INTRODUCTION

SCOPE OF THE THESIS

Many people in industrialised nations are beginning to question the inherent benevolence of technology when previously they had taken it for granted. The social and environmental consequences of many engineering projects now receive more critical scrutiny and the automatic association of technological change with progress is losing currency as controversy surrounds proposed engineering projects and technological innovations. At the same time there is a growing tendency for technological change to be portrayed as a self-perpetuating activity which cannot be controlled.

This thesis will consider the degree to which technological change is self-perpetuating, the question of just who controls technological decisions and the extent to which the adverse outcomes of technologies are the inevitable consequence of technological decision-making processes. These issues will be addressed by examining the process by which decisions about the development and implementation of technologies in the public sector are reached and the extent to which technological decisions are influenced and shaped by various social groups. In particular the role of engineers will be scrutinised.

Decision-making will be interpreted in its broadest sense so that all relevant influences upon it can be considered: those that are conventionally considered to be part of engineering decision making - the narrowly technical and economic; those that shape the philosophy of engineers and help to define "good" engineering practice; those that constrain the engineers from within their organizational niches; and the wider social and political influences upon those organisations that shape the definition of problems and limit the range of acceptable solutions.

The case study upon which this thesis is based is the development of Sydney's sewerage system. The sewerage system was chosen because it is a public sector technology which has purportedly been developed to protect the health and welfare of citizens. Such a seemingly benevolent technological system is therefore a good one to test whether adverse environmental and social consequences were entirely inadvertent and unforeseen or whether the decision making process ensured that such consequences were ignored or discounted.

The development of a sewerage system is also a good case study through which to study the issue of control of technological change and the effects of public opposition. One would expect that public health technology would reflect popular aspirations and choices more than most technologies. The development of urban sewerage schemes does not seem to offer any significant commercial advantage to any one section of the community since it is a public service available to all. And yet despite this, the engineering decisions surrounding the development of Sydney's sewerage system have been controversial and have attracted widespread media attention.

Sewerage technology is generally associated with large scale systems rather than being commodity or product based, and this offers a good opportunity to consider the degree to which technologies can be self-perpetuating when embedded within a highly complex network of people, organisations and physical components.

The development of the Sydney sewerage system can be studied from the genesis of the city, through its incorporation under colonial rule to its growth into a modern city which is the largest in Australia today. The complete history of Sydney's sewerage system can be contained within two hundred years and although the scope of this thesis is also geographically contained within the boundaries of Sydney's metropolitan area the case study also offers interesting insights into the influence of engineering practice in colonial and technologically dominant nations on local engineering decisions.

A historical perspective is necessary because past decisions can have significant effects on later decisions in terms of physical infrastructure, organisational momentum, past experience and engineering practice. Moreover, a long term perspective enables one to see the persistent patterns in decision making so that variables that change with time can be isolated. In particular, changing values and priorities can be discerned whilst more stable cultural values can be differentiated from those which are dependent on changing economic conditions and particular governments.

In this thesis the story of the development of Sydney's sewerage system will be told and its meaning for engineering decisions and technological change in general will be examined. The story has of course been told in part before. Several histories of Sydney's Water Supply and Sewerage system have been commissioned throughout the years by the Sydney Water Board.[1] The latest was published in 1988 to coincide with the Board's centenary.[2] The New South Wales Public Works Department has also commissioned and published a historical account covering some of Sydney's sewerage history.[3] These histories have been descriptive rather than explanatory and written largely to extol the virtues of organisations responsible for the developments.

In this version of the story I will be concerned with the major decisions about which removal technologies, treatment processes and disposal methods would be used and where the treatment and disposal would take place. These decisions are usually portrayed as being concerned only with technical and economic questions, simply a matter of finding the most cost-effective solution. In these terms, sewerage engineers are deemed to be in the best position to make such decisions. However, I will be looking beyond this commonplace assumption to consider the social and political elements of these decisions.

The thesis begins with the decision to sewer Sydney city after its incorporation in 1842, which followed similar moves in British cities. The role of the sanitary reform movements both overseas and in Australia in deciding that the authorities should intervene in what was previously a private matter will be examined and the subsequent debate over whether the solution lay with sewers or alternative methods of removal will be analysed. (chapters 1&2) The various

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1 For example T.J. Roseby, Sydney's Water Supply and Sewerage 1788 to 1918, William Applegate Gullick, Government Printer, Sydney, 1918; F.J.J. Henry, The Water Supply and Sewerage of Sydney, Halstead Press, Sydney, 1939; W.V. Aird, The Water Supply, Sewerage and Drainage of Sydney, MWS&DB, Sydney, 1961.

2 Margo Beasley, The Sweat of Their Brows: 100 Years of the Sydney Water Board 1888-1988, Water Board, Sydney, Illawarra, Blue Mountains, 1988.

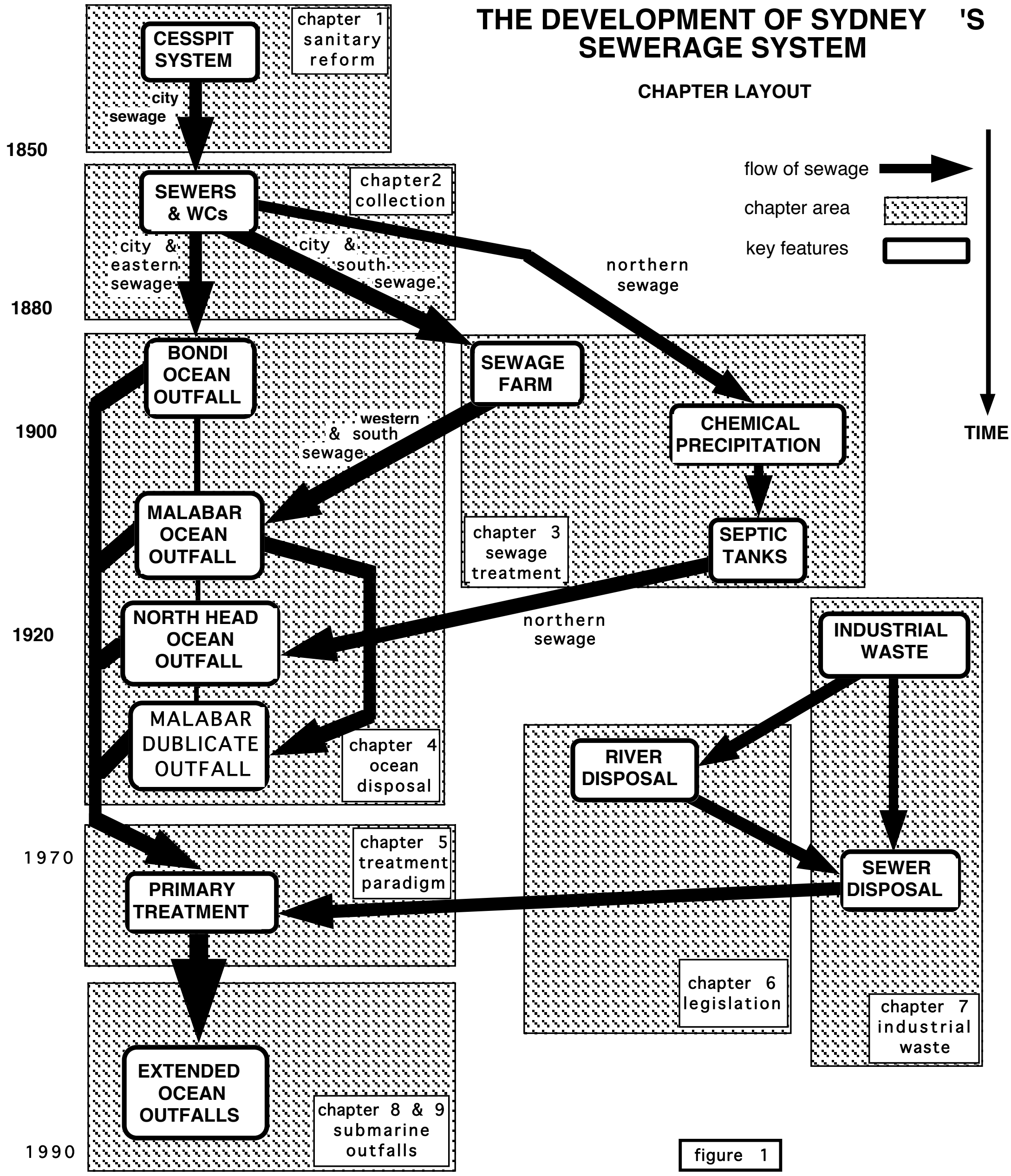
3 Lenore Coltheart & Don Fraser, eds, Landmarks in Public Works: Engineers and their Works in New South Wales 1884-1914, Hale & Iremonger, 1987.

