Systems Dynamics Modelling within British Telecommunications

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System Dynamics Modelling within the British Telecomunications Business

by

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0. Executive Summary

0.1 Overview

System dynamics modelling has been used in the formulation and implementation of strategic planning models for nearly five years within the Long Range and Strategic Studies Division of the British Telecommunications Business. This modelling has proceeded in close collaboration with the Department of Control and Management Systems of Cambridge University. The Business itself is a public corporation which means that despite a certain degree of autonomy, it is still ultimately dependent upon the Government for approval of its investment plans and also its investment capital.

It was decided in 1976 that with the rapid changes in the telecommunications marketplace, which have since led to a new Telecommunications Bill, it was essential to have a dynamic computer-based representation of the corporation. Such a model was developed using the methodologies of system dynamics which became operational early in 1978. This corporate model has been actively used for over three years during which time several thousand computer runs have been conducted under a range of policy assumptions. More recently we have developed a strategic control unit which allows us to track a set of objectives placed on key business indicators. In addition, the control unit is frequently used to evaluate the response of the business to selected crises in which the corporate objectives are usually those of the base projection. Thus we are able to design both a desirable and robust corporate future which can act as the basis for more detailed studies.

The corporate model is now run on an intelligent graphics terminal linked to a main-frame IBM 3033 over the switched telephone network. A central theme of this paper is that of interfaces in which we emphasise the importance of creating a 'user friendly' interface if the manager is not to be alienated by computer models. During the last six months in which the colour graphics interface has become operational, we have found far wider acceptance of the model through numerous successful 'live' demonstrations to senior managers.

The success of the corporate model (commonly referred to as the Long Range Planning Model or LRPM) led us to take the Marketing Module as the starting point of a new research project. This new model is known as the Integrated Communications Demand Model (ICDM) in which we have now completed the development of the conceptual framework and its implementation in FORTRAN using the same colour display

package. We are currently devoting most of our effort to 'tuning' up the ICDM to produce an acceptable base projection for future market studies. The demand model includes the demand for all communications media in which the focus is upon the possible substitution of physical media such as transportation and postal systems by electronic media.

0.2 Interfaces.

An important role for any model is that it creates a unified language in which to discuss issues which cut across a multitude of operational boundaries. When development was started upon the LRPM, many managers expressed extreme scepticism as to whether it was feasible to represent the entire corporation within a single model. However, now that this aim has been achieved, we find that we have the active participation of the operational managers in our new Integrated Demand Model which covers a rather smaller domain of the corporate dynamics.

We must note that the LRPM is a comparatively large dynamic model occupying around 6,000 lines of FORTRAN code, despite a 'compact representation'. There are around 300 policy levers available to the analyst which lead to around 200 output variables which can be plotted over a planning horizon of 30 years. It is certainly a challenging exercise to structure the input/output interface of the computer package to create a coherent display which allows the rapid comparison of alternative corporate futures under a range of policy assumptions. We have found colour graphics linked with a command menu pad to be more than adequate for this task, although we are still attempting to realise the full potential of such an interface. The only drawback is that high resolution graphics imply a degree of precision which it is actually not possible to achieve using an aggregate corporate model, but we find this is easily overcome by displaying bar charts rather than lines.

We currently view dynamic models as an intelligent form of database which can be downloaded from a main-frame as telesoftware, rather than as isolated research tools. Thus we have a small videotex database directly integrated into the computer package which includes colour 'help' pages as well as systems diagrams which can be slotted into live presentations to management. In addition we can rapidly set up pages displaying the policy assumptions and conclusions of studies which are sandwiched with the computer simulations themselves in order to reinforce our recommendations to the decision makers.

The full paper develops the themes outlined in each of these paragraphs in order to show that we can only expect a system dynamics modelling project to be successful if we accept the challenge of creating appropriate interfaces. Many problems still remain without solution but we feel that nearly five years of modelling experience in a public corporation enables us to explore many aspects of model implementation with sufficient confidence that we feel our conclusions merit a wider audience.

0.3 Conceptual Framework.

We spent nearly 50% of the development time for the corporate model on the conceptual framework which eventually led to the detailed structure of the subroutines. We explored the corporation from numerous different viewpoints making use of relevant business statistics togther with the extensive literature on general systems theory. In particular we emphasised the notion of the corporation as an evolving system in a dynamic and uncertain environment in which we should be prepared for large scale structural changes in addition to local parameter fluctuations. This led to the concept of a strategic control unit which is able to respond to imposed corporate shocks, which would otherwise lead to potential corporate disaster in the absence of any mechanism of adaptation.

Although the model structure was initially drawn up using the traditional system dynamics terminology, we found that this was largely not understood by operational management. So in order to 'market' our ideas we produced a simplified cyclic structure in order to convey the concept of the corporate model generating its own future guided by the chosen policy assumptions. Over a period of several months, the model structure was continually refined in which the main problem was in keeping the number of policy parameters and the dimensions of the model to a manageable size.

In writing reports for management or giving presentations, we are wary of leaning too heavily on mathematical or computer oriented concepts since they immediately create a modelling mystique. Instead we attempt to relate to the 'language of the decision maker' in which we are now aided to a large extent by the production of high quality colour graphics which would appear to destroy, to a certain extent, the mystique of modelling. We now try to convey the idea that dynamic models should be viewed merely as alternative forms of information and subsequent insight rather than as the corporate 'oracle' which necessarily represents any absolute truth.

This has bearings on the theme of model validation in which we have 'tuned' the aggregate corporate model to the more detailed forecasts produced by econometric and time-series models. These often go back twenty years into the past using relevant historical data and are developed within other analytical support units within the corporation. However, for the period ten to thirty years ahead there are no forecasts on which any absolute reliance can be placed. So we make use of the best available estimates of parameters which can be achieved through long term market research, literature searches, and liaison with colleagues in the research and development functions of the Business.

0.4 The Corporate Model in Use.

The corporate model is generally used to investigate strategic issues at the policy level in which a question will be passed down for analysis from senior management. We must first 'translate' this question into the 'language' of the policy levers incorporated within the modules before proceeding to set up a simple framework for the investigation of a number of scenarios. We will frequently conduct up to around 50 simulations when analysing a particular issue before attempting to draft a set of recommendations for management. The task of translating the results from the model back up to the language of the decision maker is usually far from straight-forward and will in general require a certain amount of judgment based on the experience of previous policy investigations.

We sometimes find that strategic issues arising within other operational executives such as marketing or personnel, require us to produce a 'finer tuning' of the model to shorter term forecasts. In these cases we may add further policy parameters or possibly a new subroutine for 'cosmetic' reasons. In general the insights gained from the greater disaggregation are akin to those obtained from the original model. However, we should not underestimate the importance of such amendments in allowing the modeller to relate more closely to the language of the operational manager and, in doing so, increase his confidence in the model of his domain of responsibility.

We have found that it takes several years to implement a dynamic corporate model which means that it is vital that the conceptual framework is fully thought out during the initial development phase. At British Telecom we spent nearly 9 months working on this framework before embarking on the computer program. We have recently repeated this procedure for the Integrated Communications Demand Model in which the resulting framework has already been of considerable benefit in providing a unified approach to work on new services.

This paper treats system dynamic modelling from the viewpoint of an active practitioner in a large public corporation employing around 250,000 staff and with assets totalling around £14,000 million. Clearly policy decisions in such an environment will have consequences for the nation as a whole as well as for the corporation itself, so insights gained through modelling can be of great value to the community. The close collaboration between the Long Range Studies Division of British Telecom and Cambridge University is certainly an important feature of our path to model formulation and successful implementation. Such a relationship allows us to rapidly exploit innovations in academic thinking within the modelling community so that our tools represent the state-of-the-art.

Note: The views expressed in this paper are those of the author and are not necessarily shared by British Telecom.

1. The Long Range Planning Model (LRPM).

1.1 An Overview of the Framework.

Over recent years, technological and political developments have been causing considerable changes in the operations of telecommunications administrations. This prompted British Telecommunications (then Post Office Telecommunications) in 1976 to commission the development of a Long Range Planning Model (Refs 1,3). The requirement was for a dynamic model that combined all aspects of the Business, that could operate under a wide range of assumptions in order to allow the analysis of the effects of various strategic issues on the corporation as a whole. An outline of the developments in systems dynamics modelling within British Telecom since 1976 is roughly as follows:-

1977 - Long Range Planning Model (LRPM) developed under contract by the Cambridge University, Management Systems Research Unit.

