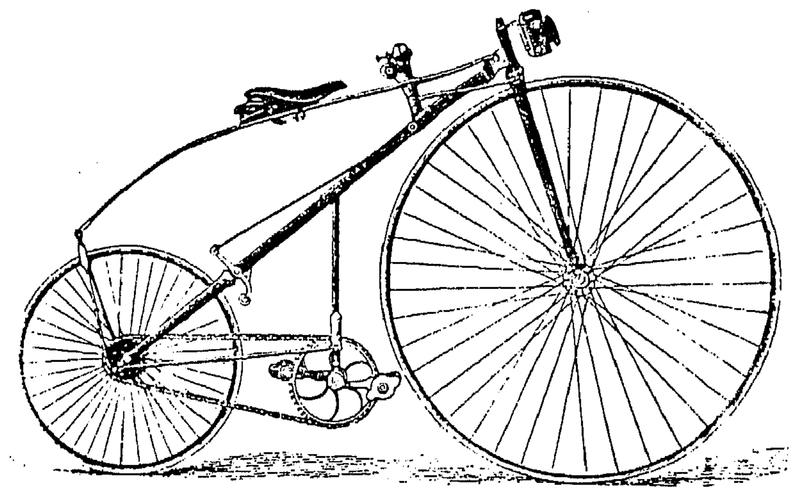
The Social Construction of Technological Artefacts

Von **Wiebe Bijker, Jürgen Bönig, Ellen van Oost**

Introduction [1,2])

The pitfall of retrospective distortion is a notorious problem in historiography. In giving an account of the social construction of technological innovations, an important task is to avoid these pitfalls. The risk of retrospective evaluation in history of technology is clearly illustrated in the following example from the development of the safety bicycle, which we will use as the main example in this article. (See also figure 1.)

Figure 1



Lawson Bicyclette (a word later adopted by the French), 1879.

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'Lawson's 'Bicyclette', patented in 1879, was perhaps the first 'safety' machine in which the outlines of the present-day bicycle are perceptible. With its big front wheel and tiny back one, it has not escaped from the idea of the Ordinary Bicycle, but the chain-wheel and continuous chain-drive is a new and progressive principle'.

(*A. Ritchie,* **King of the Road**, 1975)

To avoid such pitfalls, contemporary accounts and perceptions should be looked upon as part of the evolving technology, and not as myopic views to be corrected with the benefit of hindsight.

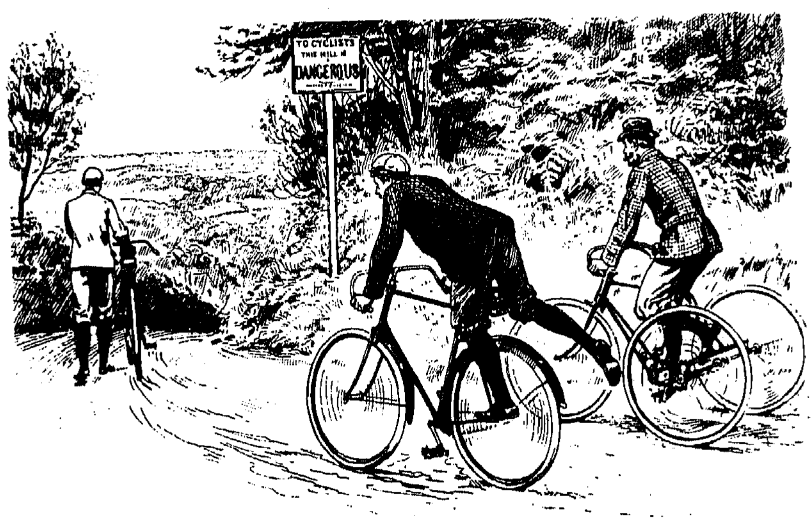
" 'Well, it's the queerest machine I ever set eyes on anyhow', remarked a bystander as we were gazing at the crocodilian form of the Bicyclette which was exposed to the admiring gaze of the cycle-knowing population of Coventry in the shop-window of a well-known bicycle agent in that city, and certainly the machine in question is a queer one. But its ungainly appearance is more than compensated for by its absolute and certain safety . . . . . Here, indeed is safety guaranteed, and the cyclist may ride roughshod over hedges, ditches and other similar obstacles without the fear of going over the handles . . .".

