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Of Bicycles, Bakelites, and Bulbs
Toward a Theory of Sociotechnical Change

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I also benefited from discussions with research groups in various places. Chapter 4 was largely written during my stay as visiting professor at the Technical University in Vienna. Chapter 5 received its penultimate and most radical revision during my visit to the Technical University of Denmark. The research group "Technological Culture" in Maastricht provided an important forum for discussing drafts of chapters 4 and 5. Tannelie Blom, Ton Nijhuis, Rein de Wilde (Maastricht), Rob Hagendijk (Amsterdam), Ulrik Jörgensen (Copenhagen), and Eduardo Aibar (Barcelona) have tried to help me avoid various pitfalls in the discussions of power in these last chapters (though I probably still fell into a good number of them). Ed Constant, Tom Misa, and Paul Rosen have provided stimulating discussion at various stages of writing.

Making a book, however, is not just a matter of academic research and teaching. In the final stage, the comments of two anonymous referees were stimulating and challenging. Bernie Carlson, Larry Cohen, and Trevor Pinch succeeded in critically following and shaping the project without jeopardizing our relationship as co-editors of the Inside Technology series. Melissa Vaughn did the crucial editing and production job of turning the manuscript into a book. Such were the professional ties, many of which have turned into friendships.

But the last—and in some respects most important—part of the weave has yet to be mentioned. This book could never have been written solely within the confines of academia. Liselotte, Else, and Sanne continually reminded me of this in their need for cooking and caring, and their claims to bicycle and football, to playing piano and cello. But mainly by just being there, three daughters provide a strong, continuous demonstration that life is more, and more complex, and more interesting, than the activities in the academic compartment of society. This book is dedicated to Tonny, who complements all those mentioned above as skeptical commentator, as supportive friend, as mother of the daughters, as love.

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Introduction

The stories we tell about technology reflect and can also affect our understanding of the place of technology in our lives and our society. Such stories harbor theories. But stories can be misleading, especially if they aim for neatness and therefore keep to the surface of events. This book will be about both stories and theory. I will start with some of the stories:

• In 1898 a female cyclist was touring the English countryside. She was dressed in knickerbockers, which seemed the most practical and comfortable clothing for a woman on a safety bicycle. After a good lap, she spotted an inn and decided to take a bit of refreshment. To her surprise, the proprietor refused to seat her in the coffee room and insisted that, if she wanted service, she would have to go into the public bar. The innkeeper's objection centered on the cyclist's clothes; evidently she did not think it proper for a woman to appear in public in anything but a long skirt. The cyclist objected, of course, and eventually brought her grievance to court, which sided with the right of the innkeeper to refuse service. This was not the end of the story, though. This lost case had an important afterlife as a symbol in the battle for women's rights. Can we say, then, that the design of this technological artifact, the safety bicycle, which allowed our cyclist to travel on her own and to choose a more comfortable form of dress, played a role in challenging traditional gender roles and building modern society?[1]

• "God said, 'Let Baekeland be,' and all was plastic." Few individual inventors have had as great an impact on society as did Leo Baekeland. This brilliant inventor created the first truly synthetic material to replace natural and seminatural materials such as ivory and Celluloid, and developed many of the applications that led society into the era of plastics. At first glance, Baekeland seems an exemplar of the American scientist-

entrepreneur. A poor Belgian immigrant to the United States, he worked his way up by cleverness and diligence, and by combining scientific discovery with commercial acumen. He became rich, served his new country during World War I in the Naval Consulting Board, and served humankind by giving it plastics. A longer look, however, shows that Baekeland was shaped not by a mythical act of creation but by several distinct sociotechnical traditions and cultures. It was only because he was enculturated in the technical and scientific practices of electrochemistry that he was able to escape the bondage of the Celluloid engineering tradition; but it was only because he was part of the Celluloid tradition that he undertook this research at all. Can one assert, then, that even cases of seemingly unique individual ingenuity and creativity are always linked to wider social interactions and cultural processes?