1978 - The LRPM becomes operational and is used to analyse "Alternative Corporate Futures".

1979 - A strategic control unit is developed for tracking corporate objectives and for the study of crisis.

1980 - Research commenced on an Integrated Communications Demand Model (ICDM) at Cambridge University, and a colour graphics interface is implemented for the LRPM.

1981 - The ICDM becomes operational as a tool for the exploration of marketing strategies for new services in a competitive marketplace.

The conceptual framework (figure 1A) is split into four key modules: "Marketing (Demand/Supply)","Technology (Equipment)" "Personnel", and "Finance". The outline structure of the model is essentially cyclic in nature (figure 1B) and the full computer package, including the user interface amounts to some 90 FORTRAN subroutines and over 6000 lines of code.

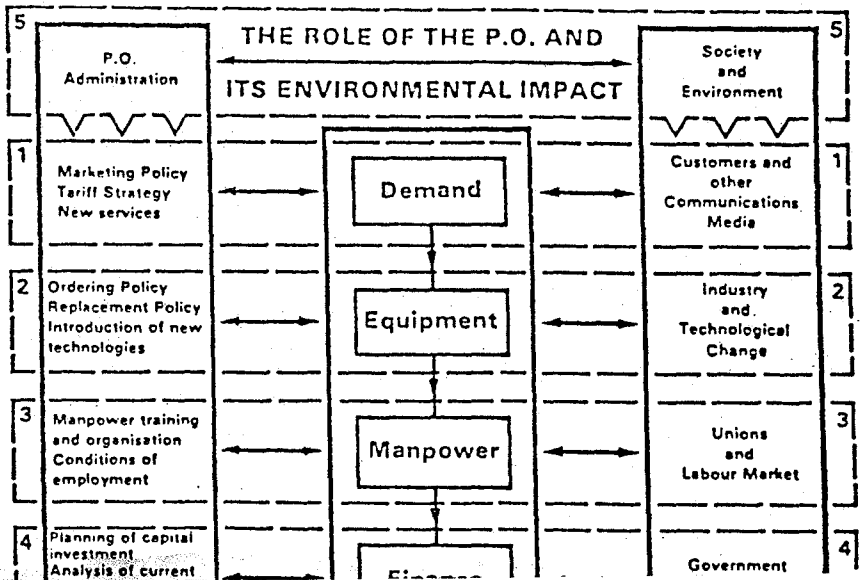
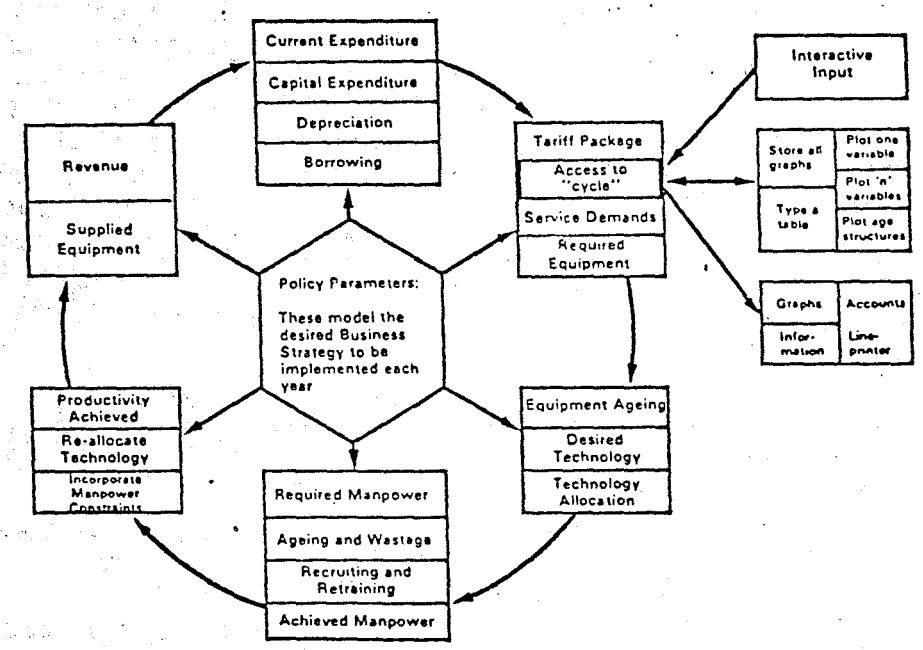


Figure 1A

The Conceptual Framework.

The core dynamic model itself takes up around 50% of this total package, whilst the major part of the user interface can be "hooked" onto other dynamic models such as the ICDM. We shall now proceed to discuss the nature of the four operational modules.

Figure 18 **THE CYCLIC STRUCTURE IN MORE DETAIL**



a) The Marketing Module - Demand/Supply for BT Services.

This models the aggregate demand/supply for telephony, data and wideband services together with traffic volumes split into local, trunk and international calls. Tariff/demand elasticities are used in the usual econometric sense to take into account the details of changing tariff structures. Competition for terminals and traffic is taken into account through allowing a diffusion of customers between suppliers according to a weighting of tariff relativities and an aggregate coefficient representing service attractiveness.

b) The Technology Module - Provision of Equipment.

This models the dynamics within the entire corporate base of capital assets split between terminals, local and trunk transmission networks together with switching equipment. The required new equipment volumes are assigned to desired technologies but may have to be re-allocated if manpower skills are found by the LRPM to be inadequate in certain sectors. Thus we are able to explore the impact of resource requirements under alternative rates of introducing optical fibres and digital exchanges within the BT network modernisation program.

c) The Personnel Module - Manpower Skill Requirements.

The manpower skills map onto the ten equipment categories but are split also between construction and maintenance for each technology. A particular feature of this module is a

retraining matrix which specifies whether it is deemed permissible to retrain between particular skills. Clearly constraints may lead to a mis-match between achieved and desired skill levels which in turn would lead to constraints on equipment provisioning. Policy parameters are used to explore recruitment, wastage, retirements and possible redundancies under a range of construction and maintenance productivity trends over the next 30 years. In addition we can study the impact of competition on skill requirements and also of changes in the length of the working week.

d) The Finance Module - Capital and Current Accounts.

