Chapter 7

Time-frames and Design Decision-making

The previous chapter looked at technical innovation from the perspective of the resource implications of systemic and incremental approaches to design and development. Innovation can also be seen as a temporal trajectory representing diffusion from a point of origin to a wider population of adopters. Diffusion also takes place through the life cycle of a particular technology or across an entire industry based on a specific set of technologies. Time becomes a key component of the diffusion of innovation in the notion of early and late adopters of technologies. Plotting an S-curve of diffusion, the vertical axis is the percentage of a given population of users adopting the innovation, the horizontal axis is time[1].

For late adopters of a technology, or for economies or regions seeking to participate in an established industry, these ‘time-frames’ determine the freedom of action available and the points of entry and catch-up strategies that will best serve the development of capability and capacity.

‘Time-frames’ consist of a distinctive orientation to past, present and future, embedded in practice (Clark, 1982, 1997; Giddens, 1981) Clark argues that organisational sociology commonly utilises “time-free” constructs. Where time is considered, it is usually chronological time, which does not allow the recognition of time itself as a socially constructed organising device. Concurrently with the development of capitalism, clock time replaced earlier event-based time reckoning systems. Clark argues for a re-appraisal of the relative importance of the two frameworks. He points out that organisational literature contains longitudinal studies monitoring situations over time, time lags between social sectors and their effect on organisational change, the time-span of the discretion of individuals within an organisation (Jacques, 1957) and planning horizons as well as Taylorist conceptions of time-study. Clark sees the problematic nature of different “sorts of times” as central to the construction of a theory of time as a socially constructed device by which one set of events is used as a point of reference for understanding, anticipating and attempting to control other sets of events. Clark wishes to shift organisational sociology from a claim to be "over time" to be "in times". From such a perspective, time-frames are embedded in practices, and incorporate assumptions about past and future conditions.

Characteristic time-frames can be identified in relation to the design, development and deployment of technologies, the construction of systems, financial and governmental processes and resultant regulations. They may be entirely socially constructed as with government terms or fiscal periods, they may be largely imposed by a specific technology throughout the cycles of its constituent processes or development periods, or they may be derived from seasonal or natural cycles as with agricultural and related activities. Time-frames thus offer a linkage between macro-economic, sectoral levels (Utterback, 1976; Pavitt, 1980) and organisational and project levels (Buchanan and Boddy, 1983; Marschak et al, 1967).

An appreciation of time-frames allows insight into discrepancies between different time-frames and their effect on technical development and design decision-making. Time-frames operate within and beyond organisations and may impose inappropriate decision-making frameworks upon the lower levels of a system. In the context of design and project management the result can be a premature decision based on an immature understanding of a design problem, or supporting technology and ultimately, a design or systems failure. At the intra-organisational level these effects are likely to be perceived simply as part of a generalised environmental uncertainty. For a design to be robust in the sense drawn from Gardiner (1984) in Chapter 6, the development process must incorporate some understanding of such externalities. Time-frame difference, if recognised, may stimulate technical innovation.

Scott (1987a) recounts how organisational typologies have been constructed around differences in production technology (Woodward, 1965), variability in organisational inputs and outputs (Thompson, 1967) and types of technology in relation to uncertainty (Perrow, 1986). Indeed, the deployment of technology within a technical organisation can be seen as one means of reducing uncertainty at its operating core (Thompson, 1967). This perspective implies a resource-dependant view of environmental interaction. Buffering the organisation's technical core from external fluctuations becomes a major concern and time-frames offer an additional insight into these fluctuations.

Galbraith's book entitled "Organization Design" (Galbraith, 1977) examines strategies of organisational control in terms of the management of uncertainty through the development of information systems. Scott

(1987a) classifies this approach as a rational open systems perspective. Information systems support innovations at the design and production levels, such as computer-aided design and computer-integrated manufacture. As shown in Chapter 6, this class of information technology can be a means of restructuring time-frames at the product and design project levels. The development of CAD was initially supported in the nineteen-fifties by the United States Air Force, as a means of reducing uncertainty in the form of quality variation in aircraft components (Arnold and Senker, 1982). Marschak et al (1967) give an account of several measures to reduce both uncertainty and development time in military projects of that period. The source of their concern was the discrepancy between technical development and project development, and the consequent difficulties for design decision-making.

The work of Rogers (1983), while acknowledging an organisational context, focuses on an individual, entrepreneurial model of innovation. Individual designers, or designs, have likewise been central to many attempts to theorise design history. Rosenberg (1979) talks of the problem of the "heroic theory of invention" obscuring the cumulative impact of small improvements during the life cycle of an individual innovation. A time-frame perspective offers a means of locating the actions of individuals within a systems overview of the design and development process.

Rosenberg draws attention to the importance of technological interdependence in the appearance of successful and wide-ranging innovation. He argues that clustering of both economic and technical conditions precede successful innovations. Chapter 6 argued both for an understanding of the distinction between incremental and systemic innovation, and of their interrelationship. Incremental strategies allow the variation of significant sub-systems but a succession of such incremental alterations may result in unacknowledged systemic change.

Similarly it may be argued that time-frame discrepancies can produce systemic effects, the origin of which will not necessarily be recognised. The immediate concern here is with the potential of technical and non-technical dependencies to frustrate the delivery of appropriate technical designs and development policies.