• When the General Electric Company tried to introduce the fluorescent lamp in 1938 as a source of color lighting, they quickly found themselves in a battle with the electric utilities, who feared that the lamp's high efficiency would jeopardize their electricity sales. Consumers and lighting engineers, however, were so eager to buy this new type of lighting that the utilities were forced to accept some form of the lamp. After a fierce confrontation that threatened the established power relations in the electric lighting business, an agreement was reached under which the lamp's design was substantially changed. This renewed cooperation did not escape the notice of the Antitrust Division of the federal government, which decided to sue General Electric and the utilities for forming a cartel. General Electric, in response, successfully lobbied the War Department into fending off this suit because, they argued, such litigation would endanger the war effort. The fluorescent lamp was thus the product of a complex economic power play in which General Electric, the electric utilities, the U.S. government, and consumers all played roles. Conversely, the power map of the electric manufacturing scene in the United States was substantially modified by the introduction of the new lamp. Can we then say that artifacts are not only shaped by the power strategies of social groups but also form part of the micropolitics of power, constituting power strategies and solidifying power relations?

These three stories highlight many of the issues that this book will address. For example, how can gender relations affect the design of a bicycle? Although it later became an instrument for women's emancipation, the first cycles in fact reinforced the existing "gender order"—women were only allowed to ride on tricycles, and preferably on two-

Figure 1.1
Women's emancipation: the wheel of the past and the wheel of the present (reprinted from Palmer (1958: 101).

seaters with a male as chaperon. It is therefore appropriate to ask: What impact did the evolution of bicycle design have on society? How did it shape social relations (see figure 1.1)? This is the companion issue of this book, for we shall explore both the social shaping of technology and the technical shaping of society.

Framing these issues in terms of "society" and "technology" should not obscure the fact that technology and society are both human constructs. Technology is created by engineers working alone or in groups, marketing people who make the world aware of new products and pro-

cesses, and consumers who decide to buy or not to buy and who modify what they have bought in directions no engineer has imagined. Technology is thus shaped not only by societal structures and power relations, but also by the ingenuity and emotional commitment of individuals. The characteristics of these individuals, however, are also a product of social shaping. Values, skills, and goals are formed in local cultures, and we can therefore understand technological creativity by linking it to historical and sociological stories. This is the second set of central issues in this book: How can we link the interactions of individual actors such as engineers and users to societal processes? And how can we link the analysis of micro case studies to an understanding of macro processes of societal and technological change?

This linking of micro stories with macro structures involves questions about the internal structure of technology: about the nature of inventors' work, about the interaction of knowledge, skills, and machines, about the epistemology of technology. But it also involves the politics of technology. The quick summary of the story of the fluorescent lamp showed how it was shaped by the power relations of General Electric and the utilities and eventually helped shift those relations. How do artifacts become instruments of power? And conversely, how do power relations materialize in artifacts? Some artifacts are more obdurate, harder to get around and to change, than others. Who was in a position to modify the fluorescent lamp design that was proposed in 1938, and who was compelled to "take it or leave it" as it was? Exploring the obduracy of technology offers one way to gain understanding of the role of power in the mutual shaping of technology and science.

From Detour to Main Route

This book is the result of a personal detour that turned into a main route. My detour started from sociopolitical concerns about the role of technology in society and then carried me into academia. Like many Dutch engineering students in the 1970s, I was drawn to the science-technology-society (STS) movement, whose goal was to enrich the curricula of both universities and secondary schools by offering new ways to explore issues such as the risks of nuclear energy, the proliferation of nuclear arms and other new weapons systems, and environmental degradation. The movement was eventually quite successful, especially in the natural science and engineering faculties, where small groups were established to teach STS courses and some of the courses even became

part of degree requirements. The secondary school science curriculum was also reformed to include STS issues, both optional and integrated into the regular physics program. At the same time, STS students and staff were among the central actors in the movement against the extension of nuclear power and the introduction of the "neutron bomb" and cruise missiles. After gaining access to the academy, however, and during our political struggles, we were increasingly confronted with the crudeness and inadequacy of our models of science and technology development. We were working in many instances on our gut feelings about technology, but were not able to back our positions with theoretical arguments. This is what spurred my detour into academia—a desire to see if I could help devise new ways to think about the development of technology and its relationship to society.