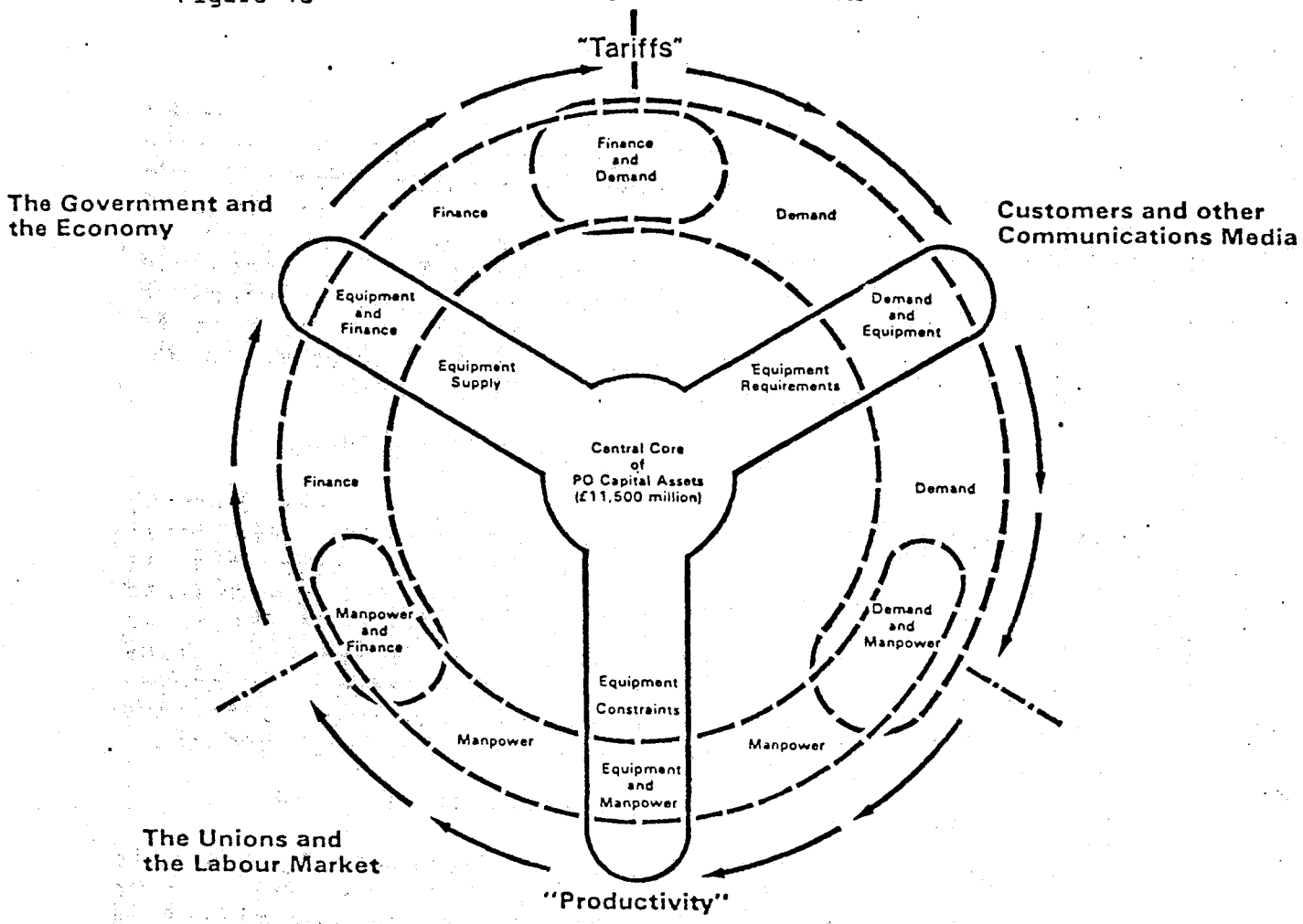
This provides comprehensive details of current and capital account expenditures, together with the standard financial indicators. In addition, the Newton-Rapheson algorithm is used to produce a tariff package which achieves the desired financial targets on either profits or real rate of return on assets, as set by the British Government. Particular policy domains of interest are those of depreciation strategy, determination of borrowing requirements, equipment lifetimes and unit costs, and assumptions concerning economic growth.

1.2 The Exploration of Alternative Corporate Futures.

There are around 300 policy paramters available to the user which are split almost equally between the above four operational modules. Sets of these parameters are stored as named corporate scenarios of which the most frequently used is the standard projection. The analyst will select a scenario and probably alter up to 10 policy parameters relevant to the strategic issue under study. The LRPM is then run for 30 years in order for the analyst to compare the relative merits of the chosen policy. The analyst will then repeat this procedure several times with different policy settings in order to develop into the range of feasible Business respones to the issue. Occasionally new strategic issues are encountered which require us to add additional policy parameters to an operational module. This will involve us either in defining existing internal variables as policy variables or else in modelling certain corporate dynamics in greater detail using additional subroutines. We have so far encountered no significant difficulties in expanding the LRPM in this way since its modular structure gives us the required degree of flexibility.

Of possibly greatest interest is the relationship between the dynamics within each of the four operational modules since the LRPM is currently the only model in the Business which puts such a spectrum of policy options within the grasp of the strategic analyst. In figure 1C we display the six binary interactions between the modules as an abstract "corporate wheel". We find that it is frequently useful to decompose a strategic issue which embraces all four modules into these component binary interactions. We are then able to build up our insights by first exploring the more intuitive dynamics of corporate activity and then proceeding onto the more complex higher order module interactions.

Figure 1C - "THE CORPORATE WHEEL"



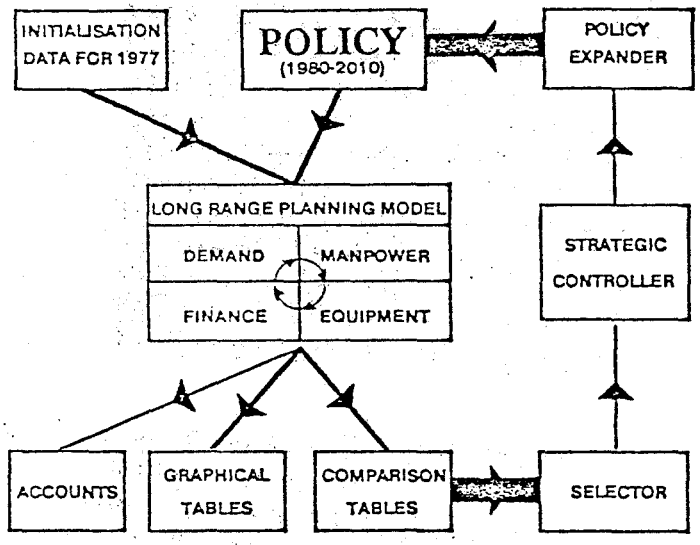


Figure 2A - The Relationship between the LRPM and the Strategic Control Unit.

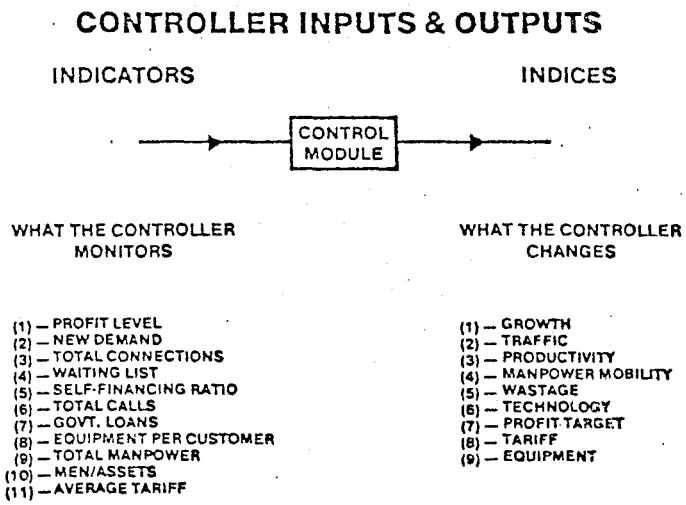


Figure 2B - The Control Unit

2. Control Mechanisms.

2.1 Overview.

In this section we shall describe how the LRPM has been enhanced to allow us to explore the implications of corporate crisis. The framework we have developed is quite general and could be of value in other domains of modelling. The strategic control unit was developed initially in order to reduce the number of simulations required to achieve both a desirable and feasible future for the corporation. However, since the controller was implemented, we have used it mainly to gain insight into the mechanism of corporate crisis and possible plans for recovery. This leads us to ask how we can incorporate additional intelligence into system dynamics models or if indeed this is even a worthwhile exercise. We shall pursue this theme more fully in section 5.

2.2 User Interfaces for Policy Analysis.

There are four modes of policy input in the LRPM Package which we shall now discuss in turn:-

2.2.1. Policy Parameter Interface.

This allows us to display and change any one of around 300 detailed policy parameters which fall within the the four modules already discussed in section 1. We can store up to 20 sets of such variables as individually named corporate scenarios which will include a base projection tuned to current British Telecom plans.

2.2.2. Policy Lever Interface.

In order to simplify the task of performing an initial policy analysis we have defined 11 "macro policy levers" each of which is an aggregation of up to around 25 of the micro policy parameters. Thus, for example, the technology lever allows us to speed up or slow down all modernisation of the networks and also the terminal devices themselves.

2.2.3. Control Interface.

The strategic control unit allows us to place objectives on any of 13 key indicators of corporate performance (Ref 2). A non-linear transformation of the error function is then calculated and applied to the macro policy levers in order to reduce the departure from the desired performance targets. The interaction between the LRPM and its associated control unit is depicted in figure 2A, whilst the control inputs and outputs are summarised in figure 2B.