Identifying Time-Frames

From a design perspective, the interaction of differing time-frames from several system levels can adversely affect project decision-making. Chapter 6 regarded the motive power policy pursued by British Railways from nationalisation in 1948 as a successful application of an incremental approach to an existing and well understood steam technology. This was not replicated with the newer internal combustion technology because financial pressures led to the abandonment of a pilot diesel evaluation scheme in favour of wholesale and premature construction of almost untried designs. Such premature decision-making is a common difficulty in long-term project management, and can be attributed to discrepancies between the time-frames governing the planning cycles operating at different levels.

A range of predictive techniques has been developed to reduce the uncertainty of long-cycle project and product planning. However, Collingridge (1982) suggests that planning for the development of systems involving extensive lags should be regarded as decision-making under ignorance, rather than uncertainty. He argues that, given the difficulties of long-term high technology projects, the best evaluation possible is rank ordering of alternatives on the basis of the cost of being wrong. He proposes a conservative strategy based not on the identification of the likeliest outcome, but on the route offering the lowest cost of subsequent alteration. His position is that inevitably, at some point in the future the decision will be seen to be wrong, and ultimately an alternative solution will have to be substituted.

Collingridge justifies this conservative strategy with the example of the lead time for large scale power generation. He sets the flexibility of a larger number of smaller units, with a relative diseconomy of scale, against the inflexibility of fewer larger units. This is in effect an argument for a choice of strategy based on time-frame characteristics. Such a strategy may be necessary with very large technical or social systems involving long development cycles, but in less extreme situations, other strategies are available.

However, even short-cycle design takes place in a context influenced by longer cycles at other levels. The design process will therefore be subject to some extent to uncertainty which can be reduced by being allocated to a number of distinct sources, rather than being merely aggregated.

Richard Scott's analysis of systems theory and its contribution to organisation theory allow an understanding of the levels at which time-frames can be seen to operate. Scott (1987a) presents a case for the division of the open system models into rational and natural variants, rather than posing rational, natural and open systems models as alternatives. Galbraith's (1977) view of information systems design as organisation design is placed within the rational systems framework by Scott. Galbraith's concern with task uncertainty and its control as determinants of organisational strategy, together with an orientation to information flows and channels within organisations, provides a context in which to consider communication between decision-making levels. He offers a framework for the consideration of the technical support of design and manufacture. Scott also places Thompson (1967) in the category of rational open systems. Thompson's concern with interdependence and its effect on the structuring of organisations provides an approach to the integrative problems created for design and innovation projects. Such a basis was used to examine the development of computer-aided design systems by one organisation over a period of some fifteen years (Little, 1988). Some aspects of this case-study are examined below.

Scott points out that the open systems approach implies an interactive relationship between organisation and environment. The natural system approach pays some regard to environment, but as a source of uncertainty, rather than as an arena in which uncertainty may be managed or reduced by adaptation or intervention. Natural selection is assumed to determine organisational survival over time.

There is a corresponding difference between a time-frame oriented approach and the concern with organisational lag shown by Mohr (1969), Aiken and Hage (1971) and Damanpour and Evan (1984). Time-frames imply cyclic interdependence, rather than the unidirectional diffusion of influence implicit in the notion of lag.

There is benefit to decision-makers in partitioning uncertainty between different levels by utilising a time-frames perspective. In a systems theoretic framework, each level in a system constitutes the environment for the units comprising the level below, and a rational open systems perspective implies an ability to either intervene in that environment, or to devise internal means of coping with its impact.

Waves, Cycles and Time-frames

Long-wave economic behaviour can be regarded as the meta-level of the cyclic behaviour influencing design decision-making and policy development. Attributed by Kondratiev (1925) to cycles of capital accumulation and interest rate changes, and by Schumpeter (1939) to clustering of technological innovation, it has influenced current discussion of the relationship between design, innovation and economic development (Freeman, 1983, 1986). Rosenberg and Frischtak (1986) examine the evidence both for the existence of cyclic behaviour, and for capital versus technology driven rationales. They argue that while the evident decline of one technology will increase interest in possible successors, the macro-economic environment can be seen to synchronise cyclical change across unrelated technologies, and that ultimately widespread technological change requires favourable macro-economic conditions.

However, long-waves themselves are not simply techno-economic phenomena. Perez (1986) attributes the recurrence of recessions to the differing rates of change of the techno-economic and the social and institutional sub-systems of the capitalist economy. The first is subject to rapid change, the second then has to become re-aligned. Downs and Mohr (1976), discussing a typology of innovation at the organisational level, differentiate between administrative and technical cycles. Both emphasise the same point: cultural and social cycles are longer than their increasingly short technological counterparts. The distinction between technical and social learning advanced by Sproull and Kiesler (1991) fits into this framework at the level of the individual technical project or intervention.

It is a truism to suggest that the time-scales of technological development are shifting from years to months. Kay (1983) argues that in such a situation the universe of the technically feasible will be larger than the economically feasible since the latter will be constrained by the social and institutional setting. This setting will depend upon the perception of a current “techno-economic paradigm” (Dosi, 1986) or “best technological common-sense (Perez, 1986). This perception will also vary between sectors of an economy. In the extreme conditions of military spending, high costs are accepted for apparently marginal improvements in performance[2]. Elsewhere a different balance of cost and return will be sought.