(**Cyclist**, April 21st., 1880).

For our purposes it is at least as important to have an account of the fun people were poking at this Bicyclette, as it is to characterize this artefact as a predecessor of the modern bicycle. When the social group of cyclists attach tó the new artefact the meaning of 'a safe bicycle indeed, but with a spoiled appearance and only suitable for riders of stunted growth', this must have some influence on the developmental process.

The 'obviousness', even 'naturalness' of our present bicycles is so overwhelming, that it implicates the risk of distortion when the technological development of cycles is recontructed. The case of the tricycle may present an example of this. (See also figure 2.)

Figure 2



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In the 1880's and 1890's the tricycle was a highly esteemed vehicle. Its novelty gave it a social cachet. Sprigs of the aristocracy had no objections to riding it. The Tricyclists' Association even sought special privileges in the London parks on account of tricyclists being better bred than bicyclists.

The use of tricycles continued a long time after the low-wheeled, rear-driven bicycle (also a solution to the safety problem of the high wheeler) appeared on the market. In the period 1885–1895 the production of tricycles constituted at least half of the total cycle production. Not only economicly, but also technologically the tricycle is interesting: in the construction of tricycles, the chaindrive had been applied before it was adopted by the bicycle, where it often figures as the crucial step in the development of the 'safety bicycle'.
Yet, in most histories of cycling the tricycle has a depreciated place. Is it possible that our modern scheme of reference, associating the tricycle with children and handicapped people, is responsible for this under-estimation of the tricycle?

So far, we have been illustrating the challenges of the skilled historian 's craft. We want to take a second step; technological innovations are socially constructed, that is, we claim that the 'evolution' of the technological artefacts depends on the shifts in meanings attached to them by social groups that develop and interact.

In this article we intend to support this claim by devising an new way of describing the developmental process of technological innovations. We will first sketch the central role of the meanings attached to artefacts by different social groups. Next, we will show how technological development can be understood as a process of variation and selection of problems and solutions. Finally, we introduce the notions of 'reification', and 'economic stabilization', in order to explain the existence of artefacts as the result of stabilization of these variation and selection processes.

The developmental process is not determined by purely technological problems, but by technological problems resulting from applications of technology by specific social groups. Thus, to understand the developmental process of a technological artefact, we have to consider more than its technical functioning. The primary point of focus should be the **perception** of problems and solutions by members of those social groups. (We use the word 'artefact' to denote material products as well as production processes. Thus 'artefact' covers the Safety Bicycle as well as the Hall-Heroult-process to produce aluminium, the Bakelite condensation-process as well as the Bakelite anti-friction material.)

A schematic representation of this view of the developmental process of a technological innovation is given in fig. 3.

In such a view, contemporary accounts and perceptions are given a central place in the description of technological development. Of course, one must be very careful in accepting these 'ethnographical' sources as representative of the interpretations of a certain social group.

Inevitably, also societal processes on a more general level than the social processes mentioned in the diagram may play an important role. However, it is almost impossible to specify in advance which of these societal processes will have to be included in the description of historical cases.

Of course, such a far reaching claim concerning the nature of technological developments is difficult to prove. In this paper, we use the first results of a set of six case-studies [3]) to illustrate the key elements in our description of the process of technological development.