2.2.4. Spike Settings.

In order to model the impact of discontinuous changes of policy upon the Business we have the facility of entering abrupt changes on any of the policy parameters or policy levers for some fixed duration. Such spike settings may represent some degree of crisis within particular domains of

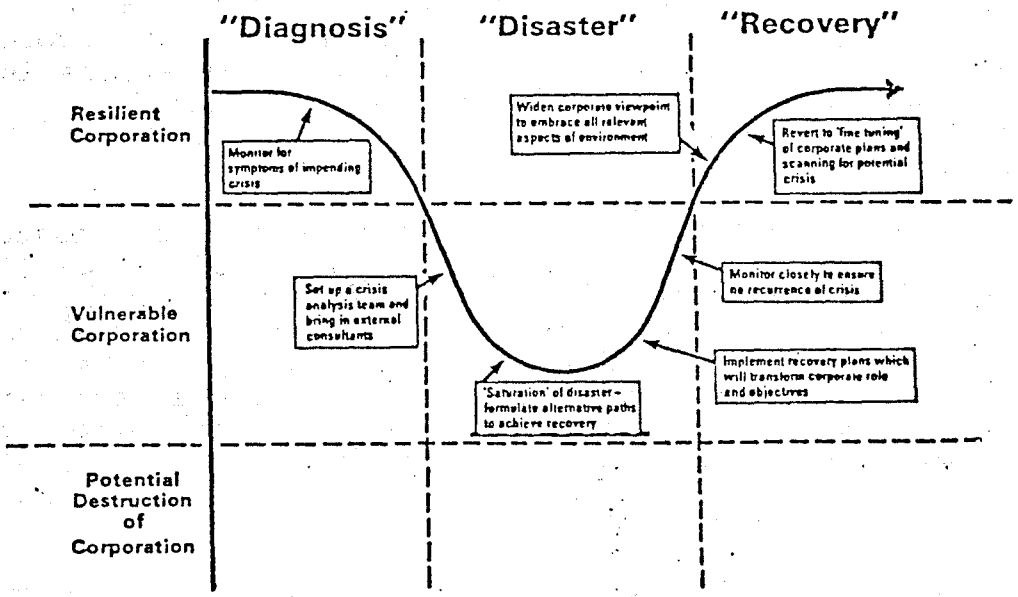
corporate activity or possibly a switch in government policy. Such spikes are also clearly of use in allowing us to get a better fit of the model to historic data, without having to incorporate too many additional dynamic relationships.

2.3 The Analysis of Potential Corporate Disaster.

2.3.1. Phases of Disaster.

We shall now explore the conceptual framework which we have developed for the study of crisis. A crisis is not normally the result of a fluctuation in a single parameter, which may itself be diagnosed and corrected. It is more likely to be an advancing front of a number of unhealthy fluctuations which together generate a disaster when the frontier exceeds some threshold strength. So even though it may appear that a disaster, such as a volcanic eruption, almost instantaneously achieves its major impact, there will always be some build-up of pressure along a number of dimensions which we hope will act as our early warning signals.

Society is currently undergoing a major transformation in which all existing industrial corporations will continue to be severely challenged over the next two decades. This process appears to have properties more akin to the transition from an agricultural to industrial society than that of the traditional 5 and 50 year cycles in industrial production. The emergence of an information society will create major structural upheavals for British Telecom in which large scale perturbations from base-line projections are to be expected, some of which may be potentially disastrous. In addition, we should note that the duration of corporate disasters is, in general, measured in years rather than months so that the analysis of corporate robustness should lie at the core rather than at the periphery of our strategic thinking.



THE PHASES OF DISASTER - Figure 2C

We first examine the emergence of disaster in which we split the complete disaster cycle depicted in figure 2C into three main phases: "Diagnosis", "Disaster" and "Recovery". The LRPM allows us to simulate the diffusion of crisis, starting with local unhealthy fluctuations which may potentially diffuse and span all corporate activities, if the core problems remained undiagnosed. We also introduce the ideas of corporate resilience and vulnerability which also play an important role within our framework. So we begin by describing the effects to be observed within each phase of disaster together with the nature of corporate activity -

a) "Diagnosis". The business is assumed to remain within this phase so long as it is resilient to applied shocks such as strikes, cash limits, loss of market share and equipment supply delays. Resilience will in general require British Telecom (BT) to remain flexible so that adaptation, with a refomulation of corporate objectives is always possible. Any mild crisis should be monitored closely in case it becomes entrenched with risk of potential disaster. However, BT's planning viewpoint should be wide in this phase encompassing all relevant components of the external environment. BT currently seems to fall within the category labelled "creative resilience" in figure 2D in which large scale transformations of organisational structure are being implemented.

b) "Disaster". If all strategies fail then we enter the zone of vulnerability in which the Business would certainly set up a dedicated crisis analysis team as well as calling in external consultants. The corporate viewpoint will decrease in range within this phase for it may well be the very survival of the Business which is at stake. The principal corporate objective is here to achieve recovery through formulating a number of possible survival plans using the LRPM to explore the implications of alternative options. It is important that the Business does not become overcommitted to a single recovery policy since a relapse with complications has been observed in many of the dynamic LRPM simulations.

c) "Recovery". As soon as the Business enters the zone of resilience it is once again expected to be able to adapt to mild crises and also to open up its corporate scanning activities to embrace most environmental sectors. However, this is also a period of convalescence to allow the numerous corporate activities to lock back into phase after the major structural transformations. It is likely that the Business now has a rather different role in the telecommunications arena so that time is required for both the internal and external corporate interactions to crystallise as new economic and political interfaces. Now at the end of the "disaster cycle" the Business is once again scanning for further potential crisis which constitutes normal corporate operation.

In figure 2E we summarise the modes of corporate resilience and vulnerability together with the objectives under each regime and the role of dynamic computer models. Figures 2F and 2G show the results of a typical LRPM crisis simulation

RESILIENCE AND VULNERABILITY

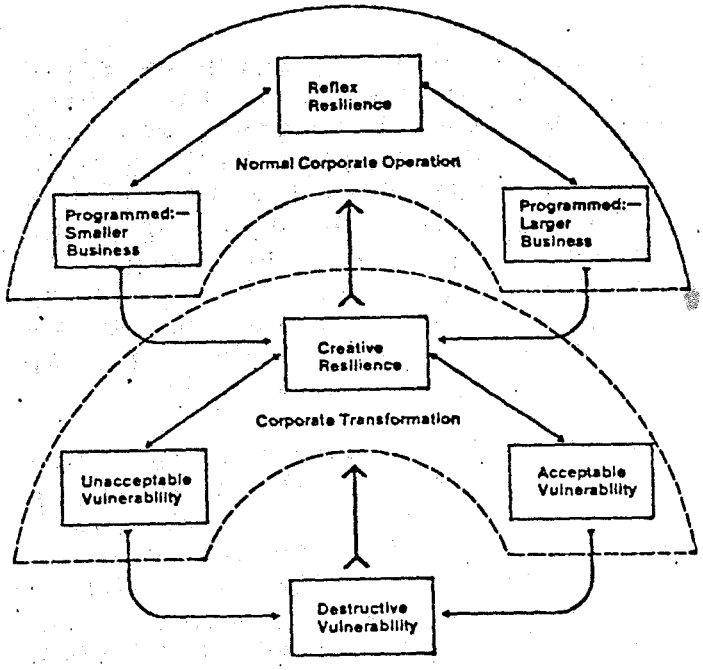


Fig 2E The Modes of Corporate Resilience and Vulnerability.

Mode	Corporate Objectives	Role of Model
1 Reflex Resilience	Achieve Targets	Sensitivity T‹
2 Programmed Resilience	Achieve Alternative Targets	Robustness Analysis
3 Creative Resilience	Diversify and Compete	Design
4 Acceptable Vulnerability	Maintain Market Shares	Increase Market Shares
5 Unacceptable Vulnerability	Quality of Survival	Policy for Recovery
6 Destructive Vulnerability	Survival	Avoid Corporate Decay and Collapse