experiments with sewage farming, chemical precipitation and septic tanks that occurred in Sydney will be covered in the following chapter (chapter 3) together with an account of the reasoning behind decisions to install these facilities, their success and the reasons why they were discarded in favour of ocean outfalls. Sydney has three major ocean outfalls and the decision to construct these and the debates over their efficacy are covered in chapter 4. Chapter 5 covers the development of an engineering consensus about appropriate forms of treatment and the decisions to install minimal treatment at Sydney's three main ocean outfalls.

The growing environmental awareness of the 1960s and 1970s and the subsequent legislative reforms are discussed in chapter 6 together with an analysis of their effectiveness in influencing the decisions of Water Board engineers. The use of the sewers to dispose of industrial wastes and the associated decisions are considered in chapter 7 as well as the effect such decisions are having on the environment. The thesis finishes with the most recent decisions to build submarine ocean outfalls at each of the major Sydney outfall sites and the defence of these decisions.(chapters 8&9) These are being constructed now and are due to be completed in the early 1990's.

A layout for this thesis is shown in figure 1. Each chapter (shown as a shaded box) covers one or more key features of Sydney's sewerage system. Although there has been some attempt to retain a chronological order, some chapters cover similar time period and the boxes are therefore shown alongside each other rather than all following down the page after one another. For example the sewage farm and experiments with chemical precipitation and septic tanks which are covered in chapter three occurred at the same time as the first ocean outfalls were built. The heavy arrows in figure 1 show the flow of sewage from the first sewers discussed in chapter 2 to both the sewage farm and the Bondi ocean outfall; from the sewage farm to the Malabar ocean outfall when the sewage farm was closed and from the septic tanks on the north shore to the North Head Ocean Outfall. Chapters 6 and 7 cover the diversion of a new waste stream from industry into the sewer system and are therefore shown to the right of the main sewage flow in figure 1.

The first nine chapters of this thesis will basically tell the story of Sydney's sewerage system as it relates to the themes that are relevant to this study and in the last chapter I will interpret the story in the light of recent theoretical work done in the field of technology studies.



RECENT DIRECTIONS IN THE STUDY OF TECHNOLOGY

The study of technology has, in the past, focussed upon three aspects; innovation studies, historical accounts and sociological accounts.[4] The innovation and historical accounts in particular have depicted a linear process of technological development with inventions leading to innovations, innovations leading to the diffusion of technological products and each technological change leading on from the last in an orderly and inevitable progression. Such accounts have tended to be descriptive[5] rather than explanatory.

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[4]Trevor Pinch & Wiebe Bijker, 'The social construction of facts and artefacts: or how the sociology of science and the sociology of technology might benefit each other', Social Studies of Science 14, 1984, p404.

[5] ibid., p405.

Key points of interest have been who the inventors were, when they made their invention and on what scientific or technological advance the invention was based. Even when the meaning of technology has not been restricted to artifacts, technology has been viewed as merely the fruits of applied science. The simplistic view that economic or market forces fully explain technological innovation has also been recognised as inadequate.[6] More recently, however, the science/technology relationship has been reappraised[7] and there is far more study directed at finding out more about the nature of invention, development and innovation.[8] Technology has been considered as a form of knowledge in its own right quite apart from science.[9] But technology as a form of knowledge is just one of many facets of technology. Others include "its material manifestation, content and effects."[10]

Sociologists of technology have, in turn, concentrated on the social effects brought about by new technologies, reinforcing an often unspoken technological determinism which views technology as being developed apart from society with its own internal dynamic of growth. Technology has been seen as a 'black box' and technologies have been evaluated by their external effects, thus ignoring any intrinsic social relationships within the technology.[11] This view has been rejected by most modern scholars of technology and the determinist model replaced with an interactive model. In this newer model the social, economic, political, technological and scientific realms interact and cannot be considered as separate causative influences on one another.

The interactive model has been expressed in various ways. One way has been to view technologies as forming systems which embody the social, economic, political, technological and scientific. The various interpretations and perspectives of a technology can also be drawn out by considering the network of social groups who have an interest in it. Another way is to focus on technological decision makers and the various social, economic and political factors they consider in reaching their decisions, or to focus on the engineers or technologists themselves and to show how they draw all these elements together in technological innovation, design and practice.

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6 David, Mowery & Nathan Rosenberg, 'The influence of market demand upon innovation: a critical review of some recent empirical studies', Research Policy 8, 1979, pp102-153.

7 Thomas Hughes, 'The seamless web: technology, science, etcetera, etcetera', Social Studies of Science 16, 1986, pp281-92.

8 Thomas Hughes, 'Emerging themes in the history of technology', Technology and Culture 7(3), 1979, p700.

9 Edwin Layton, 'Technology as Knowledge', Technology and Culture 15(1), 1974, pp31-41; Edward Constant, 'Scientific theory and technological testability: science, dynometers, and water turbines in the 19th century', Technology and Culture 24(2), April 1983, pp183-198; Rachel Laudan, 'Conference Report', Technology and Culture 23(1), Jan 1982, pp78-80.

10 Stewart Russell & Robin Williams, 'Opening the Black Box and Closing it Behind You: On Microsociology in the Social Analysis of Technology', revised version of paper to the British Sociological Association Conference Science , Technology and Society, Leeds 1987, p3.

11 Brian Wynne, 'Unruly Technology: Practical Rules, Impractical Discourses and Public Discourses', Science and Technology Studies 18, 1988, p149.

Systems and Actor Networks

Thomas Hughes' study of electricity generating systems was a key work in the system view of technological development.[12] Hughes' technological system included physical artifacts, organisations, scientific components (including publications, research programs and university courses), legislative artifacts and natural resources.[13] The perception of technology as multi-faceted has been taken up by others. For example, Wiebe Bijker has defined a "technological frame" which would include current theories, tacit knowledge, engineering practice, specialised testing procedures, goals and practice and would involve various social groups to various degrees.[14] Similarly John Law[15] and Michael Callon[16] use the systems approach.