The role of technology in the determination of the course of an innovation reflects its position in the economic cycle (Perez, 1986) and the next chapter looks at the perceived uncertainty between frames within the organisations and sectors affected by the process in question. As a particular technology becomes better understood, the rate of return on capital invested in it falls. Further investment becomes necessary to restore the pre-eminence of the original innovators over those following (Freeman, 1983; Perez, 1986; Soete, 1986). This pattern is comparable to the life-cycle of an individual product developed within a particular technology.

Roy (1984) demonstrates the ability of a mature industry, bicycles, to counter falling returns with renewed product innovation. Suckling (1986) demonstrates the impact of the cessation of research and development activities by a company dominating its market to stress the need for continuous product development in order to maintain returns by the timely replacement of older products. Initially there is little impact on market share, but once decline sets in no amount of renewed investment can reduce the decade required for even modest recovery.

Cycles can be attributed to other, non-technical aspects of organisations, and these too can be characterised from a time-frame perspective. Organisational cultures can be seen to have life-cycles which must be considered in proposals for change (Boje et al, 1982), these in turn may reflect the time-frame of the careers of key actors or groups as in the Scottish Special Housing Association (SSHA) case study presented later in this chapter. An institution may find its technical resources being applied to greatly changed political and economic conditions as shown by Couto's narrative of the Tennessee Valley Authority presented below.

At the inter-organisational level time-frame differences may reflect core technologies (Thompson, 1967). Stinchcombe (1965) relates the character of organisations to the age of the industry in which they are found. A Schumpeterian approach would relate core technologies to historical periods. Donaldson (1985) relates organisational design to product life cycle and demonstrates a linkage over time between changes in product and organisational structure. The imposition of rigid accounting periods upon public undertakings by a government is an indirect means of external control.

At intra-organisational and technical levels cycles are reflected in coupling (Glassman, 1973; Weick, 1976; Perrow, 1984). Coupling in systems may be loose or tight. Weick (1976) defines loose coupling as implying that events are responsive, but that each retains its own identity, and some evidence of physical or logical separateness. Perrow regards coupling as a critical dimension governing the behaviour of complex systems. He argues that such systems exhibit tight coupling in conjunction with a high degree of complexity.

Chapter 6 suggested that the incremental alteration of a well understood system can take it into the realm of Perrow's "complex systems" (Perrow, 1984). Similarly, environmental change may alter the characteristics of its coupling. Perrow claims that complexity in conjunction with tight coupling must be avoided wherever possible; a time-frame perspective can be valuable in understanding critical temporal features of coupling.

As argued above, in the choices confronting designers, technical possibilities will outnumber economic ones (Kay, 1983). The acceptability and successful development of individual innovations, products or projects will depend upon the outcome of processes mediating between an innovating organisation and its socio-technical setting.

Time-Frame Taxonomies

One objective of the adoption of a time-frame orientation should be the development of a methodology allowing generalisation beyond the context of specific case-studies, but retaining the detail necessary to the guidance of individual projects which is so often lost in aggregated material.

Taxonomies could enable the construction of models of design and innovation processes which incorporate both the qualitative insights of case-studies and the analytical insights of quantitative data. Such models assist in the implementation of specific programmes of innovation, and in the analysis and development of design and innovation policy. An effective linkage of disaggregated data with a strategic perspective avoids both the methodological difficulties of the statistical approach, and the limitations of case-study data. The value in the broader development context would lie in the assignment of scarce resources to projects and strategies that could deliver quick and effective outcomes

Jones (1980) illustrates a hierarchy of system levels from component and product up to community level to suggest that designers need to be able to recognise interactions between levels when they occur. An examination of the effect of interacting time-frames on design and innovation decision-making requires a model of organisational context. The work of Thompson (1967) and Mintzberg (1979) allows consideration of the impact of changing technology on complex organisations. These are regarded as constituencies of interest groups forming coalitions reflecting internal conditions, including technology.

Thompson produces a typology of interdependence. Pooled interdependence allows independent action with overall co-ordination, sequential interdependence requires adjustment between components or parties according to the direction of the relationship and the flow of actions, and reciprocal interdependence requires mutual engagement and adjustment to achieve a satisfactory state or performance (Thompson, 1967 p.55). Time-frame discrepancies can be considered as one form of unrecognised interdependence, the effects of which are often attributed to an aggregated uncertainty.

This rational open systems approach can be supplemented by the work of Gouldner (1976), on the societal implications of dependence upon technology, and Giddens (1979), on the relationship between time, action and structure in social organisms. The consideration of the role of time in the structuring of organisational processes follows from this (Clark, 1982).

A general taxonomy of time-frames could assist in the analysis of the dynamics of globalisation. However, the dynamics of international markets and trans-national organisations described in Part I of this book suggest that a hierarchical distinction between government, market and organisation may be problematic.

Such a taxonomy could, however, differentiate between the time-frames existing within adopting organisations, the sectors and institutions affected, and those implicit in both new and supplanted technologies.

As discussed earlier, Collingridge (1982) gives guidance at one end of a spectrum in which technical development cycles are considerably longer than political time-frames: the construction of large-scale power generation facilities and Perez (1986) emphasises the importance of the disjuncture of institutional and technical change. The organisational context of design and development projects is subject to change at a rate greater than either.