Many other researchers from the early STS ranks made similar detours. Now, two decades later, science and technology studies is a well-established discipline with chairs, journals, societies, and both undergraduate and graduate programs—everything that a respectable academic discipline requires.[2] But did this detour yield the politically relevant insights that we needed fifteen years ago? Or does our new discipline worry too much about its status in the academy? Have all our activists turned into scholars? The central argument of this book will be that STS can retain its edge even in the academy, that what started out as a detour can be turned into a main route without necessarily losing its societal relevance.

At the beginning of my detour I found at least three models open to me. First, there were those who looked down their noses at mere storytellers. These were the scholars, often with backgrounds in the social sciences, who advocated general typologies, precise conceptual definitions, and macrotheoretical schemes that could produce "real" insights and explanations. Second, there were those who poked fun at any theoretical generalization beyond the uniquely detailed story. These students, often of the historians' tribe, scorned the empty theoretical boxes and abstract schemata that did not display any familiarity with what "really" went on. Third, there were the political activists, who considered any detour into academia a betrayal of the immediate societal tasks that should be the constant overriding concern of critical intellectuals.

What finally changed my detour into a main route was the conclusion that all three approaches are equally necessary. I believe that effective societal action on issues of technology and science cannot do without scholarly support, while academic technology studies have much to gain

from engagement with politically relevant issues. And only an integration of detailed empirical case studies with general conceptual frameworks can build this link between academia and politics. I have come to believe that an integration of case studies, theoretical generalizations, and political analyses is called for and possible, both *to understand* the relations between technology and society and *to act* on issues of sociotechnical change. This book will start with stories, then generate theoretical concepts, and finally argue for politics. The idea of a gap between the real world and academia, at the basis of the "detour" metaphor, proved misleading.

Guideposts

What guideposts can lead us as we embark on this journey to an integrated understanding of the STS problematic? The past decade has seen the emergence of a new research program in technology studies.[3] This program, commonly labeled "constructivist studies of technology," is based mainly on the combination of historical and sociological perspectives. Infusions from economics and philosophy have hitherto been quite small, although efforts are now being made to incorporate work from these disciplines into constructivist research.[4] A central adage for this research is that one should never take the meaning of a technical artifact or technological system as residing in the technology itself. Instead, one must study how technologies are shaped and acquire their meanings in the heterogeneity of social interactions. Another way of stating the same principle is to use the metaphor of the "seamless web" of science, technology, and society, which is meant to remind the researcher not to accept at face value the distinctions between, for example, the technical and the social as these present themselves in a given situation.

Within the constructivist research program we can distinguish three lines of work: the systems approach, the actor-network approach, and the social construction of technology (SCOT) approach. This book has developed in the main from SCOT studies, but I believe that the arguments are of general relevance for the whole spectrum of modern constructivist studies.

One pitfall that the newer research programs are designed to avoid is any implicit assumption of linear development. Such assumptions were often found in earlier technology studies, sometimes at the level of the singular invention (figure 1.2) and sometimes in the genealogy of related

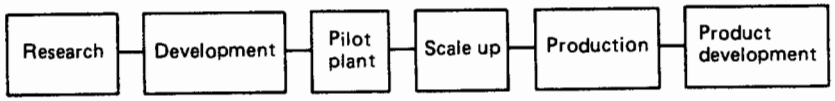

Figure 1.2
A six-stage model of the innovation process.

innovations (figure 1.3). The problem is that once students start expecting linearity, they blind themselves to the retrospective distortions that linear descriptions almost inevitably require. Too easily, linear models result in reading an implicit teleology into the material, suggesting that "the whole history of technological development had followed an orderly or rational path, as though today's world was the precise goal toward which all decisions, made since the beginning of history, were consciously directed" (Ferguson, 1974: 19). To name Lawson's bicycle "the first modern bicycle" is an example of such a false linearity, as I will show in the next chapter. This label seems appropriate at a surface level because this was the first bicycle with two relatively low wheels and a chain drive on the rear wheel. It was, however, at least in a commercial sense, a complete failure, and the relevance of the label "first" is therefore questionable. Bicycles such as the Star and the Geared Facile did much better commercially, but because they do not fit into a simple linear scheme, they are often written off into the margins of the story.