A technological system, Hughes argued, evolves and expands according to certain patterns. He identified several phases in the development of electrical power supply systems, including invention, development, technology transfer, and later stages during which critical problems were solved, conflicts resolved and the momentum of the system built up. Hughes' study served to highlight the many non-technical aspects of technological decision-making and development. In particular he showed how political factors were critical to the acceptance of a new system. He revealed how technologists concentrate their efforts on particular aspects of a developing technological system which they perceive as problematical and he clearly demonstrated the use of promotion and publicity by advocates of particular technologies.[17]

A notable contribution made by Hughes and his systems approach was incorporated in his concept of "technological momentum". As a technological system grows, he argued, it develops a mass which is made up of institutions and people who have a vested interest in maintaining the system. These include manufacturers who have invested in resources, labour and manufacturing plant for the system, educational institutions that teach the associated science and practice, research institutions, professional societies, as well as people such as engineers and managers who have invested their experience and expertise in the system. The system not only has mass but also direction; that is, development of the system proceeds along conservative lines that can be extrapolated. Changes in direction are resisted and radical inventions are unpopular because they deskill people, wipe out financial investments and stimulate anxiety in large organisations. When faced with a problem that threatens the stability of the system, the engineer, rather than considering building a new system, tries to

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[12] Thomas Hughes, 'The evolution of large technological systems' in Wiebe Bijker, Thomas Hughes and Trevor Pinch (eds), The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology, MIT Press, 1987, pp51-82; Thomas Hughes, Networks of Power: Electrification in Western Society, 1880-1930. John Hopkins University Press, 1983.

[13] Hughes, Networks of Power, p15.

[14] Wiebe Bijker, 'The Social Construciton of Bakelite: Toward a Theory of Invention, in Bijker et al, The Social Construction of Technological Systems, pp159-190.

[15] John Law, 'Technology and heterogeneous engineering: the case of Portuguese Expansion' in Bijker et al, The Social Construction of Technological Systems, pp111-134.

[16] Michael Callon, 'Society in the making: the study of technology as a tool for sociological analysis' in Bijker et al, The Social Construction of Technological Systems, 83-106.

[17] Hughes, 1983, Networks of Power.

rearrange or manipulate the system components or perhaps to incorporate a hostile environment.[18]

Law and Callon also highlighted the role of engineers, as system builders, in preventing the system from being radically changed. They argued that engineers view these systems as being constituted of a number of components which may be animate and inanimate ranging from people, to skills, to artifacts, to natural phenomena. The engineer puts up no barriers between the social, the economic and the political. The engineer, as system builder associates these disparate elements into a form that holds together. Law and Callon argued that engineers treat these various components or elements in the same way, always seeking to change the most malleable and adapting to take advantage of the most durable, in an effort to sustain and hold together the system and achieve the system goals. One thing which Law & Callon do not make clear is that the system goals may become more related to preserving the system than to realising the original goals that it was set up to achieve.[19]

Whilst Hughes looks at the development of a system, other authors have focussed on the original choice between competing technologies which may be at the basis of a technological system. The use of actor networks has been used to elaborate on the role and perceptions of various social groups in this choice. The key point that these analyses make is that the choice of a technology is not merely based on narrow economic and technical considerations, but involves social choice.

Trevor Pinch and Wiebe Bijker adopted this approach. Using the Empirical Programme of Relativism (E.P.O.R.), which argues that scientific knowledge is socially constructed, they put together an analogous programme called the Social Construction of Technology (S.C.O.T.). The interpretive flexibility attributed to scientific findings by the E.P.O.R. programme was applied to technological artifacts and it was consequently argued that various social groups could attribute very different meanings and problems to the one technological product or artifact and for each problem associated with the artifact there would be various possible solutions, including moral, judicial or technological solutions.[20]

The resolution of conflict between different social groups with differing preferences and perceptions cannot be attained in the same way that a consensus is attained within a scientific community. Pinch and Bijker argued that the stabilization of an artifact happens when the relevant social groups see the problem as being solved and that this can occur through rhetorical closure or redefinition of the problem.

Rhetorical closure may be achieved through claims in advertising or propaganda which are aimed at changing or shaping the meaning that various social groups attach to an artifact and thereby enrolling their support. Closure by redefinition can be procured by redefining the problem for which the artifact is then seen to be a solution.

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18 ibid.

19 Law, 'Technology and heterogeneous engineering'; Callon, 'Society in the making'

20 Pinch and Bijker, 'The social construction of facts and artefacts'

Both these forms of closure imply a degree of ultimate consensus which is not always present and Pinch and Bijker seem to ignore the ability of technologists and firms or authorities to force closure despite the objections of consumers or other interest groups which are in a less powerful position. Consumers are only able to exert influence where they have a choice to reject a particular technology through doing without it or choosing a better alternative.

Peter Weingart has observed that technological systems, even those producing consumer goods for the market, can be implemented without regard for public acceptance.

> The alliance of government bureaucracies, engineers and private corporations - the latter acting as quasi-public agencies by being subsidized directly or indirectly - circumvents the market and operates through the medium of political power. Consequently, non-acceptance of such technologies by the public can only find expression in political resistance, leading to legitimation problems with grave political rather than mere market failures.[21]

The same criticisms can be applied to Cowan's concept of the consumption junction. Cowan argues that technological choices can be elucidated by studying the consumer's point of view, finding out why consumers acted the way they did.[22] This only really works in the case of public sector technology if the consumer is considered to be the government or public authority who is paying for or instituting the technology, for it is they who interpret and weigh the views of the users. If the public as user is to influence the choice of a technology it is through the mediated perception of public servants and politicians.

Moreover, as Stewart Russell has pointed out, many alternative technologies are never presented to the consumer or outside social groups because of an internal selection process in the invention and innovation process. Those that are presented are already socially shaped and formed "the product of researchers' or designers' interpretation of need".[23] Making the same point in a different way Rosenberg and Mowery[24] and later Giovanni Dosi[25] pointed out that needs expressed through market signalling are not necessarily the prime movers of innovation.

Russell argued that the problem with the Pinch and Bijker scheme is that social groups are not located within a "structured and historical context"

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21 Peter Weingart, 'The structure of technological change: reflections on a sociological analysis of technology' in Rachel Laudan (ed), The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?, D.Reidel, 1984, p130.

22 Ruth Schwartz Cowan, 'The consumption junction: a proposal for research strategies in the sociology of technology' in Bijker et al, The Social Construction of Technological Systems, pp261-280.

23 Stewart Russell, 'The social construction of artefacts: a response to Pinch and Bijker', Social Studies of Science 16, 1986, p343.

24 Mowery & Rosenberg, 'The Influence of Market Demand upon Innovation'

25 Giovanni Dosi,'Technological paradigms and technological trajectories', Research Policy 11, 1982, p148.

and therefore the economic, political and ideological constraints and influences acting upon those groups are not taken into account. For this reason Pinch and Bijker failed to explain, for example, "why a workforce is excluded from the design of equipment it must use, or why a population suffering harm from a toxic effluent cannot bring about the adoption of a different chemical process."[26]

The mechanisms by which a particular alternative or artifact succeeds at the expense of other competing alternatives, therefore, remains unclear if consideration is only given to the various meanings attributed to that artifact. The reason that one set of artifactual interpretations triumphs over others still needs to be examined. The ideas of "rhetorical closure" and "redefinition" may well be generalizable tactics employed in technological controversies, but why some groups are able to apply them more effectively than others is the crucial question.

Emphasis on interpretive flexibility and negotiation can all too often lead to a neglect of the question of power, especially power in its material forms which enables some groups to control negotiation and sometimes arbitrarily limits interpretive flexibility. Politics and the uneven distribution of power and influence between social groups and actors make any simplistic view of a consensus process difficult to defend. In most technological controversies the role of vested interest groups, engineers and government authorities in shaping or overriding the views of less influential social groups needs to be considered.

Engineers, Expertise & Influence

The power of engineers and government authorities in engineering decision making arises in part from the power that is accorded to government but also in part from the use which governments make of the authority which the community vests in its experts. The body of literature on expertise and its use is therefore relevant once the role of power in technological decision making is recognised. Even if one accords a more even spread of power between social groups interested in a technology, the use of experts in enrolling groups, redefining the problems or in rhetorical closure is essential.