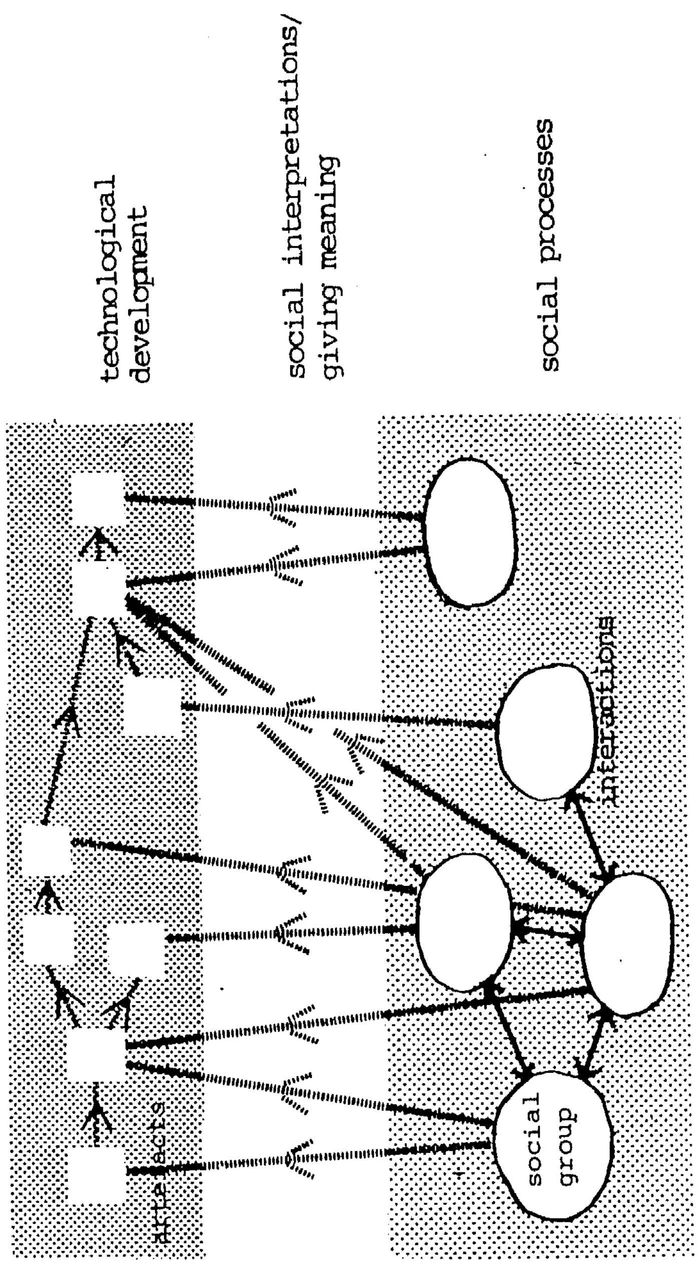

Figure 3

The technological development as a process of evolution

We describe the technological development as an alternation of variation and selection. In deciding which problems with respect to an artefact are relevant, a crucial role is played by groups concerned with the artefact: a problem is only a problem when there is a social group for which it has the meaning of a problem. A problem, existing for a certain social group, may not be bothering another relevant group at all. Thus, for each artefact we have to specify first the relevant social groups and second, the problem(s), each group experiences with respect to that artefact.

The following sketch of a part of the fluorescent lamp case offers an illustration of this procedure.
In 1910 the Frenchman *Andre Claude* designed the neon gas discharge tube. One of the relevant social groups was the advertising and decorating branch. The red colour and the possibility to vary the length and form of the tube made it suitable for light-advertisements. On the other hand, the fact that red was the only available colour was felt as a restriction by this group. A second social group was formed by the general public, who needed indoor lighting. For this group the neon tube had two problems: its red colour and the high voltage, which made expensive electrical installations necessary. To the third group of industrial indoor-users the problem of the red colour was as important as it was to the second group; the problem of a separate electrical installation was perhaps somewhat less important, due to lower overhead costs. To the incandescent lamp industry the neon lamp presented a problem of possible market competition. The following diagram illustrates this situation (figure 4).

The colour problem was rather prominent: it presented a problem to three of the four relevant social groups. Several variants of solution were considered and tested (fig. 5).

As the end of the 1920's it was possible to obtain almost any desired colour by using mixtures of gases and tubes which were internally coated with fluorescent powders.

A problem, originally seen by a particular social group, can be 'adopted' by another group. The classical 'market-pull' scheme presents an example of this phenomenon: the group of producers adopt a problem, that was originally seen only by a certain group of (potential) consumers.

Variants of solution need not only be technological. Some problems may require judicial or social solutions. As mentioned in the previous example, the incandescent lamp industry (mainly General Electric Company) feared a weakening of its monopoly in the U.S.A. resulting from the introduction of the neon tube. G.E. might have solved this problem in a technological way: for instance by developing a discharge lighting device within its own laboratory or by developing better forms of incandescent lighting. However, the problem was solved in quite another way. General Electric and Claude Company agreed upon a division of the market. Claude Company would only sell devices for outdoor use; General Electric kept its monopoly as a producer of general indoor-illumination.