Time-frames which are international in character can be seen to operate at the environmental level of natural cycles. For example, European beet sugar producers have a distinct advantage in competition with tropical cane sugar producers because they rely on an annual crop, whereas cane sugar requires two years to mature, and must be planted on the basis of a two rather that one year forecast of demand. Economic upswings and downswings are increasingly international in character and at the level of national and trans-national government, political and regulatory changes reflect electoral and other cycles. At the level of sectors or industries, markets move towards maturity and require strategies for differentiation. Design decisions at the level of organisations are influenced by accounting time-frames and product life-cycles.

Any taxonomy must distinguish between the effect of time-frames associated with core technologies and those existing in other sections of complex organisations. Identification and consideration of the differing time-frames of alternative technologies would indicate to what extent Collingridge's (1982) conservatism should be heeded.

A useful taxonomy should also relate the trajectory of particular innovations to their position in the economic cycle. This would allow examination of Rosenberg and Frischtak's (1986) suggestion that macro-economic conditions determine the impact of particular innovations, although they themselves regard a causal linkage between both economic and technical variables and economic long waves as essentially unproven.

The best illustration of the analytical value of a time-frame taxonomy, or at least a sensitivity to timer-frames is its application to some longitudinal case-study material. A most dramatic illustration of the potential use of time-frames in analysing the design of complex state-of-the-art technologies can be provided from published material on the Three Mile Island nuclear powerplant accident of 1979.

Longer term changes in organisational environment, and their effect on technology policy and design practice are illustrated by account of post-war changes in two organisations both of which were created to support economic and social development prior to the Second World War. These are: the Tennessee Valley Authority (TVA) as described by Couto (1988) and the Scottish Special Housing Association (SSHA) described by Little (1988).

Three Mile Island Nuclear Power Plant: Technical and Regulatory Time-frames

Perrow (1984) illustrates his term "normal accident" with a description of the sequence of events in the early morning of March 28th 1979, Stephens (1980) provides a wider description of the genesis and development of Unit 2 at the power station. Between them the two writers provide the following examples of time-frame dependent events at a succession of systems levels.

At an organisational level, Stephens (1980) describes the initial estimation that a single reactor would be sufficient at the Three Mile Island location. In 1967, when the design of what was to become Three Mile Island Unit 2 was completed, it was to be located alongside an existing reactor at Oyster Creek, New Jersey. When it was decided to relocate this unit, from a salt-water river to a fresh-water location, design changes were kept to a minimum because of the expense and delay of alteration and subsequent re-certification. Nevertheless, the delay meant that when the plant was commissioned, the design of the control room was already over ten years old. Another result of the change of location was that the two units at Three Mile Island had relatively little in common, being produced by different contractors, but staffed by the same operators.

Construction work did not begin until 1972, and there were considerable pressures on prompt completion. Stephens points out that, with mandatory overtime, completion was achieved, with power being supplied to the grid on 30th December 1978, some twenty five hours before the loss of between $37 and $48 million in tax depreciation and tax credits.

At the technical level, both Perrow and Stephens draw attention to design features intended to reduce down-time, by allowing the reactor to run through short transients which would cause rival designs to shut down automatically.

Perrow gives an extended account of the events of March 28th 1979, pointing out that although the first four critical failures in the accident took place within thirteen seconds, relevant information was queued in the computer for some hours before being printed out among a mass of other data. Perrow suggests that the realisation that the pilot operated relief valve on the reactor was jammed open came after two hours and twenty minutes and a shift change which brought fresh personnel on duty. This particular failure of understanding was a principal component of the accident.

The above account identifies a number of levels across which time-frames created discrepancies in decision-making frameworks. Difficulties in the forecasting of demand are a major concern of energy utility companies. They result from the time-frames implicit in the large scale plant deemed necessary for economic generation of electricity, and from the time-frames implicit in the discovery and development of new sources of energy.

Delays and consequent expense inherent in the certification process for nuclear power stations led to the adoption of an existing design, and the construction of a control room which was a decade behind current practice by the time it was commissioned. This situation was a product of both the long lead time of power station construction which concerns Collingridge (1982) and the requirement of regulatory bodies for early, detailed approval. The needs of regulation are often at odds with a design perspective, since they are geared to the requirements of checking and enforcement, not design decision-making[3]. Decisions on the commissioning of the nuclear plant were strongly influenced by the fiscal time-frames imposed by the U.S. taxation system. Concerns at this level commonly impinge on project decision-making, since financial viability can be considerably affected by accounting frameworks, or tax and investment incentives.

Certain design decisions which resulted in a plant with relatively unforgiving operating characteristics were influenced by the need to minimise down-time and thus safeguard profitability. At this level, the behaviour of the plant in time, and hence the time-frames imposed upon the operators, was itself the product of design decision-making.

Many of the features of the above situation are common to large complex systems, and have led Perrow (1984) to identify dimensions of complexity and coupling as critical to the understanding of their behaviour. Here it is argued that a full understanding of coupling must include a time-frames perspective. A systems perspective is essential to understand the implications of the counter-intuitive impact of the regulatory system, designed to safeguard safety, yet resulting in an obsolete control room design central to the propagation of a major accident.

The Tennessee Valley Authority: Institutional Time-Frames

Couto (1988) examines changes in post-war policies of the Tennessee Valley Authority (TVA) from the perspectives of Gouldner's "metaphysical pathos" (Gouldner, 1955). Selznick (1949) had analysed TVA policy in terms of co-optation of stakeholders into decision making as a means of survival in a potentially hostile environment, rather than an altruistic philosophy.