A second pitfall the constructionist programs are designed to avoid is what one might call the asymmetrical analysis of technology. Staudenmaier (1985) observed that in the first twenty-five volumes of the journal *Technology and Culture*, only nine articles were devoted to the analysis of failed technologies. The focus on successful innovations suggests an underlying assumption that it is precisely the success of an artifact that offers some explanatory ground for the dynamics of its development. Many histories of synthetic plastics, for example, start by describing the technically sweet characteristics of Bakelite. These features are then used implicitly to position Bakelite at the starting point of the glorious development of the synthetic plastics field, as in Kaufman's (1963: 61) quotation of God at the beginning of this chapter. However, a more detailed study of the developments of plastic and varnish chemistry following the publication of the Bakelite process in 1909 shows that Bakelite was at first hardly recognized as the marvelous synthetic resin it later proved to be.[5] A historical account founded upon the retrospective success of Bakelite (its "working") leaves much untold. More specifically, such an

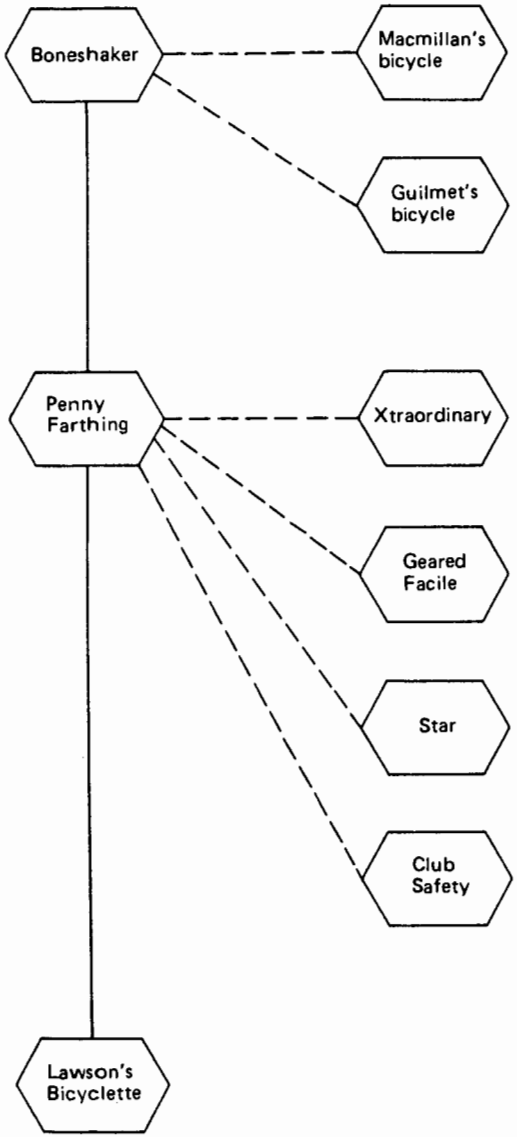

Figure 1.3
The traditional quasi-linear view of the development of the high-wheeled Ordinary bicycle until Lawson's bicycle. The solid lines indicate successful development, while dashed lines indicate failure.