Selection of one of the variants of solution means an adaptation of the artefact into that direction. The resulting new artefact will again present various problems to different social groups and an analogous alternation of variation and selection follows.

The following part of the description of the bicycle-case offers an example of such an evolving series of problems and solutions. (See also figure 6.)
The safety-problem of the high-wheeler has already been mentioned: an angular obstruction on the road, a hole or even a too hasty application of the brake, could make the whole thing tip over.

Figure 4

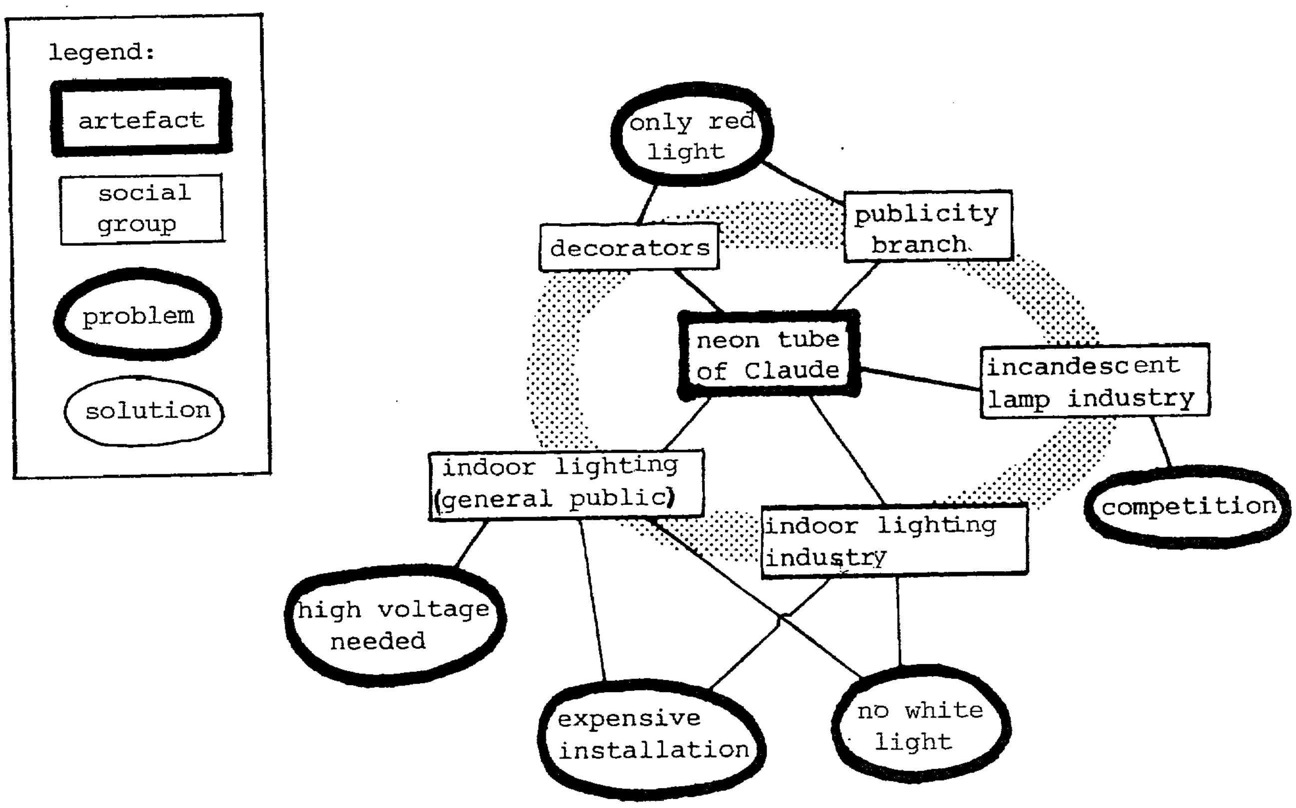

Figure 5

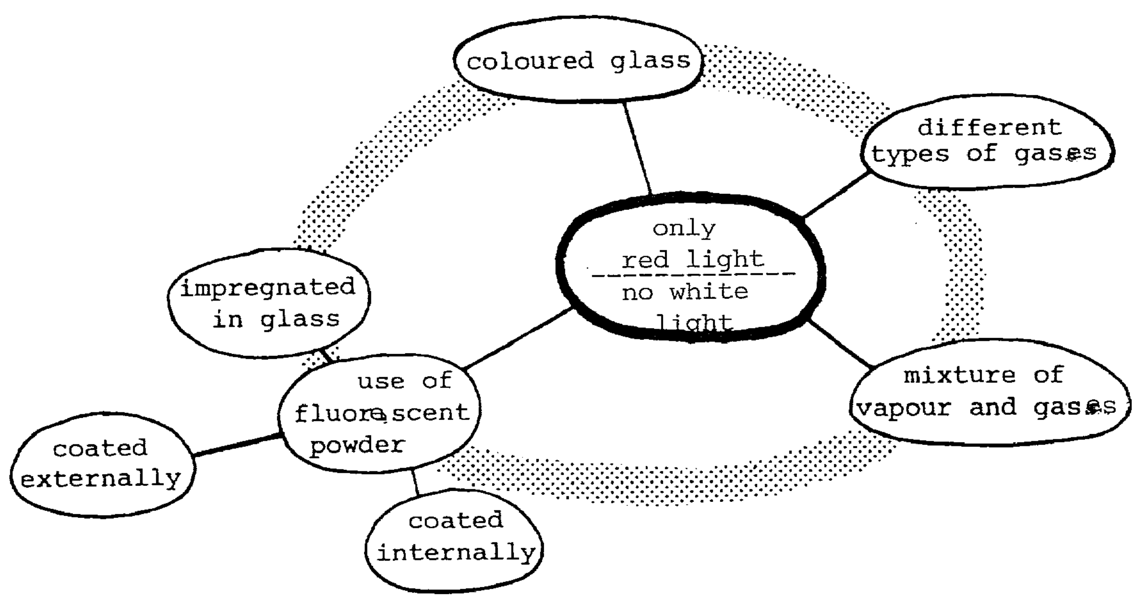

Figure 6

published in: Woodforde, John, **The Story of the Bicycle**, Routledge & Kegan Paul, London, Boston and Henley, 1970.
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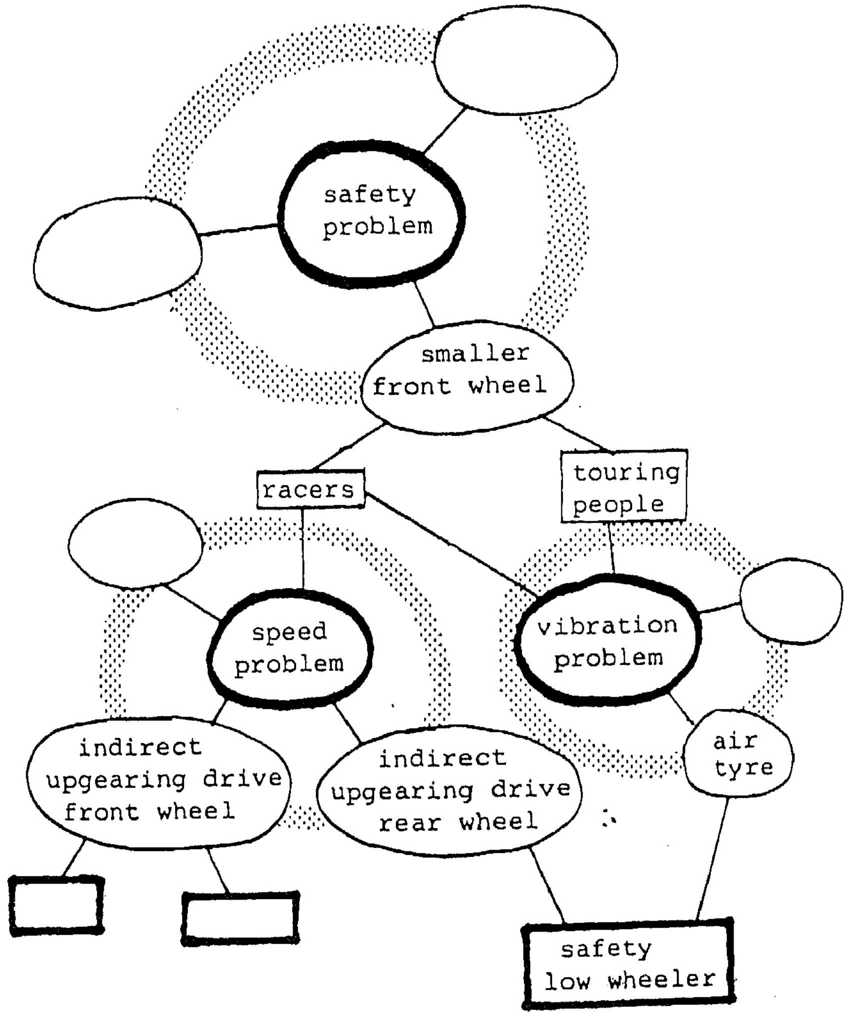
originally published in: Badminton Cycling, 1886.