Much was written in the 1970s on the use of experise by people in power by authors such as Benveniste[27], Elliot & Elliot[28], King and Melanson[29], Mazur[30], Macrae[31], Primack & von Hippel[32], Sklair[33] and Nelkin[34]. Dorothy Nelkin has

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26 Russell, 'The social construction of artefacts', p336.

27 Guy Benveniste, The Politics of Expertise, Croom Helm, London, 1972, p62.

28 David Elliot & Ruth Elliot, The Control of Technology, Wykeham Publications, 1976.

29 Lauriston King & Philip Melanson, 'Knowledge and Politics: Some experiences from the 1960s', Public Policy xx, Winter 1972, pp83-101.

30 Allan Mazur, 'Disputes Between Experts', Minerva xi(2), April 1973, pp243-262; Allan Mazur, 'Opposition to Technological Innovation', Minerva xiii(1), Spring 1975, pp58-81.

31 Duncan MacRae Jr, `Technical communities and political Choice', Minerva xiv(2), Summer 1976, pp169-190.

32 Joel Primack & Frank von Hippel, Advice and Dissent: Scientists in the Political Arena, Basic Books, New York, 1974.

33 Leslie Sklair, 'Science, technology and democracy' in Godfrey Boyle, David Elliot & Robin Roy (eds), The Politics of Technology, Longman & Open University Press, 1977.

written extensively on the subject. She has observed that it is not only knowledge, but also assumptions of rationality and objectivity, which lead the public to look to the experts for advice and solutions. She argued that government decisions are often defined as technical decisions and the issues at stake also as primarily technical. This is more comfortable for the policy makers.[35] In this way, the decision appears to be subject to objective criteria that can be evaluated by the experts using economic and scientific models, calculations and statistics.[36] Difficult issues such as conflicting interests do not have to be resolved and the alternatives can be compared solely on the basis of cost and effectiveness in solving the immediate problem.[37] Defining a problem as technical also conveniently hides the political choice and priorities involved and reduces the debate to arguments over technical details.[38] Proposals can be "thrust upon the public as if they were non-controversial technical decisions".[39] Unspoken objectives such as maximising economic growth and priorities afforded to industrial concerns do not become explicit.[40]

Leslie Sklair also noted the tendency of policy makers to want to keep issues confined to technical discussion, and in so doing avoid making their objectives and priorities explicit whilst ensuring that any argument is confined to an arena in which experts have authority. If it is admitted that a decision has social and political dimensions then it is much more difficult to maintain that only scientists and technologists should discuss and influence it.[41]

Various writers have observed how those in power use experts to legitimate decisions. Lauriston King and Philip Melanson noted that decision-makers can make use of the esteem given to experts in order to justify, legitimate and gain acceptance for their decisions.[42] This does not mean, they said, that the technical considerations are foremost in making the decision. Rather "specialised knowledge merely becomes another weapon in the decision-maker's political arsenal".[43]

Similarly Joel Primack and Frank von Hippel argued that legitimation might merely involve invoking an authority as a substitute for evidence[44] or informing the public that the policy maker has consulted eminent experts, even if in fact the experts did not whole-heartedly support the proposal but reported confidentially so no one knows the difference. Instances have been reported

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34 For example Dorothy Nelkin, 'Scientists in an environmental controversy', Science Studies 1, 1971, pp245-261; Dorothy Nelkin, `The political impact of technical expertise', Social Studies of Science 5, 1975, pp35-54; Dorothy Nelkin, ed, Controversy: Politics of Technical Decisions, Sage Publications, 1984.

35 Nelkin, `The political impact of technical expertise', p36.

36 Nelkin, Controversy, p18.

37 Nelkin, `The political impact of technical expertise', p36.

38 Harvey Brooks, `Scientific concepts and cultural change', Daedalus 94(1), Winter 1965, p68.

39 Dorothy Nelkin & Michael Pollack, `The politics of participation and the nuclear debate in Sweden, the Netherlands, and Austria', Public Policy 25(3), Summer 1977, p355.

40 Nelkin, 'Scientists in an environmental controversy', p254.

41 Sklair, 'Science, technology and democracy', p174.

42 King & Melanson, 'Knowledge and Politics', pp88-9

43 ibid., p100.

44 Primack & von Hippel, Advice and Dissent, p72

where officials have selectively published expert reports, have summarised expert reports in a misleading way, have lied about expert reports, have suppressed information available only to them or have manipulated their advisers to ensure a favourable report.[45]

Duncan Macrae also pointed out that often a decision about a proposal will precede the detailed investigations, feasibility studies and environmental impact statements which are supposed to be enquiring into that proposal.

> It is common for heads of organisations and their advisers to accept that their task is to authenticate or justify the policies previously chosen and to deny the validity of the arguments introduced in support of the alternative recommendations made by others.[46]

This requires that investigations be selective and damaging evidence be suppressed.[47] Nelkin too agrees that technical advice can be slanted by using different criteria for collecting data and interpretations and studies based on diverse premises will require different sampling techniques.[48]

Guy Benveniste, in The Politics of Expertise, argued that one should not assume that experts are fooled by the pretensions that a problem is totally technical. Most engineers are fully aware of the political dimensions of the decisions they make and the advice they give but they cannot make those political dimensions explicit for fear of undermining the faith others have in expertise.[49] They must appear to be apolitical for, after all, they are not elected and it is their perceived neutrality which allows them to have power.

> a principal function of the apolitical definition of the policy expert's role is the exact opposite of the definition: it provides access to social power without political election.[50]

Benveniste also notes that organisations are able to consolidate a monopolistic position by either acquiring widespread external professional consensus on their proposals or by "creating a large integrated research team whose advice cannot easily be dismissed".[51] When widespread consensus is not feasible, organisations can limit outside interference by resorting to secrecy or by not allowing the public enough time to study the huge amount of research data that it has produced before the decision is made.[52]

Similarly King & Melanson pointed out that expertise is not equally available to all those who might wish to use it to support their case and it thus becomes an "instrument of power and privilege".[53] Sklair also argued that public access to

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[45] Primack & von Hippel, Advice and Dissent, pp34-5.
[46] MacRae, `Technical communities and political Choice', p177.
[47] ibid., p177.
[48] Nelkin, `The political impact of technical expertise', p45
[49] Benveniste, The Politics of Expertise, p62.
[50] ibid., p65
[51] ibid., p126.
[52] ibid., p128.
[53] King & Melanson, 'Knowledge and Politics', p100

debate is further limited by the use of specialist jargon and making reports overbearingly and unnecessarily technical and esoteric.[54] Nelkin said that by hiring their own experts opponents of a technological project can either question the evidence put forward by government experts or point to evidence that has been ignored. Debate, however, tends to remain focussed on technical issues rather than the conflicts over values and priorities which are really at the heart of any disagreement.