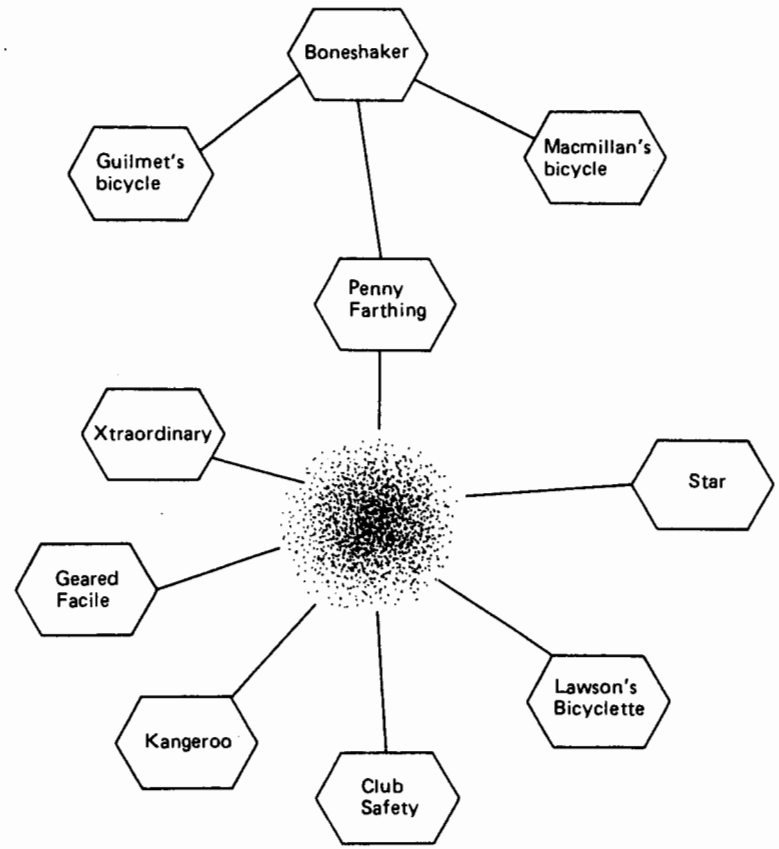

Figure 1.4
A nonlinear representation of the various bicycle designs since the high-wheeled Ordinary bicycle. The various designs are treated equally, without using hindsight knowledge about which design principles eventually would become most commonly used.

account misses the interesting question of how Bakelite *came to be seen as* a practical molding material; instead, in these asymmetrical accounts Bakelite simply *was so* all along. (Figure 1.4 shows a possible visualization of an alternative analysis for the bicycle example—symmetrical and without a linearity assumption.)

Other beacons to guide our journey come from the individual disciplines on which STS studies draw. For example, a key debate in the history of technology[6] has involved the primacy of internalist versus contextualist (or externalist) studies. Internalists maintain that we can

understand the development of a technology only if we start with an understanding of the technology in all its minute details. Contextualists, by contrast, claim that the economic, social, political, and scientific context of a technology is as important to its development as are its technical design characteristics. I lean toward the contextualist side of this debate. To understand the development of bicycle designs, for example, I think it is important to know about the industrial development of Coventry, a visit to the Queen by the English "Father of the Bicycle," and the early professional bicycle races. At the same time, I believe that details are important, and I hope to demonstrate that it is only by going down to the "nuts and bolts" level of analysis that we can gain insight in the *design* development of technology.[7] By the end of the book I will also take one additional step outside the "pure" contextualist path, arguing that, rather than being satisfied with the distinction between technology and its context as the basic dimension for analysis, we must figure out a way to take the common evolution of technology and society as our unit of analysis.

Technological creativity has been another long-standing research topic from which we can draw guideposts. One key issue that absorbs many researchers is uncovering the "Mother of Invention." Is it "necessity," implying that an invention will sooner or later emerge out of felt needs, independent of individual creativity? Or is it the "act of ingenuity," without which needs might never be fulfilled (but perhaps not explicated either)? In arguments for the individual act, one still sees numerous references to the claim by Jewkes et al. (1958) that the majority of inventions in the twentieth century have resulted from individual work rather than large-scale organized research. Often, a stress on the role of the individual inventor is accompanied by a declaration that the topic is immune to research: "like a poet or an artist, therefore, the inventor participates in an act of creation, and no amount of theoretical construction can encompass the terms on which such creativity can be achieved."[8]

Nevertheless, two lines of research are now bearing fruit. The first focuses on inventors as system builders, thus combining analysis of individual creative actors with descriptions of their systemic constructs and contexts.[9] The second combines history of technology with the insights of psychology to explore acts of individual creativity.[10] A quite opposite approach is possible as well. Rather than taking individual ingenuity as given, this approach tries to describe the label "individual genius" as

the result of a series of attribution processes by which one person eventually "wins all." My approach to the problem of creativity is probably closest to this last one. I tend to analyze the development of technology (including its invention) as a social rather than a psychological process. I will not argue, however, that individual engineers and their histories do not matter. For example, I found it quite illuminating to delve into Baekeland's early work in photographic chemistry as a source for his research gusto (he dissolved his father's watch when he needed more silver), and I found his work with the new electrochemical plants at Niagara Falls an aid to understanding his experience with upscaling chemical production. But I will also introduce a conceptual framework that will link these stories about individual inventors to a sociological analysis of their positions in a specific technological culture.