Couto examines the period following Selznick's study of the implementation of the original "New Deal" programme of economic and social development, and reports changes in policy emerging during the nineteen-fifties. He identifies unintended consequences reflecting priorities which placed economic development above the needs of the weaker sections of the community. These escalated to the point where the TVA reneged on its commitment to balanced regional development. Instead the Authority pursued a future as a large scale producer of cheap electricity. This led to intervention in the process of coal production in several coalfields, and involvement in the leading edge of technical development of both coal-fired and nuclear power generation.

By the time Selznick's study had been published, the TVA had completed the navigation system for the Tennessee River, and had embarked on its first coal-fired steam-generation power stations. Hydro-electricity had been developed in conjunction with flood control. Cheap and plentiful electricity had become synonymous with development. When it had utilised all potential for significant new hydro generation, the TVA turned to coal. In the ten years from 1949 to 1959 total capacity was tripled, so that hydro-generation provided only a minor proportion of output.

A change in political climate saw the defeat in Congress of proposals for a Missouri Valley Authority in 1948. A Democrat majority, from 1949 to 1952 allowed the TVA to embark upon a programme of seven steam-plants, totalling 8000 megawatts capacity. Each of the first three was in turn the world's largest plant incorporating the world's largest generating unit, each supplied a Federal defence establishment. The Shawnee Plant supplied the Atomic Energy commission at Paducah, the Kingston Plant the Atomic Energy Commission facilities at Oak Ridge, and the Widow's Creek Plant supplied the Redstone Arsenal. The TVA was now firmly located in the Cold War frame.

In the face of growing congressional opposition to the regional development component of its mission, the TVA emphasised the demands of its new customers as the basis of a national mission. Couto argues that a second national mission was rationalised around the role of the organisation as a yardstick of technical efficiency for private electricity producers. Both missions assumed a continued emphasis on low-cost power.

During the nineteen-fifties the TVA engaged in a variety of strategies to maintain or lower the cost of coal for its growing number of large steam-plants. These included both manipulation of an already depressed coal market and significant technical innovation.

Couto explains that the price of coal represented 80% of the operating cost of the steam plants. The TVA moved from long-term contracting, to an increasing reliance on spot-market buying. By utilising its own navigable waterways the TVA created price competition between physically distant coal fields, and between barge and rail transport. The design of its new plants allowed the use of lower quality coal than with previous technologies. Innovation in coal extraction was promoted, with capital supplied to companies prepared to tackle the new, large-scale strip-mining techniques favoured by the TVA.

Couto points out that the TVA had originally set the price of its hydro power below that of steam generated power, to stimulate the demand necessary for adequate economies of scale. In pursuing a large-scale steam-generation programme, the TVA contributed to the decline of employment in the Tennessee coalfields. The introduction of strip mining caused environmental damage by removing vegetation at high altitude, and contributed to a decline in water quality through run-off from the cleared land.

Following its policy of technical innovation as a stimulant of competition, the TVA became interested in nuclear power generation. The Price-Anderson Act had been passed in 1957, limiting the public liability of electric utilities for nuclear accidents, the TVA attempted to secure the AEC's support for a federally funded programme of reactor construction. The AEC, however, preferred a private enterprise route to a nuclear industry, at least for the domestic market (Pringle and Spigelman, 1982). In 1959 the Authority achieved a capacity for self-finance through bond issues and in 1966 GEC produced an acceptable fixed price bid to construct two 1000Mw units at Brown's Ferry, Alabama. Following the Three Mile Island accident, and an earlier near-disaster in its Brown's Ferry plant, the TVA ran into licensing problems with its nuclear plants. In 1984 work was suspended on the world's largest nuclear plant, at Huntsville, Alabama, comprising four pressurised water reactors. At that point the TVA was generating no electricity at all from a $13bn investment in nuclear plants. Although Brown's Ferry was eventually re-commissioned, by the end of the century five of seventeen reactors started by the TVA were operating, with eight cancelled after significant expenditure.

Couto is concerned with the impact of nationally derived policy at an economic periphery, and the effective subversion of an agency charged with the task of addressing regional inequities through economic development. A time-frames perspective can give a different view of the change of organisational objectives.

The policy of the TVA during the fifties was influenced by a coincidence of time-frames, with the exhaustion of hydro potential coinciding with a change in national political context. Boje et al (1982) cite the TVA of Selznick's period of observation as an organisation able to maintain and conceal political interests through the use of a myth of benevolence. As the power and effectiveness of this myth declined, an alternative was sought.

In pursuing a strategy of organisational survival, the TVA used technical innovation in conjunction with its geographical resources to develop complementary roles as a large-scale supplier of power to the military-industrial complex, and a public sector exemplar of efficient practice. This led to an expensive excursion into nuclear generation during the nineteen-sixties, justified in part by the environmental damage wrought by its own coal-fired policies of the nineteen-fifties.

The changes imposed on the original direction of the authority reflected the time-frames of national governments and economic cycles. Technical developments in coal combustion, steam generation and finally nuclear reactors were used to pursue ever greater economies of scale. These in turn involved the TVA with longer time-frames at a technical level, with consequent difficulties in responding to changes in forecast demand. This development was also conditioned by an essentially conservative, market oriented view which ignored many of the costs and dis-benefits that the TVA, as a regional development agency, was originally created to address.