One of the solution variants of this safety problem was the lowering of the front wheel. However, to the group of cyclists already using the high-wheeler, the lower top speed resulting from the smaller wheel presented a new problem: going fast was one of the qualities, making bicycling a challenging activity for young men of means and nerve. Another problem was the increased vibration on a small wheeled bicycle. This problem was felt by the 'old' cyclists as well as the group of 'new' cyclists, who considered mounting a bicycle after the solution of the safety problem. The situation is presented schematically in figure 7.

Figure 7



Eventually the speed problem was solved by applying indirect (upgearing) drive. The vibration problem was solved by the air tyre.

Although one could speak of the **evolution** of a technological artefact, and use the Darwinian terminology of 'variation' and 'selection', it should be emphasized that 'variation' and 'selection' are not independent (as in neo-Darwinian biological evolution)[4]). An artefact is changed by the incorporation of new solutions, resulting in a different perspective on the artefact and its problems as seen by relevant social groups. For this reason we like to speak about 'the adaptation of an artefact in the direction of certain solutions'. Moreover, the possibility of a two-way adaptation exists. Not only the adaptation of an artefact to the requirements of certain social groups, but also the adaptation of requirements to the technological (im)possibilities can be described in this model.
Thus, the aesthetics of the design of Bakelite products were adapted to the technological possibilities of the casting properties. (To mark the difference with biological evolution: such a two-way adaptation would mean the possibility of a downward adaptation of trees to a short-necked giraffe.)

Stabilization of artefacts and constraints on further developments

The developmental process does not simply produce the Innovation. Rather, the process of variation and selection will result in more and more stabilized variants of solution. In this process, certain artefacts are becoming accepted as satisfactory to specific groups. It is no longer necessary to refer explicitly to alternatives and to justify the accepted solution. Thus, the invention of the safety bicycle as one isolated event (1884) dissolves into a nineteen year process (1879–1898). In the beginning of that period (1879) the relevant groups don't see the safety bicycle, but a wide range of bi- and tricycles and among those a rather ugly 'crocodile'-like bicycle with a relatively low frontwheel and rear drive (*Lawson's* Bicyclette). At the end of the period the word 'safety-bicycle' denotes a low wheeled bicycle with rear chain drive and diamond frame, but, as a result of the general acceptance of the artefact at that moment (1898), one does not need to specify these details: they are taken for granted as the essential 'ingredients' of the safety bicycle.

The safety bicycle has, in a way, become decontextualized. This process of growing stabilization can be 'measured' by tracing the decreasing indexicality of the words 'safety bicycle' [5]). We want to extend the meaning of 'reification', and use this concept to denote socio-cultural stabilization of technological artefacts [6]). The **reification** of an artefact connotes the social existence of that artefact: the familiarity of different social groups with that artefact. The place of this concept in our descriptive model will be clear: again we are not primarily interested in the material existence of an artefact, but in its existence in the consciousness of the members of relevant social groups. When we encounter a very early specimen of a rear driven bicycle (*Mac Millan's*, 1839), we will not analyse its technical content to answer questions like 'was this one really the First?'. For our description of the developmental process of the bicycle other questions need to be answered: for which social groups did it have the meaning of a rear-driven bicycle?; if there are no such groups, why not?; if there are, why didn't this bicycle get a high(er) degree of reification in other social groups too?

Closely connected, but not identical with socio-cultural stabilization is politico-economic stabilization. Thus an artefact which has been developed up to the stage of economic 'makebility', has a higher degree of economic stabilization than an artefact which has been realized in prototypes only, without considering the costs. An artefact which has shown to be 'having a market' has still a higher degree of economic stabilization.