Yet another guidepost comes from political science. Power has always held a peculiar place in studies of technological development. It is hardly ever invoked by the historians as part of their explanations of events—mainly, I think, because their stories do a much better job of explanation than any crude "power" concept might. The older sociology of technology did not address either the question of technological development or that of the role of power in that process.[11] Recent sociohistorical studies of technology have also avoided the use of "power" as a central category, not because everyone is equal, or because there are no hierarchical relations between particular individuals and social groups, but because explanations in terms of power so easily result in begging what seem to be the most interesting questions. Thus it is just not very insightful to state that the introduction of the fluorescent lamp was held up because the electric utilities were more powerful than General Electric; nor is it illuminating to state that the fluorescent lamp finally appeared on the market because General Electric proved more powerful. Instead, I want to raise the question of which strategies the utilities and General Electric (and other companies, and the U.S. government, and all the other actors) employed to create a certain outcome—an outcome that can then be conveniently summarized by drawing a map of the power distribution. In this analysis of power strategies, I will especially focus on the role of artifacts.

Project Design

The core of this book is formed by three case studies: the safety bicycle, Bakelite, and the fluorescent lamp. In selecting these cases, I employed

two crude criteria. The first was to focus on the actual design process of technology, on the details of the technical machines and processes. The second was to secure an empirical base broad enough to render generalizations interesting.

The first criterion suggested implicitly what in this study would constitute "technology." The aim was to select cases that would allow a focus on the "hard" contents of technology rather than its systemic aspects. I therefore decided to focus on "elementary innovations" rather than technological systems, and this led me to the bicycle rather than the automobile, Bakelite rather than synthetic materials in general, and the fluorescent lamp rather than electric lighting.

An intuitive and commonsense idea about what "technology" and "society" are, and what there is to be asked about their developmental process, further informed the selection. However, what starts out as an intuitive assumption about the object of research of this study will by the end of this book have become a key question: What constitutes "an artifact," "design," "technical change," "technology," "society"? The object of research will thus, in the course of the book, evolve from elementary technical artifacts to "sociotechnical ensembles."

My second criterion was founded on a desire to create a relatively broad empirical base for generalizations. Several dimensions were used to check the heterogeneity of alternative cases: the period in which the invention was made, the disciplinary background of the invention, the industrial context, the intended market, and the invention's process or product character. Thus I selected cases that, taken together, span most of the period after the second industrial revolution: the bicycle covers 1860–1890; Bakelite, 1880–1920; and the fluorescent lamp, 1930–1945. The cases are also varied in terms of their underlying engineering background: mechanical engineering (the bicycle), chemical engineering (Bakelite), and electrical engineering (the fluorescent lamp). With respect to industrial context, the cases move from a blacksmith's workshop (bicycle) to an early scientific laboratory (Bakelite) to a large industrial laboratory (fluorescent lamp). The bicycle was exclusively aimed at the consumer market, Bakelite as a molding material was aimed at the industrial market, and the fluorescent lamp has in this respect a hybrid character. In the patent literature a distinction is often made between product and process types of inventions. The bicycle and the fluorescent lamp are clearly both product inventions, while Bakelite is primarily a process invention.

Table 1.1
Requirements for a theory of technological development

1. Change/continuity	The conceptual framework should allow for an analysis of technical change as well as of technical continuity and stability.
2. Symmetry	The conceptual framework should take the "working" of an artifact as *explanandum*, rather than as *explanans*; the useful fuctioning of a machine is the result of sociotechnical development, not its cause.
3. Actor/structure	The conceptual framework should allow for an analysis of the actor-oriented and contingent aspects of technical change as well as of the structurally constrained aspects.
4. Seamless web	The conceptual framework should not make a priori distinctions among, for example, the social, the technical, the scientific, and the political.