> Thus power hinges on the ability to manipulate knowledge, to challenge the evidence presented to support particular policies, and technical expertise becomes a resource exploited by all parties to justify their political and economic views. In the process, political values and scientific facts become more difficult to distinguish.[55]

More recently authors such as Barry Barnes[56], David Edge[57], David Dickson[58], Arie Rip[59] and Michael Pollack[60] have also contributed to the literature on experts, covering much of the same ground in new ways. Barnes and Edge demonstrated how the credibility of experts cannot be established by strictly logical arguments and that credibility depends upon the consensus between experts; where experts disagree their influence is weakened. Moreover they argued that power is not only achieved by access to expertise but also by being able to define rationality, define who are the experts and the bounds of their expertise and by being able to control the terms of disputes.[61]

Barnes highlighted the way our society has come to rely on and trust experts because of the impossibility of examining each argument and claim on its merit alone. The "high division of intellectual labour" in our society means that it is necessary to grant authority to knowledge specialists.[62] However he went on to show how the authority of science is extended beyond its accepted bounds and how some experts merely "take on the trappings of science, its symbols and rituals, and thereby seek to clothe themselves in scientific authority." [63]

As previous writers have done Barnes pointed to the ways in which experts are called upon to provide justifications and legitimations rather than technical knowledge. But he went on to argue that the rewards and privileges the expert gets for his/her role in the decision-making process are accompanied by a price of anonymity and confidentiality. Experts must pass all their information upwards to those in power and keep it from the rest of society, thereby ensuring that they are subservient to those in power and are unable to use their information for

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54 Sklair, 'Science, technology and democracy', p173

55 Nelkin, Controversy, p17

56 Barry Barnes, About Science, Basil Blackwell, 1985.

57 Barry Barnes & David Edge, eds, Science in Context: Readings in the Sociology of Science, Open University Press, Milton Keyes, 1982.

58 David Dickson, The New Politics of Science, Pantheon Books, New York, 1984.

59 Arie Rip, 'Experts in Public Arenas' in Harry Otway & Malcolm Peltu (eds), Regulating Industrial Risk, Butterworths, 1985, pp94-110.

60 Michael Pollack, 'Public Participation' in Otway, Regulating Industrial Risk, pp76-93.

61 Barnes & Edge, Science in Context, introduction to part 5.

62 Barnes, About Science, p83.

63 ibid., p96.

other ends. Their own role and that of the public in the decision making is thereby restricted.[64]

Dickson recognised two approaches when dealing with technological controversies. The 'technocratic approach' is the search for a rational solution agreed to by experts and requires solutions to "display both technical efficiency and economic rationality". The 'democratic approach' seeks to maximise participation in decision making and argues that a redistribution of power is just as likely to achieve a favourable outcome as anything the experts will come up with; humane and socially just solutions are sought.[65] Whilst there was increasing pressure for the second approach to be taken, those in power have done their best to gain control of and limit the possibilities of such mechanisms as technology assessment, which were supposed to meet the demands for greater participation in setting technological goals.[66]

Dickson also argued that a move towards a greater role for science in regulation has been used as a way of hindering and manipulating regulation by demanding proof and certainty where uncertainties and judgements are involved and by defending decisions on the grounds that they were dictated by science when political factors influenced the decision.

> arguments about rationality are used to limit the substantive content and impact of rationality itself-or, more accurately, to defend restrictions on regulations against external criticism.[67]

The politics of expertise literature, clearly recognises that technological decision-making is a social and political activity which is often portrayed as a purely technical process. However much of this literature focuses on scientists rather than engineers, and often scientists employed in the role of adviser rather than on engineers employed to design and execute technological projects and to defend the choice of technology in that project. Moreover,there is a tendency to place the expert in a subservient role as adviser and to concentrate on the policy maker as decision maker without exploring the extent to which the relationship is a two way process in which an expert may attempt to manipulate the politician and influence the decision by exploiting the dependence of the politician on him/her for information. Because of this the ideologies or values of that expert are not examined.

This latter angle, with respect to engineers, is covered more fully in the sociological literature. There have been various studies of the social backgrounds of engineers, their personalities, qualities, interests, attitudes, reasons for choosing engineering, professional associations, their work situations and even their ethics.[68] There has been relatively little study of engineers and their

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64 ibid., p100.

65 Dickson, The New Politics of Science, pp219, 264-5.

66 ibid., pp219-256.

67 ibid., p264.

68 For example Robert Perrucci & Joel Gerstl (eds), The Engineers and the Social System, John Wiley & Sons, 1969; J.E.Gerstl & S.P.Hutton, Engineers: The Anatomy of a Profession, Tavistock Publications, 1966; Stanley Hutton & Peter Lawrence, German Engineers: The Anatomy of a Profession, Clarendon Press, 1981; E.G.Semler (ed), The Engineer and Society,

history.[69] Two notable works in this area, which have attempted to elucidate the ideology and social relationships of engineers through the study of the history of the engineering profession, have been Edwin Layton's The Revolt of the Engineers[70] and David Noble's America by Design.[71]

Layton traced the emergence of a professional identity amongst engineers which embraced three key elements; the engineers' self-image as agents of technological change and progress, as unbiassed logical thinkers, and as socially responsible for ensuring the benevolence of technological change. Layton argued that the engineering ideology, which emphasised the superiority of engineers, was accompanied by a dissatisfaction with status and the lack of autonomy of engineers in their work. Engineers felt they were well suited to be society's leaders, to control public works and to solve social problems by the application of logic and scientific principles. This ideology was distinctly elitist and hierarchical. Engineers did not have great faith in democracy and felt that some people were better able to judge things than others.

A more recent study of American and Canadian engineers specialising in water resources problems found that this ideology persists. Engineers were sceptical about involving the public in their decisions. The public were seen to be ill-informed and irrational with such a wide range of opinions that decision-making became impossible. The engineers considered themselves to be more effective decision-makers than other professionals because they were "precise and accurate" and took a practical view rather than an idealistic one.[72]

Sociological studies have also studied what professionalism means to engineers. Kenneth Prandy concluded that professionalism, in the case of engineers, was an expression of a status ideology that, unlike the ideology of class consciousness, accepted the "employers' ideology of stratification". Engineers accepted the existing hierarchical relationships within society because they were "employed in positions in which they either share directly in the exercise of authority, or in which their work gives them the feeling of being close to management."[73] Put another way, technologists support a social system which grants favour and influence to educated elites.[74]

Layton similarly concluded from his historical study that engineers have unquestioningly accepted "the structure, power and basic ideological principles of business."[75] Noble went one step further in saying that engineers have not only

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Institution of Mechanical Engineers, London, 1973; Robert Perrucci & Joel Gerstl, Profession Without Community: Engineers in American Society, Random House, New York, 1969.

69 Hughes, 'Emerging Themes in the History of Technology', p703.

70 Edwin Layton Jr, The Revolt of the Engineers: Social Responsibility and the American Engineering Profession, Cape Western Reserve University, Cleveland and London, 1971.

71 David Noble, America by Design: Science, Technology and the Rise of Corporate Capitalism, Alfred A Knopf, New York, 1977.

72 W.R.Derrick Sewell, `The role of perception of professionals in environmental decision-making', in Keith Attenborough et al (eds), Pollution: the Professionals and the Public, Open University Press, 1976, p151.

73 Kenneth Prandy, Professional Employees: A Study of Scientists and Engineers, Faber & Faber, London, 1965, p185.

74 Stuart Umpleby, 'Is greater citizen participation in planning possible and desirable?' in Boyle et al, The Politics of Technology, p234.

75 Layton, The Revolt of the Engineers, p67.

incorporated capitalist values but also came into being expressly to serve the purposes of the capitalist.[76] In a later book Noble argues that technical people rely upon their ties with power because it is access to power and resources that allows them to dream big and have their designs built.[77] It is no accident, he said, that the best engineering designs are well suited to the requirements of those in power. Noble also claimed that science and technology were about control, manipulation of nature and the construction of devices to improve human power over events. Engineers can hardly help themselves from getting all caught up in such endeavours "propelled by enthusiasm and a will-to-power".[78]

Two recent sociological studies of engineers by Peter Whalley and Robert Zussman also conclude that the engineers in their studies have incorporated business values. Zussman argues that "cost is itself a criterion of technical efficiency" which must be considered along with the physical properties of the materials. Engineering is viewed by engineers as a means to achieve corporate goals rather than an end in itself.[79] An earlier study by Richard Ritti also found that engineers placed greater importance on having the opportunity to help their employing company increase its profits than on any technical goals such as exploring new technologies or establishing their own professional reputation.[80] Whalley suggests that engineering employees "are socialised and selected from the beginning to accept the legitimacy of both bureaucratic authority and the dominance of business values." These are secured by a career structure which rewards the trustworthy.[81]

Most studies of engineering ideology and behaviour have focussed on engineers working in private industry rather than in the public sector and there still remains the question of whether engineers who do not work in the private sector still incorporate or even sympathise with business values, whether they take on just as easily the values of their employer if that employer is a government body; and to what extent economic measures of performance prevail.