Stabilization of a technological artefact implies a being taken-for-granted and accepted as a 'natural' part of the socio-cultural and politico-economic landscape.

The higher the degree of reification, the more – we think – the structure of conceptual reality is determined by it: a highly reificated artefact constrains the possibility of shifts in problemdefinition and determines to a great extent the domain of possible solutions. In other words: the social existence of an artefact partly dominates the conceptual reality for the relevant social groups. To describe this kind of conceptual constraints we will use the concept 'technological style'. This concept refers to much the same as 'paradigm' [7]), 'technological regime' [8]) or 'style of thought' [9]).

However, we extend the application of this concept to all relevant social groups; that is, also to the groups which are not immediately involved in technological research and development. In this sense we are more indebted to Fleck than to other students in this tradition, and for that reason we want to avoid the use of words like 'paradigm' or 'regime'. Someone with a high involvement ("inclusion") in a specific technological style (in Fleck's words: member of an esoterical circle) thinks, acts and experiences to a great extent in terms of that style. Someone with a low inclusion in that style (being in the exoterical circle in Fleck's binary vocabulary) will accept more easily problemdefinitions and variants of solution which are alien to that style.

The Sulzer weaving machine (another of our case studies) provides an example. Within the technological style of the shuttle-loom (dating back to the end of the 18th century), a number of problems were solved.
But obviously not all problems could be solved within the technological style of the shuttle-loom. The variant of solution of a shuttleless loom was conceived by an engineer who, it is true, worked in the textile industry but who wasn't specifically trained in that technological style. However, it proved to be impossible to find the opportunities to develop this conception inside the textile industry. The solution of replacing the heavy shuttle by a light gripper-projectile was realized outside the textile-machine industry. Sulzer was a large firm whose interests were primarily with the manufacture of diesel engines, hydraulic machinery, etc. The engineers of the Sulzer firm had a relatively low inclusion in the technological style of the weaving industry. This enabled them to follow other ways of problem-solving than those valued in the weaving industry.

Concluding remarks

In this short paper we have not been able to do more than illustrate why we consider our approach of the study of technological developments to be a fruitful one. It will also be clear that further elaboration will lead to added distinctions and specifications. For instance, a distinction can be made between artefacts which need a rather new production system and artefacts which can be made within existing production installations. In the case of the bicycle it was possible to produce the artefact within the existing sewing machine industry. The resulting low capital investments made it possible to have the selection almost 'on the street'; many variants could be produced without taking much financial risk. Thus, the various social groups of cyclists were rather directly related to the selection part of the technological development. (Even, sometimes related to the variation part, as the famous case of the dentist Dunlop shows. Dunlop made an air tyre for the bicycle of his son because it vibrated too much.) In the case of the production artefact 'Sulzer weaving machine' the situation is evidently different. The development of the shuttleless loom required such a high capital investment that the course of its technological development between the 1930's and the 1950's is probably better explained by referring to financial and economic than to technological problems.
Another distinction refers to the problem-solution structure of the developmental process. Some of these processes mainly have a problem → solution structure: first there is a problem

(as viewed by some social group) and then there is the artefact presenting the solution (again: according to the meanings given by that social group). The history of the Sulzer weaving machine offers a clear example of an artefact, following a process marked by this problem → solution structure. The developmental process of other artefacts may be characterized by what we may call a solution → problem structure. Only after the stabilization of the artefact, it starts to have the meaning of a solution to a certain problem, viewed by a certain social group. Aluminium has this solution → problem structure rather clearly: first there was aluminium, depicted as 'Silver from Clay' at the Paris Exhibition of 1855. Only later the problem for which aluminium presented a very good solution presented itself: the need for light but strong construction metal as a consequence of the emergence of especially the aircraft industry. This distinction between different kinds of structures of the developmental process of artefacts replaces the distinction of market pull versus science and technology push with respect to the economic structure of the developmental process.