Scottish Special Housing Association: Political and Technical time-frames

The Scottish Special Housing Association (SSHA) was established by the U.K. government in 1937 to assist the Commissioner for Special Areas in his task of relieving unemployment in the economically depressed regions of Scotland. It was established in the same decade, and with a similar remit of economic and social development as the TVA, although on a more modest scale.

For fifty years the organisation existed to provide technical support to local authorities through the construction and management of public sector housing. By the end of the nineteen-eighties however, changes in government policy, and the disposal of housing stock through a combination of sales to tenants and transfer to the voluntary housing sector had changed the character of the organisation. In its final incarnation as Scottish Homes, the organisation was absorbed by the Scottish Executive in 2002, following devolution and the re-establishment of a Scottish Parliament within the United Kingdom.

As a housing development organisation, SSHA made recourse to technical innovation at several points, and the locus of innovation has shifted across the range of activity, from methods of production towards those of management. Similarly, the focus of the exemplary activity by which the organisation influenced practice in public sector housing moved from production to management of existing stock, and then to the disposal of that stock, reflecting the changing concerns of central government.

The industrial provision of housing is a key distinction between developed and less developed economies. The poorest people on the planet house themselves, while for the richest housing is either a commodity provided by a highly organised industry, or a means of investment and wealth accumulation. The industrialisation of housing was part of the modernist agenda described in Chapter 3 and as a consequence highly inappropriate models of housing provision have been exported to developing countries.

The post-war activities of the SSHA as an organisation committed to the development and management of housing resources coincided with the creation and development of the Bretton Woods institutions. The provision of affordable housing for the industrial workforce is another facet of the "Fordist compromise" (Lipietz, 1992). The period in which the organisation was primarily engaged in the development and management of housing stock can be divided into three distinct phases which reflect changes in government policy and objectives which in turn transformed the environment of SSHA.

PERIOD I: Post-war Reconstruction: 1944-1960:

In 1944 the Association's remit was extended from the "special areas" identified as in special economic need to the whole of Scotland. Work began on the infrastructure required for the resumption of peace-time development. A technical policy of "laissez faire" allowed contractors to construct their own house types, or those provided by the SSHA around street and infrastructure layouts provided by SSHA engineers.

General conditions of materials shortage during this period led to frequent substitution of alternative materials during construction, with consequent difficulties in recording such variations. For example, a single development of houses might have begun construction using timber ground floors, switching to solid concrete floors part way through because of a lack of imported timber. Twenty years later such undocumented changes were causing problems for subsequent upgrades, such as the renewal of plumbing or the installation of central heating. This lack of detailed technical control was in marked contrast to the subsequent periods and reflected planning difficulties at a national level.

PERIOD II: Economic Expansion: 1961-1978

The second period emerged around 1960, by which time a concern with closer technical control of design standards had displaced the immediate post-war concern with output.

Closer technical control to ensure a higher quality product involved the development of rationalised procedures to maintain the necessary volume without requiring increased staff levels. The change from the previous preoccupation with numbers above other technical and social issues was associated with policy changes introduced by new staff in senior positions. This resulted in more detailed technical control of design and construction. The technical section was expanded beneath a single head and strengthened. Existing house types were re-designed and co-ordinated into "Suites", each intended to deal with particular site contingencies.

The introduction of mandatory "Parker Morris"[4] standards for space and facilities in public housing from 1966 provided added impetus for a thorough reappraisal of existing house plans. Technical support for staff was developed through the creation of a central library of technical details and a multi-disciplinary technical co-ordinating committee established, with building department representation, to evaluate policy through feedback from contracts and to assess proposed innovation.

A high degree of feedback to designers was possible because during this period the SSHA's own Building Department handled some 50% of the construction workload. Where external consultant designers were used their contribution was guided by the framework of the standard house type range, to which they frequently contributed designs, and by standardisation of specifications and details.

Computerised techniques were introduced during the sixties, when the rationalisation of quantity surveying procedures allowed computer production of Bills of Quantities which were the contract document specifying the quantities of material and the practices to be used in construction. The rate of change of statutory and technical requirements increased in this period. These all had to be incorporated into the large number of house types in use and computer assistance for this chore was investigated.

Development work commenced, under a series of contracts with the Edinburgh University Computer-aided Architectural Design unit (EdCAAD). However, the prospect of quantification from the information required for the production of drawings led to a more ambitious programme. The advantages of this integrated approach, deriving drawings, specifications and bills of quantities from the same database were considerable. Development was correspondingly more complex, however, and the consequent delay in this pioneering work resulted, in turn, in interim measures being necessary. Meanwhile, metrication of the building industry, completed in 1972, placed additional burdens on the existing manual system.

The division of drawn information into repetitive standard details and relatively simple key drawings for each house type subsequently became a feature of the CAAD system. Once the full system had been tested on a pilot project it was rapidly applied to a large number of contracts. A significant change was already imminent in the character of the Association's workload, however.

PERIOD III: Redevelopment Assistance: 1978-1986:

During the late 1970s both the size and character of the SSHA's workload underwent rapid change. With the increasing age of the post-war stock, capital resources were increasingly required for modernisation to current standards of amenity and performance to maintain its viability.