Engineering Practice

The sociological and historical material on engineers highlights the ideologies and values and alliances of engineers. But most studies of engineers have not attempted to link their findings with the content of engineering design.[82] Also very little work indeed has been done on the philosophy of engineering compared with the vast studies in the philosophy of science.

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[76] Noble, America by Design, p34.

[77] David Noble, The Forces of Production: A Social History of Industrial Automation, Knopf, New York, 1984, p44.

[78] ibid., p46.

[79] Robert Zussman, Mechanics of the Middle Class: Work and Politics Among American Engineers, University of California Press, 1985, pp121-3.

[80] Richard Ritti, The Engineer in the Industrial Corporation, Columbia University Press, 1971, pp48-9.

[81] Peter Whalley, The Social Production of Technical Work: The Case of British Engineers, MacMillan, 1986, p124.

[82] Donald, McKenzie & Judy Wajcman (eds), The Social Shaping of Technology: How the Refrigerator Got Its Hum, Open University Press, 1985, pp297-8..

Engineers have power in the shaping of technology from two different sources. As experts they can align themselves with those in power and as the originators and designers of technology they occupy a central position in the shaping of technologies before they are even subject to wider debate and competition. Even after the technologies are conceived, in a very real sense many of the views and interpretations of the other social actors are filtered and reinterpreted through the perceptions of the engineers who continue to design and reshape the technologies and decide on their configurations.

Some writers have considered the design process itself. J.Christopher Jones[83] and Christopher Alexander[84] examined pre-engineering design methods to highlight some of the key features of modern design. These authors noted the increasingly self-conscious nature of design, the distancing of design from construction, the consequent division of labour, the need to use models, both physical and abstract, and the increasing removal of the designer from the context of their work.

Eugene Ferguson observed the move away from non-verbal thinking to more analytical and scientific modes of thought as drawing the engineer away from the "complexities of the real world". He suggested that too much emphasis on analysis could leave the way open for stupid mistakes and wrote of the "chaos that results when design is assumed to be primarily a problem in mathematics."[85]

Arnold Pacey also regretted the way design seems to be divorced from the end use context of technological products. He argued that engineers overemphasise construction and neglect maintenance, operation and use. This occurs, he said because of the orientation towards problem solving rather than problem prevention amongst technologically trained experts. He also noted that maintenance work, unlike construction, is inconspicuous, routine, repetitive and even tedious work.[86] Henry Petroski singled out the use of computers in particular as further increasing the separation of the designer from the context of their work and from an intuitive grasp of whether computed results are realistic. Engineers, he said, can gain an "unwarranted confidence" in the numbers they come up with using their computer models.[87]

Petroski', in To Engineer is Human gave an important insight into the experimental nature of engineering design. He pointed out that engineering construction is uncertain by its very nature and that engineers learn more from failures than from successes. He explained how engineers are always trying to reduce the cost of their structures by reducing the materials used and this causes a tendency to reduce safety factors when a design method appears to be continuously successful. In this way "successful structural concepts devolve into

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83 J.Christopher Jones, Design Methods: Seeds of Human Futures, 1980 edition, John Wiley & Sons, 1980.

84 Christopher Alexander, Notes on the Synthesis of Form, Harvard University Press, 1970.

85 Eugene Ferguson, 'The Mind's Eye: Nonverbal Thought in Technology', Science 197(4306), 26 August 1977, pp834-5.

86 Arnold Pacey, The Culture of Technology, Basil Blackwell, 1983, chapter 3.

87 Henry Petroski, To Engineer is Human: The Role of Failure in Successful Design, St Martins Press, New York, 1985, chapter 15.

failures."[88] D.I.Blockley makes the same observation about design rules. He says that in time a design rule may be extended under economic pressures "until an accident occurs which will define the boundary of its use." [89] Both Petroski and Blockley are structural engineers who apply their analysis to structural engineering. However, other writers have also emphasised the experimental nature of engineering in general.[90]

Recent scholars in the field of technology studies have looked to the parallel but more developed field of history and philosophy of science for approaches to their work. For example, Kuhn's work on the nature of scientific revolutions and the every day, "normal" work of scientists[91] has been found to yield analogies in the area of technological change and engineering practice. Edward Constant, [92] David Wojick[93] and Giovanni Dosi[94] have made notable contributions in this vein.

Constant argued that the routine work of engineers and technologists, which he called 'normal' technology, involves the "extension, articulation or incremental development" of existing technologies. A technological tradition, Constant said, is subscribed to by engineers and technicians who share common educational and work experience backgrounds. The tradition relates to a field of practical endeavour rather than to any academic discipline.[95] Rachel Laudan argued that the function of traditions is to allow technologists to focus on potentially solvable problems and to provide the methods with which to solve those problems.[96]

Dosi described a technological paradigm as "an "outlook", a set of procedures, a definition of the "relevant" problems and of the specific knowledge related to their solution."[97] Such a paradigm, Dosi said, embodies strong prescriptions on which technological directions to follow and ensures that engineers and the organisations for which they work are "blind" to certain technological possibilities. Dosi identified a technological paradigm in four dimensions. The first related to the generic tasks to which it is applied and the second to the material technology it selects. The third related to the physical/chemical properties it exploits and the fourth dimension was the technological and

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[88] ibid., p163.

[89] D.I.Blockley, The Nature of Structural Design and Safety, Ellis Horwood, Chichester, 1980, p75.

[90] Mike Martin & Roland Schnzinger, Ethics in Engineering, McGraw-Hill, 1983; Jerry Gravander, 'The Origin and Implications of Engineers' Obligations to the Public Welfare', PSA 1980 2, 1980, pp443-55.

[91] Thomas Kuhn, The Structure of Scientific Revolution, 2nd edition, University of Chicago Press, 1970.

[92] Edward, Constant, 'Communities and hierarchies: structure in the practice of science and technology' in Rachel Laudan (ed), The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?, D.Reidel, 1984.

[93] David, Wojick, 'The structure of technological revolutions' in George Bugliarello & Dean Boner (eds), The History and Philosophy of Technology, University of Illinois Press, 1979.

[94] Dosi, 'Technological Paradigms and Technological Trajectories'.

[95] Constant, 'Communities and hierarchies', p29.

[96] Rachel Laudan, 'Cognitive change in technology and science' in Laudan, The Nature of Technological Knowledge, p95.

[97] Dosi, 'Technological Paradigms and Technological Trajectories', p148.

economic dimensions and tradeoffs which are associated with it. These tradeoffs, he said, provided the direction for improvement of the technology.[98]

Richard Nelson and Sidney Winter also observed that there is sometimes a technological "regime" or paradigm operating which relates to the technicians beliefs about what is feasible or at least worth attempting. They put forward a more convincing explanation of why technological change within a paradigm seems to follow certain directions.

> The sense of potential, of constraints, and of not yet exploited opportunities, implicit in a regime focuses the attention of engineers on certain directions in which progress is possible, and provides strong guidance as to the tactics likely to be fruitful for probing in that direction. In other words, a regime not only defines boundaries, but also trajectories to those boundaries.[99]

In many cases, Nelson and Winter argued, those directions involve improvements to major components of a system. Similarly Laudan said that problems tackled within a tradition tend to be those of cumulative improvement.