Fig 2F **NO CRISIS — NO CONTROL**

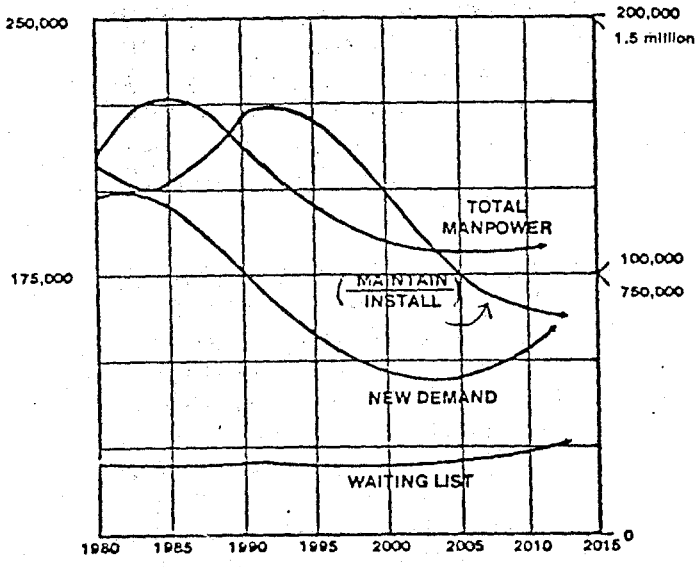
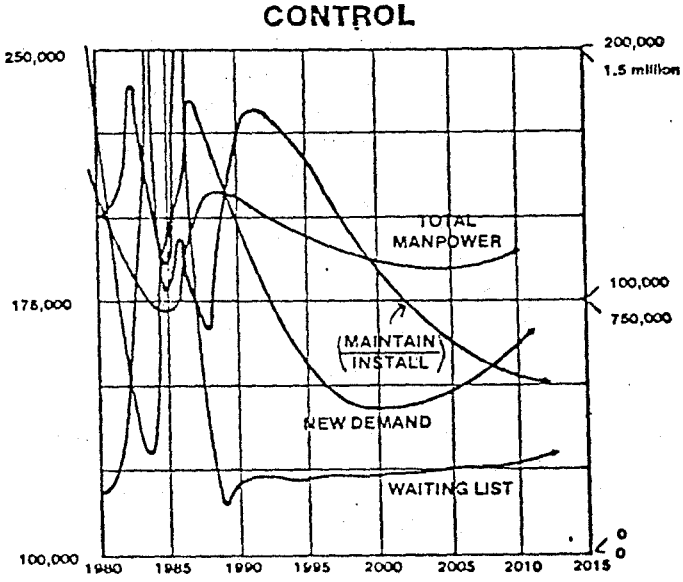


Fig 2G **SEVERE CRISIS WITH SUBSEQUENT CONTROL**



These results do not constitute real forecasts nor do they represent BT policy.

in which the strategic control unit formulates a successful path to full recovery, according to a ranked set of corporate objectives set by the user.

2.3.2. Possible Paths to Disaster.

In figure 2H we show in outline several possible paths to disaster which have all been explored in some detail using the LRPM strategic control unit. These scenarios are given as examples which demonstrate the use of the methodology and are in no way intended to reflect official BT policy.

a) Base Projection - This corporate future is "tuned" to the 1981/1991 Business Plan, and from 1991 onwards we use the best policy information and long term forecasts available.

b) Optimistic Corporate Future - This acts as an optimistic base-line with rapid network modernisation and expansion into new market sectors. However, we note that this entails a decreased resilience during the 1980's due to the additional capital requirements and risk on entering new markets.

c) Pessimistic Corporate Future - This acts as a pessimistic base-line with slow network modernisation and an emphasis on existing services rather than embarking on new ventures.

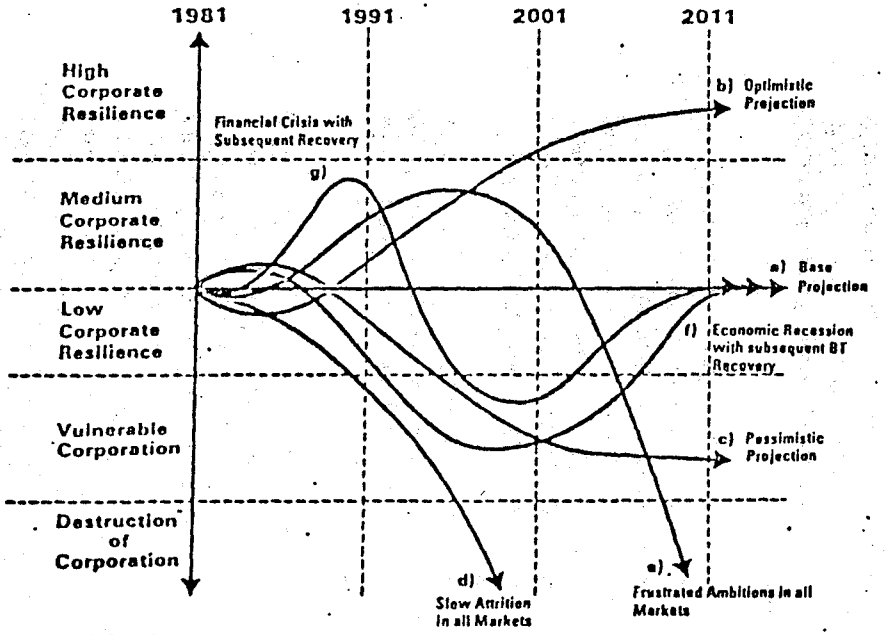
d) Slow Attrition in all Markets - This scenario is utterly disasterous in which LRPM simulations indicate that recovery rapidly becomes more difficult as our market share declines.

e) Frustrated Ambitions in New Markets - Here the Business implements marketing plans in new sectors but encounters fierce competition which could, for example, flood the market with even cheaper products and services.

f) Economic Recession with subsequent corporate Recovery - The corporate objectives are those of the Base Projection but these are frustrated by a severely depressed economy. This in turn leads to decreased company profits, union turbulence and decreased demand for both existing and new services, resulting from a drop in real disposable income. This scenario is similar in nature to that depicted in figure 2G.

g) Financial Crisis with subsequent Recovery - In this corporate future the Business expands into new services too rapidly leading to the classic cash flow crisis as experienced by many new commercial ventures.

The formulation of contingency plans as "follow-up" to potential crises should constitute an important part of our strategic planning activity for a corporation can only rarely be expected to follow some narrowly defined trajectory. If we merely define "good" Business Plans as an integration of responses to strategic issues without taking account of their robustness then the Business is "walking on a tightrope" of potential instability. The concepts outlined in this section have allowed us to place more emphasis on the production of robust responses to strategic issues, including a full dynamic stability analysis of the resulting integrated Business Plan.