An increasing concern for the general condition of housing in inner-city areas led to the re-allocation of resources earmarked for Stonehouse New Town to the Glasgow Eastern Area Renewal programme in 1976. The Association became one of the participants in what was a precursor of "inner-city partnerships" elsewhere in the U.K. This period was also marked by the emergence of a more central concern for the 90,000 houses in the Association's management as a resource requiring improvement and development.

Much closer cost control, through the introduction of annual cash limits in 1976, meant that the relative priorities of projects had to be more carefully assessed, with some attention paid to the patterns of spending implied, as well as total expenditure.

In addition to inner city Glasgow, the Association's attention was specifically directed to a programme of redevelopment assistance for the other major Scottish cities. New construction projects were frequently concerned with redevelopment sites. These involved complex boundary constraints yet were only a fraction of the size of projects on “green field” sites of between two and three hundred dwellings to which the CAAD system had been tailored.

Consequently, the CAAD system could address only a proportion of new-build work, itself a declining proportion of capital expenditure. Further expenditure on the development of the system became difficult to justify. Although some work was carried out to assess the feasibility of using the system on comprehensive modernisation schemes, the design content of this work was also declining as a result of changing government policies.

As the computing industry as a whole became more mature, the development of sophisticated software for individual users was becoming prohibitively expensive in relation to increasingly available general commercial packages. The close relationship between SSHA and EdCAAD involved interchange of staff and refinement of the software at the Association. This restricted the general commercial appeal of the system, as with the British aircraft designs discussed in Chapter 6. The relatively uncommon hardware on which the system was mounted also frustrated attempts to support the cost of further development through income from sales.

SSHA involvement in the Glasgow Eastern Area Renewal programme led to the establishment of a multi-disciplinary regional office. This enjoyed considerable autonomy to allow the necessarily close liaison with the other statutory bodies involved. It became apparent that the existing management structure of the Association as a whole was in need of examination in the light of the reduced scale of development operations and the increased need to liaise with other bodies.

In 1982 the Association was reorganised as a matrix structure, with the existing functional divisions related to three geographical, multidisciplinary regional units, similar to the Glasgow office. The central technical services became available to Regional Managers while retaining responsibility for standards of professional performance of the technical staff at regional level. In effect the organisation was shifted away from the technical focus that had dominated the first two post-war periods.

The shifts in focus for the Association are equivalent in degree to those of the Tennessee Valley Authority, from a development focused organisation to a management focused organisation, from building housing to be rented and managed to building housing for sale alongside the disposal of existing housing stock. Finally, following devolution, the organisation was absorbed into the Scottish Executive in 2002.

The extensive change across the three major periods described shifted the focus of attention from the production methods used in the construction of housing, via the rationalisation of control over technical standards, to a concern with management information systems, and finally the co-ordination of the resources required to maintain this existing housing stock. This required a fundamental change in organisational culture.

Attention was first drawn to the problem of maintenance of existing stock relatively early in the development of CAAD techniques. Planned maintenance was being adopted, so that all property would be inspected on a five year cycle. Repairs and replacements would be conducted on the basis of the survey. This cyclic approach represented a considerable advance over the previous method of allocating an annual maintenance budget based on previous average expenditure. The increasing age of the post-war stock suggested that a form of active forward planning would be needed to predict peaks in expenditure as specific sub-systems (e.g. plumbing, electrical wiring) required renewal. Construction information would be required to identify the points at which such work would be necessary to maintain the viability of this stock. The information technology required to sustain such a system was not available when this requirement was first identified, and the quality of recorded information from the immediate post-war period was very variable.

This product life-cycle approach was obvious to organisations responsible for both the construction and management of building stock. Even so, the potential of the reuse of production information for the prediction of life-cycle expenditure could not be realised while priorities concerned the oldest, least well documented stock. The introduction of annual cash-limits ran counter to the requirements of a life-cycle approach, but annual priorities could at least be assigned with confidence.

The support of design computing by a mainframe machine used for normal financial computing and rent collection produced conflicts over resources during its development, both within and between departments. Government financial reporting requirements had to take precedence over refinement of the design facilities in the annual allocations of resources and this source of uncertainty and delay seriously compromised development. Time-frame discrepancies occurred on a monthly basis as payroll and rental processing adversely affected the performance of design software. The eventual phasing out of the mainframe machine in favour of a distributed net of minicomputers provided an opportunity for the co-ordination of computing activities and the development of multi-disciplinary management information systems for the new Regional Managers.

Making Sense of Time-Frames

The examination of the Three Mile Island accident offers a bottom-up identification of time-frame discrepancies. This serves to emphasise the significance of interaction between relatively remote levels. Unlike the other two cases, it focuses on a single project, and traces the origins of its failure to a variety of time-frames and discrepancies.

Nuclear power was just one of the technologies utilised by the Tennessee Valley Authority in its attempt to adjust to its changed environment. The redefinitions of organisational mission, identified by Couto, reflect political and economic changes stemming from the Second World War. The core technology of TVA was changing at the same time, here a coincidence of time-frames governing intra- and inter-organisational concerns assisted the substantial change in practice necessary to the change in mission. The life cycle of organisational myths proposed by Boje et al (1982) can be seen to be derived from changes in their explanatory power within the organisation and its environment. The case-studies suggest that such change reflect in turn national political time-frames

In the U.S. system, political time-frames are linked to a rigid schedule of elections, so the most regular feature underpinning Couto's account is the succession of changes at a national political level. The successive core technologies exhibit a degree of regularity, however, with overlapping frames of some twenty years each for the dominance of hydro, thermal and nuclear generation.