There seems to be some confusion in various accounts of technological development between technological research and technological practice. Nelson and Winter's notion of a technological regime, and to a lesser extent Constant and Dosi's concept of a paradigm, seem to focus on the research and development of technology rather than its application. But the idea of a technological regime or paradigm is even more appropriate to the practice of engineering where the practitioner seeks to apply a selected technology in a specific location and situation. The paradigm or regime defines the range of technologies which such an engineer draws upon for such purposes and therefore determines 'normal' practice.

Wojick concentrated more on engineering practice in his description of technological paradigms and he said that 'normal' technology involved the "artful application of well-understood and well-recognised decision-making procedures". In this way there is no ambiguity or doubt about what counts as a good solution within the engineering community.[100]

Not all writers agree about the degree to which Kuhn's work can be applied to technology. It is generally agreed that the work of engineers exhibits some of the qualities of "normal" science in that research is generally of a gradual cumulative nature, making improvements on past achievements and that solutions are sought from within a restricted range of possible solutions. Similarly practice is based on applying the appropriate technological methods from an arsenal of "tried and true" methods. The main points of contention have been whether the idea of a technological paradigm as a "supertheory" or even a set of shared beliefs, values and techniques, is too vague, whether a

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98 ibid.

99 Richard Nelson & Sidney Winter, 'In search of useful theory of innovation', Research Policy 6, 1977, p57.

100 Wojick, 'The structure of technological revolutions', p241

paradigm must be based on an exemplar[101] and whether a technological community is analogous to a scientific community.

The problems with the application of Kuhn's concept of paradigms and scientific revolutions to technology come to the fore when applied to paradigm change or the "technological revolution" that would be analogous to the scientific revolution. Kuhn argued that scientists become aware of anomalies in the paradigms they are working within when there is a recognition by scientists that "nature has somehow violated the paradigm-induced expectations".[102] Contradictions between theory and reality are not sufficient to dislodge an engineering paradigm which is, after all a social construction. The utility of such a social construction having been socially negotiated, the interested parties must then agree about its disutility.

A similar problem is associated with the systems approach. Hughes has coined the term "reverse salient" to describe the situation where components fall behind or out of line as a technological system evolves. This impedes the growth of the whole system.[103] Hughes argued that when a reverse salient can't be corrected within the context of the existing system then the problem becomes radical and the solution may bring about a new and competing system. Whilst engineers perceive their technologies to be successful, to "work", their traditional practice is reconfirmed and the incentive to have such a perception is great. MacKenzie argued that reverse salients depend on goals, actors and what is solvable. Moreover, because the rewards from solving critical problems are great, there is a tendency to identify as critical those problems which are seen by the engineers to be solvable.[104] "Critical" anomalies and "incorrectable" reverse salients are designated as such by the actors involved, they are not in the nature of the world or the system.

Nonetheless some writers have tried to make analogies with Kuhn's concept of anomalies. Constant identified "presumptive anomalies" which are presumed to exist when it is predicted by the engineer that a conventional technology will fail under certain future conditions or it is predicted that an alternative technology will do a better job. The second type of anomaly which Constant identified is the "functional-failure" when the technology does not work very well because conditions have changed, allied technologies have changed or other parts of the system have advanced more quickly.[105]

This difficulty in identifying when a technology is working satisfactorily was recognised by Wojick who defined technological paradigms in terms of an "evaluation policy" which enables engineers and managers to judge their designs and plans. Such evaluation policies, which may be based on scientific theory, engineering principles, rules of thumb, legislation,

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101 Gary Gutting, 'Paradigms, revolutions, and technology' in Laudan, The Nature of Technological Knowledge, pp48-49; MacKenzie & Wajcman, The Social Shaping of Technology, pp11-12.

102 Kuhn, The Structure of Scientific Revolutions, p52.

103 Hughes, Networks of Power, pp79-80.

104 Donald MacKenzie, 'Missile Accuracy: A Case Study in the Social Proceses of Technological Change', in Bijker et al, The Social Construction of Technological Systems, pp197-8.

105 Constant, 'Communities and Hierarchies', p31.

professional standards or moral precepts, determine decision-making procedures within which "normal technology" can take place.[106]

Anomalies occur in such paradigms, Wojick argued, when standard procedures repeatedly "fail to eliminate known ills" or when knowledge shows up the importance of factors which have previously been incorrectly evaluated. Those contesting the evaluation policy may be outside the paradigm community and their view may be disputed. They can then, Wojick says, turn to the government for a ruling.

Constant referred to traditions of testability which may play a role in defining and sustaining specific traditions of technological practice. Such traditions embody norms such as the overt commitment to objective, scientific, replicable and public testing. He argued that traditions of technological testability permit practitioners to know which designs and modifications represent progress by helping them to see how closely they are approaching the ideal.[107]

John Law argued that just because a technology "works" does not mean that it is beyond explanation; what counts as working has to be socially negotiated.[108] Similarly Ruth Schwartz Cowan pointed out that the criteria for "betterness" vary depending on the domain of interest.[109] Trevor Pinch and Wiebe Bijker criticise previous studies of technology because of their asymmetrical focus on "successful" technologies. They argue that whilst there is a need to explain the success of an artifact, equal treatment should be given to technologies which have been discarded. Understanding failure is a crucial element in understanding technology.[110]

STRATEGY OF THIS THESIS

The various bodies of literature, as outlined above are not particularly contradictory and in fact many of the central themes are common to each of them. Their main differences lie in their focus. The literature on competing technologies is most relevant to a stage of technological development before a technological system or paradigm has been set up. At this point vested interests are minimised and professional control is weak or non-existent. The theoretical perspectives provided by this literature are most appropriately used at the initial stages of the development of a sewerage system and, in particular, prior to the consolidation of the sewerage engineering profession.

The key concern of the work on competing technologies is that equal attention must be given to failed technologies if we are to understand technological development. In keeping with this I will not be confining attention to those technologies which were implemented but also considering those which were

106 Wojick, op.cit., p240.

107 Edward Constant, 'Scientific theory and technological testability: science, dynometers, and water turbines in the 19th century', Technology and Culture 24(2), April, 1983, pp195-6.

108 John Law, 'International workshop on new developments in the social studies of technology'. *4S Review*. vol 2. no4, 1984; p9.

109 Cowan, 'The Consumption Junction', p273.

110 Pinch and Bijker, 'The social construction of facts and artefacts', pp405-6.

only discussed, and also those which were tried but later discarded, in particular the debate between water-carriage technologies and dry conservancy technologies for collection of sewage and between various means of treating sewage (chapters 2 & 3). A major weakness in the technology studies literature is in the descriptions of closure, or how disputes are settled, in particular, how various parties are enrolled, the attempts to manipulate public opinion and the use of power and privilege. These are all aspects which will be explored in this thesis. In doing this I will be considering the various interpretations that different people gave to proposed sewerage technologies and uncovering the process by which the interpretations of one group came to dominate and win over the others.

The thesis will also explore the on-going development of a technology once it becomes dominant and subsequently becomes entrenched and will therefore draw on the complementary literature on technological systems and paradigms. I will also be making use of the literature on the history and sociology of engineers and on the politics of expertise to cover political and sociological dimensions that is often neglected by the systems/paradigm approach. The thesis will also consider the translation of ideas into physical artifacts by engineers and seeks to contribute in this way to the newly emergent philosophy of technology literature.