Because I wanted to create a relatively broad base of data, I chose to present a larger number of cases using mainly published sources rather than one or two cases using unpublished archival material.[12] The studies are not intended primarily to unveil new historical facts, though they are presented in such detail that I hope readers will come away with new insights into the events they describe. I expect, however, that the primary benefit of the book will come from the generalizations made on the basis of the case studies–from the surplus value of the comparison of cases. It is to the requirements for this theoretical framework that I turn now (see table 1.1).

Requirements for a Theory of Sociotechnical Change

Elster (1983) has distinguished two approaches to the study of technical change. The first conceives of technical change as a rational, goal-directed activity. The second places emphasis on technical change as a process of trial and error, as a cumulative result of small and mostly random modifications. Two decades of studies in the sociology of scientific knowledge have stressed the contingent character of scientific development, and one of the basic assumptions of this book is that an analogous approach will be fruitful for studies of technical development.[13] This suggests that trial-and-error models, often cast in evolutionary terms, have specific advantages over models that stress the goal-oriented character of technological development. In the SCOT model that will be

developed in this book I will also try to account for the contingent character of technical development, but will do so without employing a truly evolutionary framework.[14]

An emphasis on contingency seems to be the historian's delight as much as the sociologist's curse, offering no structuralist explanations for human action but free rein for individual actors. The other side of the coin, however, is that too much contingency would result in actors who have no meaningful history of their own: If there are no systematic, structural constraints, there are no limits to the spectrum of possibilities. There may be constraints, but they are contingent and unpredictable themselves. Therefore, evidently, one requirement for a theory of technical change is that it should be able to show how constancy and continuity exist in history, and under what conditions they exist. It should allow us to account not only for technical change but also for the stability of artifacts. If only rupture and revolution had a place in the analysis, while flow and evolution did not, the resulting framework would turn into (some) sociologist's delight and (some) historian's curse. Setting up such a truly dynamic conceptual framework is a notoriously difficult task. The typical way to tackle this problem is to give a static description and then add the time dimension—but to leave the concepts intrinsically static. Following this approach, one might try to explain the ability of a bicyclist to ride upright by drawing on a model of the bicycle as a pair of scales, with the bicyclist achieving balance by equating left- and right-hand forces.[15] The equilibrium of a rolling bicycle can, however, only be understood by using the intrinsically dynamic concept of "angular momentum." To meet the first requirement, our conceptual framework must have a similarly dynamic character.

Earlier in this chapter I discussed the idea of asymmetrical analysis—analysis in which the success and the failure of artifacts are explained in different terms. Using the "working" of an artifact as an *explanans* in the study of technology seems equivalent to using the "hidden hand of Nature" as an *explanans* in studies of science. That is to say, it was often assumed that scientific facts had to turn out the way they did because that is the way Nature dictated them to be. Recent science studies have called for an explanation of Nature as the result, instead of the cause, of scientific work. Similarly, for a theory of technology, "working" should be the *explanandum*, not the *explanans*. The "working" of a machine is not an intrinsic property of the artifact, explaining its success; rather, it should figure as a result of the machine's success. Thus, the success or failure of an artifact are to be explained symmetrically, by the same conceptual framework. An asymmetrical explanation might, for example, explain the commercial success of an artifact that we now consider to be working by referring to that "working," while the failure of that same artifact in another context might be explained by pointing at social factors. In a symmetrical explanation, "working" and "nonworking" will not figure as causes for a machine's success or failure. The claim is not that "working" is merely in the eye of the beholder, but that it is an achievement rather than a given. Understanding the construction of "working" and "nonworking" as nonintrinsic but contingent properties is the second requirement for the theory of technical change I shall try to develop.

The third requirement, pertaining to the actor/structure dimension, is closely related to the change/constancy requirement. The emphasis on the contingent character of technical change may seem to imply that anything is possible, that each configuration of artifacts and social groups can be built up or broken down at will. This, of course, cannot be: A theory of technology proposing such a view of our technological society clearly underestimates the solidity of society and the stability of technical artifacts. A theory of technical development should combine the contingency of technical development with the fact that it is structurally constrained; in other words, it must combine the strategies of actors with the structures by which they are bound.