PATHS TO DISASTER – Figure 2H

Figure 3A COLOUR GRAPHICS WORK STATION

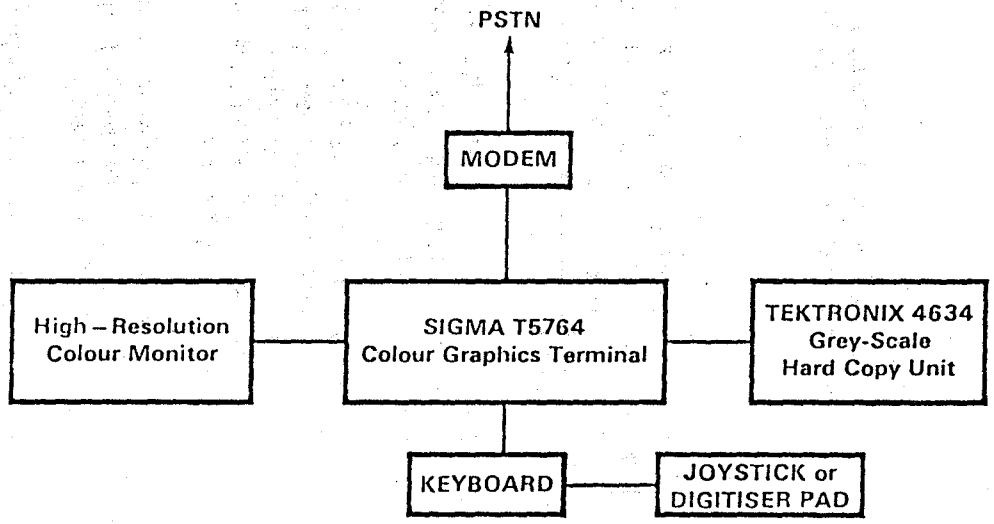


Figure 3C LRPM BASIC COMMANDS

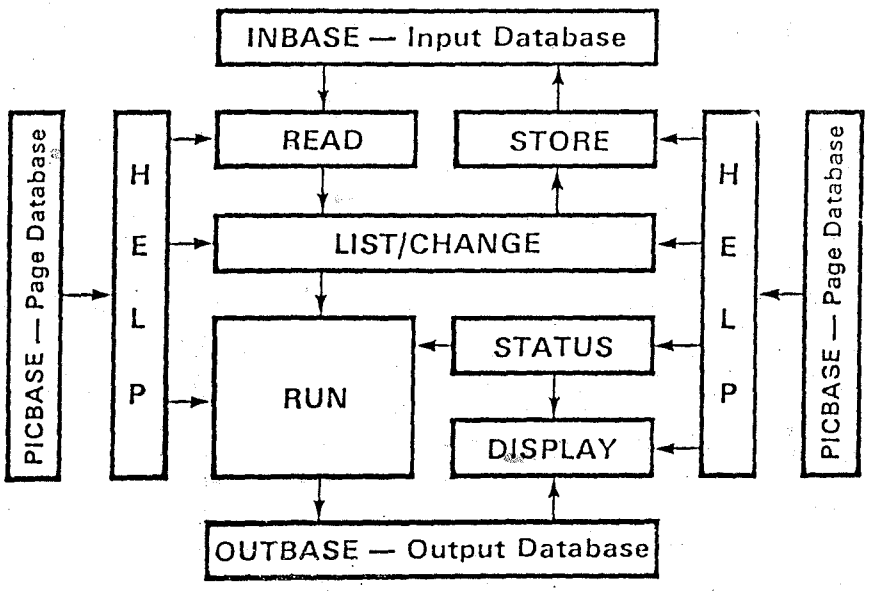
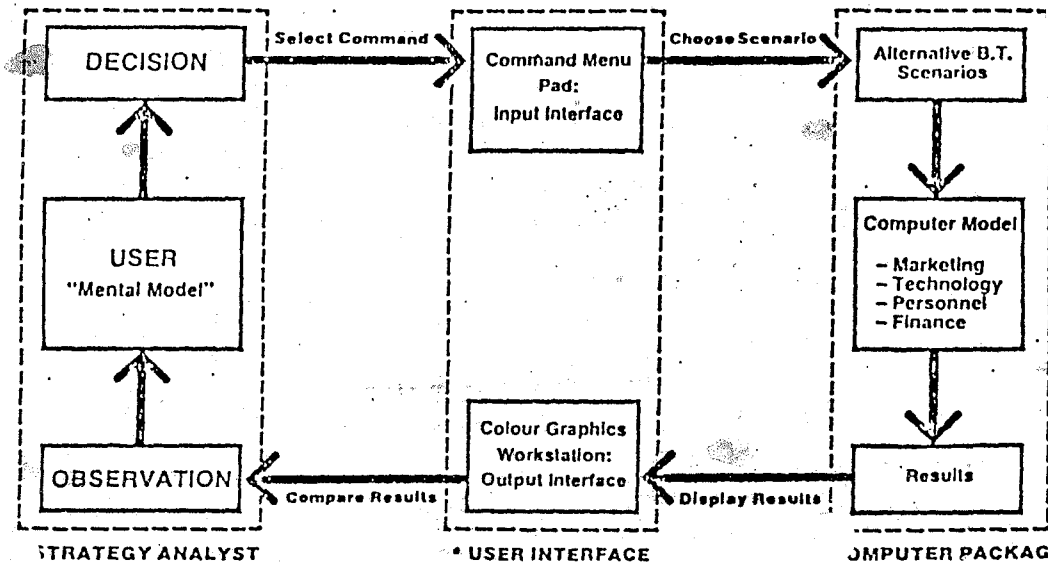


Figure 3B – THE USER INTERFACE FOR STRATEGIC MODELLING



3. The Colour Graphics Interface.

3.1 An Outline of the Interactive Interface.

We have recently devoted very considerable effort in attempts to develop an appropriate user interface for our dynamic corporate models, and in figure 3A we display the layout of the new graphics workstation (Ref 7) This is linked to an IBM 3033 main-frame over the public switched telephone network (PSTN). We usually study alternative strategies in direct communication with the corporate model (figure 3B) in which several analysts may participate at once, grouped around the workstation.

The development of this new user interface falls naturally within three main phases:-

a) The design of a videotex page editing system

b) Development of a command interface with menu selection.

c) Design of graphical display options to allow simultaneous comparison of up to around ten alternatives futures.

We now think of such interactive modelling as a natural extension of current videotex systems such as Prestel (U.K.) and Telidon (Canada) in which we attach intelligence to clusters of information pages. This is likely to mean that models become far more acceptable as just another source of information rather than as a tool specifically for the trained modelling experts. The aim underlying these ideas is that we should integrate the computer model as closely as possible with the user's "mental model" so reducing the alienation so often experienced when attempting to decipher reams of computer output. We hope that we will then succeed in achieving the penetration of such telesoftware into the executive suite as a natural extension of current decision support systems.

3.2 The Interface Command Structure

In figure 3C we sketch the current structure of the model in which all commands are mapped into "menu cells" within a 14x14 graphics pad grid. We shall now give a short overview of the main features of this interface for systems dynamic modelling:-

3.2 1. Videotex Database.

Here we include pages of information which describe the structure and conceptual framework of the models and which are used for presentations within the Business. We are also able to enter pages of text which introduce and explain the main conclusions to be drawn from graphical results being shown at presentations. This means that we can generate a form of computerised "slide show" for management. Finally we include "help" pages for the command interface itself so that to a large extent, the system is able to explain its own operation.

We have defined a minimum of basic active commands which are summarised below:-

a) Run - This command will run the model under the currently defined policy for the desired planning horizon.

b) Read/Store - These commands allow the analyst to read or store up to ten sets of policy parameters as named corporate scenarios.

c) Change/List - These permit alterations in the current policy assumptions, corporate objectives and the control mechanism.

d) Macro - This command allows the user to store sequences of selected commands within a file for "playback" on future occasions. This facility is used mainly for giving pre-programmed presentations to management.

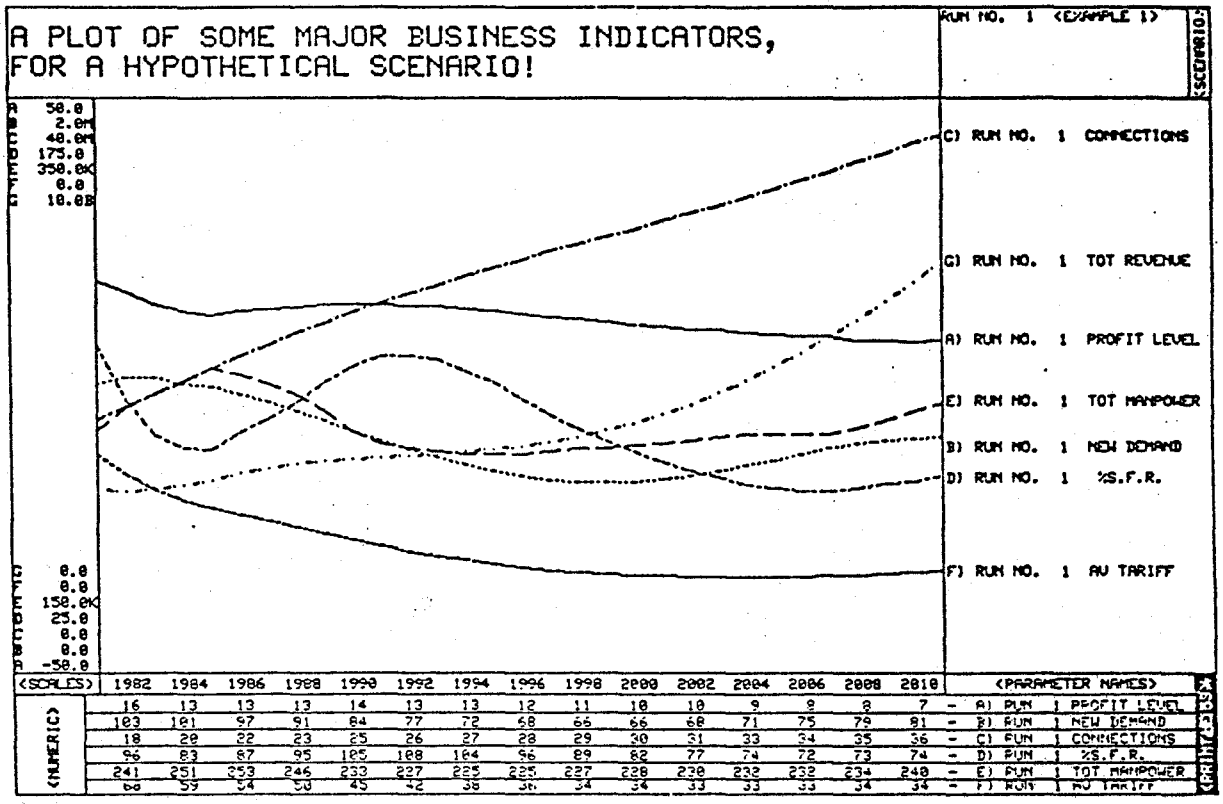
e) Copy - This command will produce hardcopy of the current display in a maximum of 16 grey scales.

f) Picture Editor - This is a full videotex editing package for the creation of the graphics/text database, which includes the help pages.