The way I intend to integrate these fragmented bodies of literature is shown in figure 2 on the next page. Of course, such a diagram merely shows how various studies of technology will be fitted together and says nothing about the relationships between the parts, including the various people and social groups, bodies of knowledge, legislation etc. It is hoped that these relationships will become clearer as the case study presented in this thesis unfolds.

The sewerage system will be considered as a technological system to include relevant legislation, administration, education, and organisation. In particular, I will be interested in how these elements of the system defined the problems which the developments in Sydney's sewerage system were supposed to deal with and constrained the technological solutions. The paradigm perspective will be considered by examining whether a sewerage engineering 'paradigm' limited the range of possible solutions considered by engineers.

In particular, the vexed question of just how much control engineers have in shaping and choosing technologies is central to this thesis. One of the key points at issue in recent studies of technology is just how central the engineers are. On the one hand, Law, Callon & Hughes put the system builder at the centre of their studies and the system builder is either the engineer or the organisation for which the engineer works. On the other hand, some writers have put the engineer on a par with other players, or stressed the subordinate role of the engineer as employee. It is hoped that the detailed examination provided in this case study will illuminate the role of the engineer further, although there may be basic differences between various types of technological system that may limit the application of this case study.

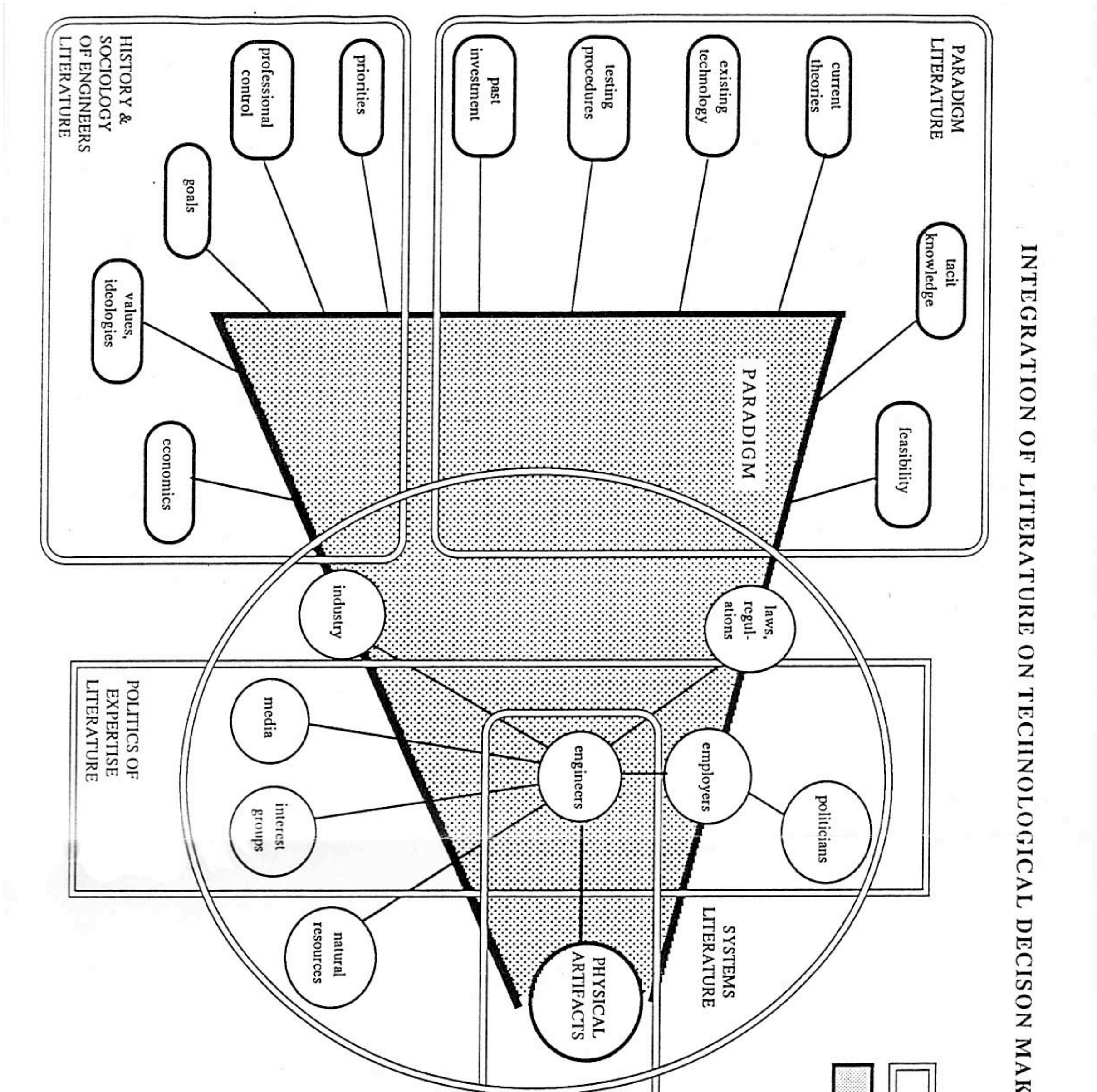

figure 2

Figure 2 is an attempt to show the relationships between various bodies of literature that deal with technological development. The paradigm is featured as a triangular shape to show the narrowing range of options that are considered by those who subscribe to a paradigm. The form and direction is shaped by various factors that are shown feeding into the base of the triangle that represents the paradigm. These factors include cognitive and technical factors which are discussed in the literature on paradigms but also social, economic and political factors that are covered in the literature on the history and sociology of the engineering profession. The social groups involved and non-human components of a technological system all influence the engineers, who conceive, design and shape the physical artifact. The engineer is therefore shown at the centre of the system, completely embedded in the paradigm. Others components of the system are partly embedded in the paradigm because of their varying degrees of commitment to the paradigm. Whilst the systems literature covers all components of the system, the literature on the politics of expertise focuses on the relationship between policy makers, experts and the public and the literature on the philosophy of technology literature focuses on the relationship between the engineer and the engineering product.

This thesis will not only consider the social construction of technological knowledge but also the social construction of prediction and evaluation mechanisms. This is a problem which is pointed to in various recent studies but has not been sufficiently analysed is the question of how a technology is evaluated: what counts as "working", how problems are identified and recognised. These questions are all central to understanding technological change, whether it be the introduction of a new system or a new paradigm. Closely related to this is the question of prediction: how knowledge of a particular technology and how it will work is constructed. Whilst much work has been done on the social construction of scientific knowledge, little has been done on the social construction of technological knowledge, partly because technological knowledge does not purport to seek truth, only to produce products that "work".

In discussing the issue of the social construction of knowledge, I have made my own personal judgements about how Sydney's submarine ocean outfalls will "work" and drawn my own conclusions from the data presented in the various engineering reports. This poses difficulties for analysis, because I have been unable to remain detached from the debate. This problem, which all analysts must face, means that I have focused on and been more critical of the knowledge claims and predictions of government engineers more than those opposing them. Any resulting impression that government engineers or consultants are somehow perverting the practice of engineering or that different engineers in their position would have reached "the right conclusions" is unintentional. I am merely seeking to show the way engineering knowledge is purposefully shaped.

The role, rhetoric and action of all relevant social groups will be discussed, especially that of the public authorities, politicians, engineering employees, engineering societies, industry representatives, environmentalists, media and public protest groups. Rather than taking arguments at face value, I will be attempting to differentiate between actual goals and rhetorical justifications. The literature on the history and sociology of engineers is relevant here, as is the literature on the politics of expertise and public participation.

The next chapter, then, sets the scene in terms of developments in sanitary reform in Australia and abroad, and examines the values, goals and priorities behind the sanitary reform movement and the pressure for a public sewerage system.