Whatever further elaboration may produce, it will be clear that our approach tries to create an alternative to the current traditions (or 'styles of thought') of history of technology and of innovation research. Historians of technology focus on specific artefacts and innovations and try to produce faithful reconstructions of what happened. Our aim is to explain developmental processes, making use of the concept of 'social construction of technological artefacts' in order to expose regularities in these processes. Innovation studies share this aim, but work with highly aggregate data: macro-economic analyses or comparative studies of conditions of innovation in many case-studies.
We think that a more substantial insight in regularities is to be obtained by focusing on social interactions and social interpretations.

By thus avoiding both the micro-level of singular artefacts and the macro-level of aggregate data, we hope to find an empirical basis which will enable us to sail between the Scylla of a purely theoretical analysis without empirical basis and the Charybdis of an analysis, based on aggregate data but without much theoretical perspective.

Notes:

1) The project in which the authors are engaged is jointly executed by the Twente University of Technology, subdepartment Philosophy and Social Sciences, and University of Hamburg, Institute for Social and Economic History.
The project is financed by Stiftung Volkswagenwerk (Fed. Rep. Germany) and the Twente University of Technology (Netherlands).

2) The extensive comment of Arie Rip has been of great value to the modification of our congress paper into the present article. We are greatly indebted to Yolande Samwel who assisted in translating the article into English.

3) The six cases being studied are:
aluminium (1854–1909), bakelite (1906–1919), fluorescent lamp (1910–1940), safety bicycle (1879–1898), sulzer weaving machine (1928–1951), and transistor (1945–1951).

4) Most of the evolutionary models used in philosophy of science have a 'coupled' character.
Cf. *S. Toulmin*, **Human Understanding, Vol. 1**, (Oxford, 1974), p. 338.

5) Cf. *H. Garfinkel*, **Studies in Ethnomethodology**, (Englewood Cliffs, 1967), and *B.Latour* and *S.Woolgar*, **Laboratory Life, the construction of scientific facts**, (London, 1979).

6) Reification (German: **Verdinglichung**) originally is a Marxian concept, developed in terms of the 'fetishism of commodities'. In the context of Marxist theory, reification has a rather negative connotation, closely related as it is to the concept of 'alienation' (**Entfremdung**).
We use 'reification' in a more neutral sense, as do *Berger* and *Luckmann*: 'reification is the apprehension of the products of human activity as if they were something else than human products – such as facts of nature (. . .). Reification implies that man is capable of forgetting his own authorship of the human world, and further, that the dialectic between man, the producer, and his products is lost to consciousness'. (p. 89). By using 'reification' to denote socio-cultural stabilization of technological artefacts as well, we mean to stress their socially constructed character.
We do not want to use the rather Popperian term 'decontextualization', since its connotations are contrary to the central role which, in our view, is played by the ever-changing social contexts of an evolving artefact, and to the eternal state of incompleteness proper to this evolution.
The latter consideration also accounts for our rejection of the term 'sedimentation'. A high degree of reification of an artefact does not necessarily imply the end of its process of evolution; the artefact can dereificate again. In this sense, we preclude the existence of completely reificated artefacts the way *Barnes* and *Law* preclude the existence of non-indexical terms. Cf. *P.L. Berger* and *Th. Luckmann*, **The Social Construction of Reality**, (New York, 1966), and *B. Barnes* and *J. Law*, 'Whatever should be done with indexical expressions?', **Theory and Society**, 3 (1976), p.199–222,
A. V. Cicourel, 'Notes on the integration of micro- and macro-levels of analysis', in: *K. Knorr-Cetina* and *A. V. Cicourel* (eds), **Advances in social theory and methodology, Toward an integration of micro- and macro-sociologies**, (Boston, Mass., 1981), p. 51–80.

7) *Th. S. Kuhn*, **The Structure of Scientific Revolutions**, (Chicago, 1962).
G. Dosi, 'Technological paradigms and technological trajectories', **Research Policy** 11 (1982), p. 147–162.

8) *R.R. Nelson* and *S.G. Winter*, 'In search of a useful theory of innovation', **Research Policy** 6 (1977), p. 36–76.
The difference between Nelson & Winter's and our approach is that they discuss technological regimes in terms of promising heuristics and 'natural' trajectories, while we emphasize that it is the socially negotiated success of certain problem solutions that constrains further development in certain directions.

9) *L. Fleck*, **Entstehung und Entwicklung einer wissenschaftlichen Tatsache**, Frankfurt am Main, 1980. First published in 1935. (English translation: Chicago, London, 1976).