3.2.3 Display Menu.

The LRPM produces results for around 200 variables over a planning horizon which is usually set to be 30 years. The nature of long range and strategic planning requires us to closely examine and compare the outcomes from many alternative scenarios which all have to be stored in some output file. We are thus confronted with the challenge of presenting the response to such analysis in a neat and compact manner which is acceptable to management. Our first step in setting up the display routines was to agree on the overall screen design and management framework which would allow the user to interactively plot curves, bar charts and numerical values in chosen colours and drawing mode.

There are 13 colours available for drawing graphs, which once defined, can be manipulated in various ways. This includes rescaling, switching the graph on/off and also displaying or deleting the associated numerical values. It is currently possible to store ten full LRPM runs as named sets of results in which we can take percentage deviations between any two runs at any particular time. The graphical display options allow us to plot variables in a great variety of ways as shown in the examples of figures 3D,3E,3F, and 3G. Possibly the most powerful way to represent variables such as capital investment or manpower skill profiles is to plot bar charts incorporating variables each as a different colour. Such profiles can be drawn either as absolute values or else normalised so that, for example, the percentage of each manpower skill is clearly depicted.


A PLOT OF SOME MAJOR BUSINESS INDICATORS,
FOR A HYPOTHETICAL SCENARIO!
RUN NO. 1 <EXAMPLE 1>
C) RUN NO. 1 CONNECTIONS
G) RUN NO. 1 TOT REVENUE
A) RUN NO. 1 PROFIT LEVEL
E) RUN NO. 1 TOT MANPOWER
B) RUN NO. 1 NEW DEMAND
D) RUN NO. 1 %S.F.R.
F) RUN NO. 1 AV TARIFF
<SCALES> 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010
<PARAMETER NAMES>
(NUMERIC)
16 13 13 13 14 13 13 12 11 10 10 9 8 8 7 - A) RUN 1 PROFIT LEVEL
103 101 97 91 84 77 72 68 66 66 68 71 75 79 81 - B) RUN 1 NEW DEMAND
18 20 22 23 25 26 27 28 29 30 31 33 34 35 36 - C) RUN 1 CONNECTIONS
96 83 87 95 105 108 104 96 89 82 77 74 72 73 74 - D) RUN 1 %S.F.R.
241 251 253 246 233 227 225 225 227 228 230 232 232 234 240 - E) RUN 1 TOT MANPOWER
60 59 54 50 45 42 38 36 34 34 33 33 33 34 34 - F) RUN 1 AV TARIFF

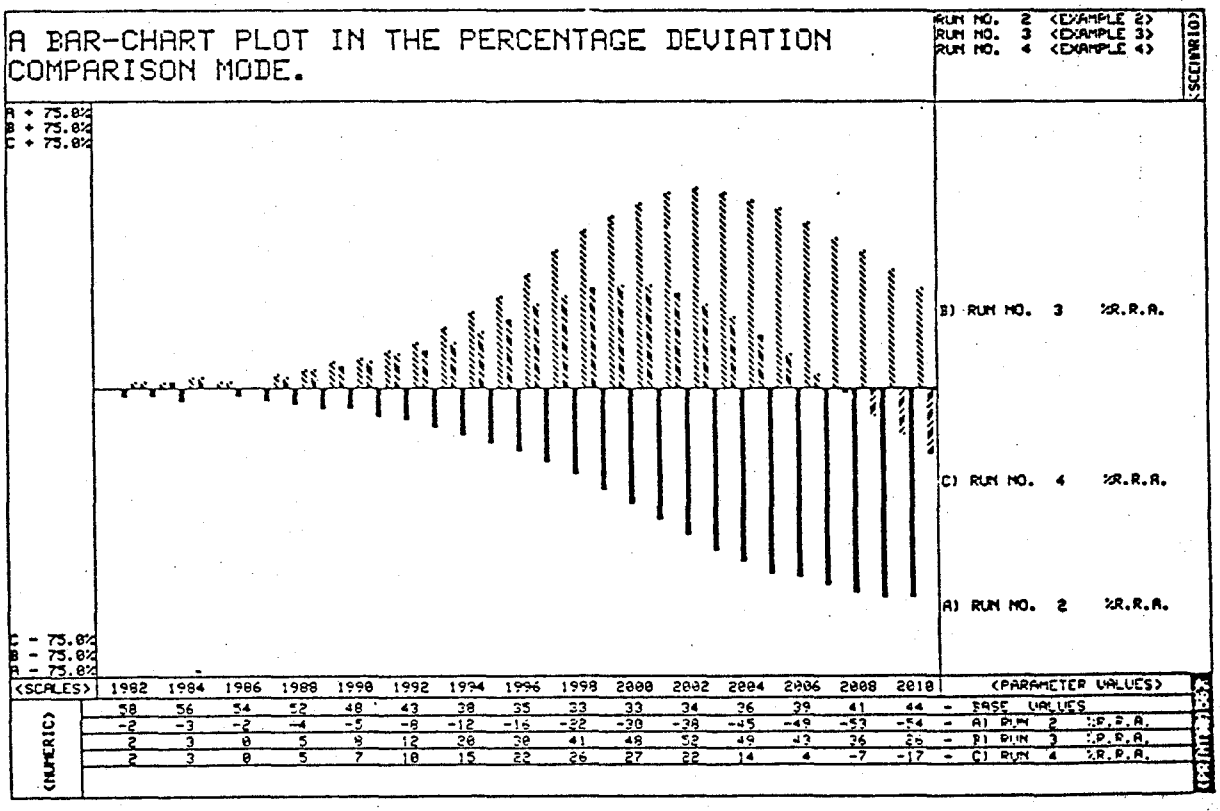

A BAR-CHART PLOT IN THE PERCENTAGE DEVIATION
COMPARISON MODE.
RUN NO. 2 <EXAMPLE 2>
RUN NO. 3 <EXAMPLE 3>
RUN NO. 4 <EXAMPLE 4>
B) RUN NO. 3 %R.R.A.
C) RUN NO. 4 %R.R.A.
A) RUN NO. 2 %R.R.A.
<SCALES> 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010
<PARAMETER VALUES>
(NUMERIC)
58 56 54 52 48 43 38 35 33 33 34 36 39 41 44 - BASE VALUES
-2 -3 -2 -4 -5 -8 -12 -16 -22 -30 -38 -45 -49 -53 -54 - A) RUN 2 %P.R.A.
2 3 0 5 8 12 20 30 41 48 52 49 43 36 26 - B) RUN 3 %P.R.A.
2 3 0 5 7 10 15 22 26 27 22 14 4 -7 -17 - C) RUN 4 %R.R.A.