Just as the events at Three Mile Island can be viewed in the wider context of changes in the power industry, which also affected the TVA, changes in Scottish Special Housing Association policy can be related to post-war changes in the development and construction industry in the U.K. and elsewhere. Russell (1981) indicates a range of pressures behind the move to increase both industrialisation and capitalisation in the building industries of East and West in this period. The factory environment was seen as free from the natural, seasonal variation and disruption of the building site, in effect reducing seasonal time-frame dependence.

As noted in Chapter 3, the theoretical underpinning for designers and architects had been laid in the twenties and thirties, within the Modern Movement. The ideology was already available when economic and political conditions became favourable. To combine Boje et al's (1982) and Rosenberg and Frischtak's (1986) terms, the myth was in place, awaiting favourable macro-economic conditions.

The notion of cycles of organisational culture must be linked to the life-cycles of individual key actors. The consideration of dominant personalities reflects Rogers' (1995) concern with individual innovators. The tenure of two key individuals a chief technical office and a chief quantity surveyor coincides with the key period of technical development at SSHA. A coincidence of changing personalities and conditions enhances the prospect of organisational change. An additional dimension is created, however, through the career progression of other relatively junior actors to more senior positions. Such individuals may form a concealed constituency which could provide a revival, after time, of an earlier cultural orientation[5].

The SSHA's core technologies changed out of synchronisation with those environmental changes which led to re-assessment of the organisation's task. CAAD technology was not fully available within the duration of the conditions it was intended to address. Nevertheless, with further technical development, it was able to facilitate an appropriate change in organisational structure as the basis of a management information system. There is additional evidence, however, that by the time these changes had been accomplished, discrepancies between the internal and external labour markets were creating problems in staffing the new arrangements with appropriately skilled personnel.

In one sense the delay in CAAD development can be explained in terms of straightforward lag. However, the reorientation of the organisational mission of the SSHA around a life-cycle approach reflects an organisational assimilation of the time-frames operating at its technical core. The success of this reorientation reveals the difference between political and institutional change. While political conditions altered for all the case-studies within the time-frame of particular technical project and processes, institutional change, as discussed by Perez (1986) is a different matter. For example, in the nineteen-eighties accurate predictions of the UK's national health service building stock maintenance costs for the following decade became available as a by-product of computer aided design and related databases. These were of no interest at the national governmental level. The problems lay beyond more than one election, and there was no perceived institutional need to plan that far ahead. By the turn of the century, the predicted backlog of maintenance was being tackled by a combination of massive reduction in long-term care facilities and the increasing use of use of controversial private finance initiatives.

Time-Frames and Development

The cases presented above provide a range of examples of levels at which differing time-frames can be seen to impact on technical innovation and design policy. The lags and interactions described, and the strategies promoted by Collingridge and others are relevant to large top-down development projects typified by large scale dam construction. Such projects lock up resources over a long period and represent significant opportunity costs to economies with limited resources. The development of local initiatives and the availability and diffusion of appropriate technologies is also subject to these dynamics.

Innovation policies or specific programmes of innovative design would benefit from an understanding of the dependence of the trajectory of a particular innovation upon its position in the economic cycle. Similarly, both technology transfer and development strategies could benefit from sensitivity to the range of relevant time-frames

A time-frame approach can assist both theoretical examination of the spatial and temporal aspects of diffusion of innovation and technology, and the implementation of programmes of innovation in complex organisational circumstances. Understanding of the differential between the time-frames existing within adopting organisations, the sectors and institutions affected and those implicit in a technology implies a taxonomy of levels linked to an open systems model.

Just as Perrow (1984) characterises complex systems on two dimensions: low and high complexity and loose and tight coupling, so time-frames might be usefully characterised by plotting them against the dimensions of length of cycle and inter/intra organisational origin. Short, inter-organisational time-frames would contribute to a turbulent organisational environment (Scott, 1987a, Galbraith, 1977). Long intra-organisational time-frames can be argued to contribute to organisational inertia as examined by Hannan and Freeman (1984).

The environmental context of many developing countries includes extremes of climate and the consequent loss of working time. Equally productivity may suffer from seasonal problems of health, particularly in areas where malaria in endemic. The cultural practices that develop in such environments differ from those prevalent in the developed economies, and add a further dimension. Nicholson and Sahay (2001) describe frictions between the work practices of collaborating information technology specialists based in India and the U.K. Significant misunderstanding was attributed to different expectations over the timing and priority given to work tasks.

These broader organisational dynamics and their influence on design cultures and the determination of design outcomes are dealt with in the remaining chapters. Chapter 8 opens this wider consideration with an argument for the notion of “metatechnical” frameworks of understanding.

Notes

1 Rogers (1962, 1983) provides perhaps the best known overview and explanation of the origins and development of this work.
2 Chapters 8 and 9 will provide further illustrations and discussion.
3 Lawson (1982) gives an account of the impact of such thinking on architectural design processes.
4 See Chapter 3 for a more extensive discussion of the standard and its implications.
5 See Little (1988) for an extended treatment of these issues.