The final basic assumption in my theoretical project is that modern society must be analyzed as a seamless web. The analyst should not assume a priori different scientific, technical, social, cultural, and economic factors. Rather, whatever creases we see are made by the actors and analysts themselves. Another way of expressing this idea is to recognize that a successful engineer is not purely a technical wizard, but an economic, political, and social one as well. A good technologist is typically a "heterogeneous engineer" (Law, 1987).

The metaphor of the seamless web has implications not only for empirical work but for our theoretical framework as well. I propose that we require our theoretical concepts to be as heterogeneous as the actors' activities. If we would do otherwise, the old a priori distinctions would return through the back door by the step of generalization, after having been kicked out through the front door by empirical research. The fourth requirement for a conceptual framework is thus not to compel ourselves to make any a priori choices as to the social or technical or scientific character of the specific patterns that we see by applying it.

To develop this empirically based theory of sociotechnical change, we need a descriptive model that will help us create a set of case studies that can be compared and combined in the process of developing generalizations. The descriptive model should allow analysts to get into the black boxes of the various cases, but also to get out again to compare case descriptions. Thus the model should strike a fine balance between describing the "nuts and bolts" and staying at a sufficient analytical distance to allow for cross-case comparisons. The development of such a descriptive model will be the main purpose of the second chapter, while in the third and fourth chapters the theoretical framework will be developed.

Book Design

The broad aim—to start from the more strictly disciplinary research questions of the history and sociology of technology, but to work toward an interdisciplinary result—implies certain constraints on form. This academic detour is built up from many smaller detours—sociological detours for historians and historical detours for sociologists. I can only hope that each detour will be attractive enough to be followed through by readers of whatever background, and that in the end the results will prove the detours worthwhile. These results should also yield the conclusion that what started out as a series of detours has turned out to be a new main route toward interdisciplinary STS studies.

At the outset, I have tried to use different styles of writing for the narratives and for the theoretical analyses and model building, highlighting the disciplinary character of both parts. Toward the end of the book the alternation between narrative and theoretical intermezzi fades away, and both blend into a single STS vocabulary. The narrative will present a thick description with many historical details. The cases per se merit such detailed descriptions—each offers a fascinating story of technical development and engineering life—but they also allow readers to check the interpretations I will propose during the theoretical detours. The theoretical framework, on the other hand, will be presented quite explicitly as a formal model. This is done for reasons of candor and clarity: It will allow more transparent discussions of the strengths and weaknesses of the theoretical framework. That theoretical framework does provide a coherent view of the joined development of society and technology; but it does not represent a closed world, outside of which no stories can be told. The aim, then, is not to make a model that pretends to explain all of technological development. The model will not be a set of narrowly defined concepts to be employed indiscriminately in empirical research. Rather, it will be a heuristic device, a set of sensitizing concepts that allow us to scope out relevant points, but one that will require adaptation and reformulation for use in new instances.

If this book has any usefulness as a teaching text, it will come from this combination of empirical case studies with theoretical modeling. I do not envisage the book as an instrument primarily meant to educate students about either the SCOT model or the details of the bicycle, Bakelite, or the fluorescent lamp. What I do hope is that the book will be useful in two other respects. First, it should make students think about the interplay of empirical research and theoretical modeling, about the relations between case studies and conceptual frameworks. Second, it should introduce students to recent constructivist perspectives in technology studies by putting one approach on the test bench. Finally, of course, I hope that the "detour-becomes-main-route" thesis will lead to high-spirited discussions about the relationships between society and technology, about the future of STS studies, and about one's societal roles and responsibilities as engineer, social scientist, or citizen.

In a way, this is an effort to write four books in one. The first three are the case studies, which focus on design, biography, and economics, respectively. The fourth is the combination of the first three, presenting a comparative analysis of changes in technology and society. All together I hope they will make the case for combining empirical case studies with theoretical analysis to strengthen the link between academic STS studies and politically relevant action.