Figure 3E

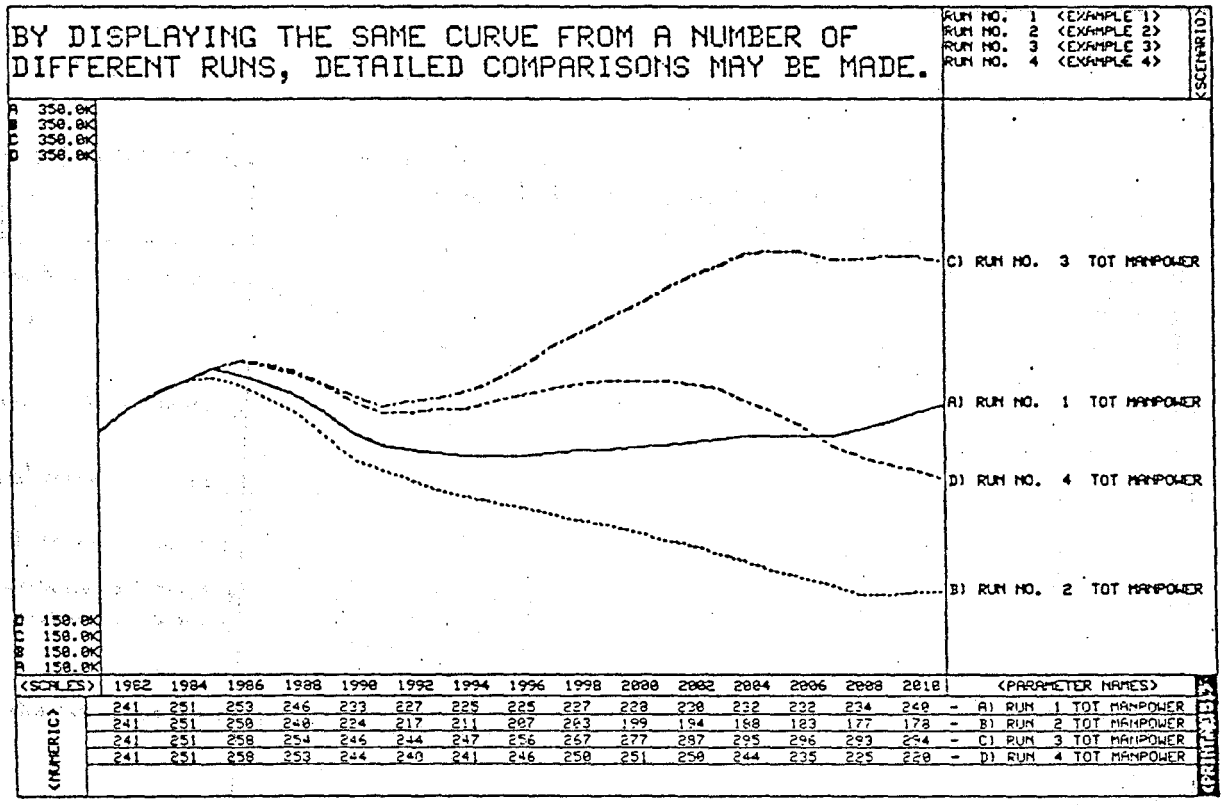


Figure 3F.

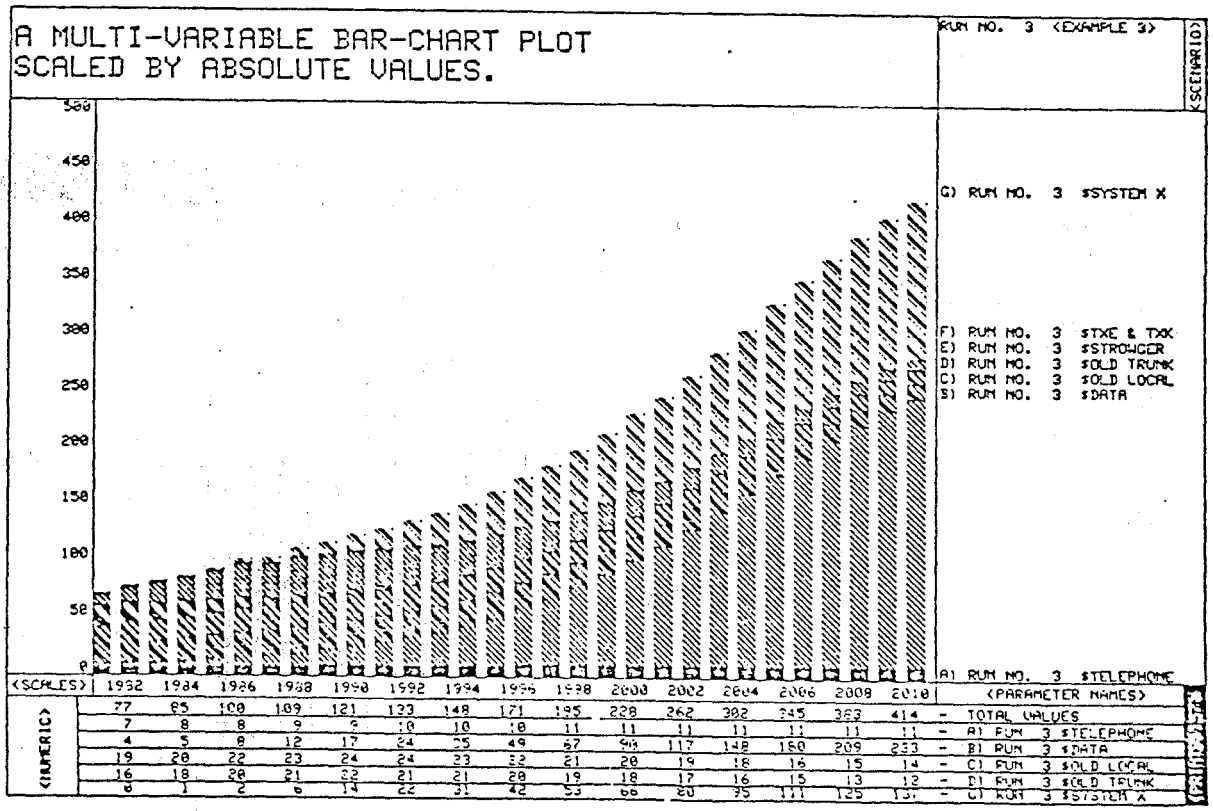


Figure 3G.

These results do not constitute real forecasts nor do they represent BT policy.

4. The Integrated Communications Demand Model (ICDM).

4.1 Introduction.

In the previous sections we have given a comprehensive overview of the LRPM. It was found that the weakest part of the structure was the marketing module which was becoming particularly important with the impending liberalisation of the marketplace under the 1981 U.K. Telecommunications Bill. The decision was taken during 1979 to begin developing an entirely new model which integrated the demand for all communications media, with the emphasis on competition for the provision of telecommunications services. The conceptual framework was developed by a research team at Cambridge University over a period of nine months, in close liaison with the Strategic Modelling Group within British Telecom. This led to the production of the Phase I Report (Ref 6) in which we note that the ICDM framework and the demand categories, as listed in Table 4F, are certain to evolve as we run the model and refine our insights into the demand generation mechanisms. Indeed, the project has already highlighted numerous areas in which there are severe data deficiencies which will enable us to proceed with greater confidence in defining market research studies over the next few years. This will aim towards the creation of a well defined database both as a source for the ICDM and also for more detailed market sector studies.

4.2 The Use of the Model for Strategic Analysis.

In figure 4A we display the outline structure of the model with the three components of the telecommunications marketplace mapping onto the domains of policy and the relevant external environment. In figure 4B we fill out the three lobes of terminals, networks, and services to give a reasonably detailed idea of the linkages we shall be including within the model. We have summarised the main dimensions of analysis within the figure 4C which shows how we intend to apply the ICDM for the analysis of strategic issues within the Business.

4.2.1. Policy Options.

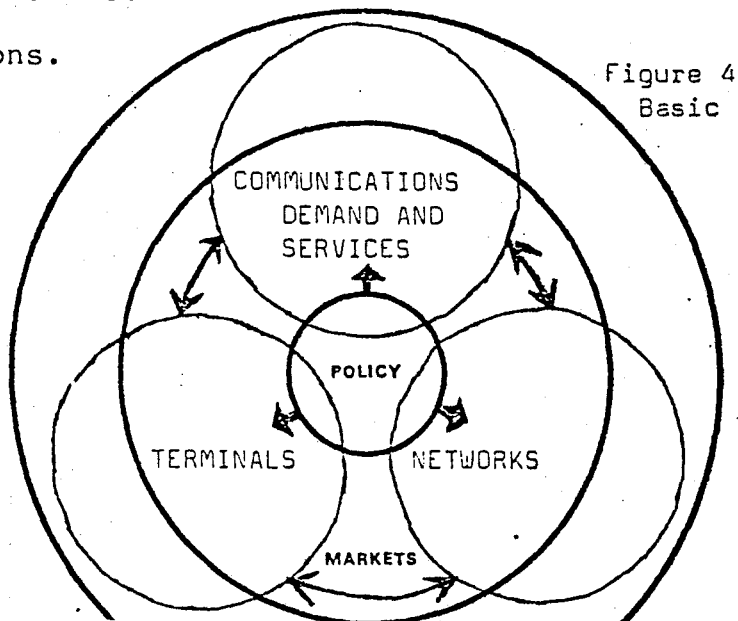


Figure 4A – The Basic Framework.

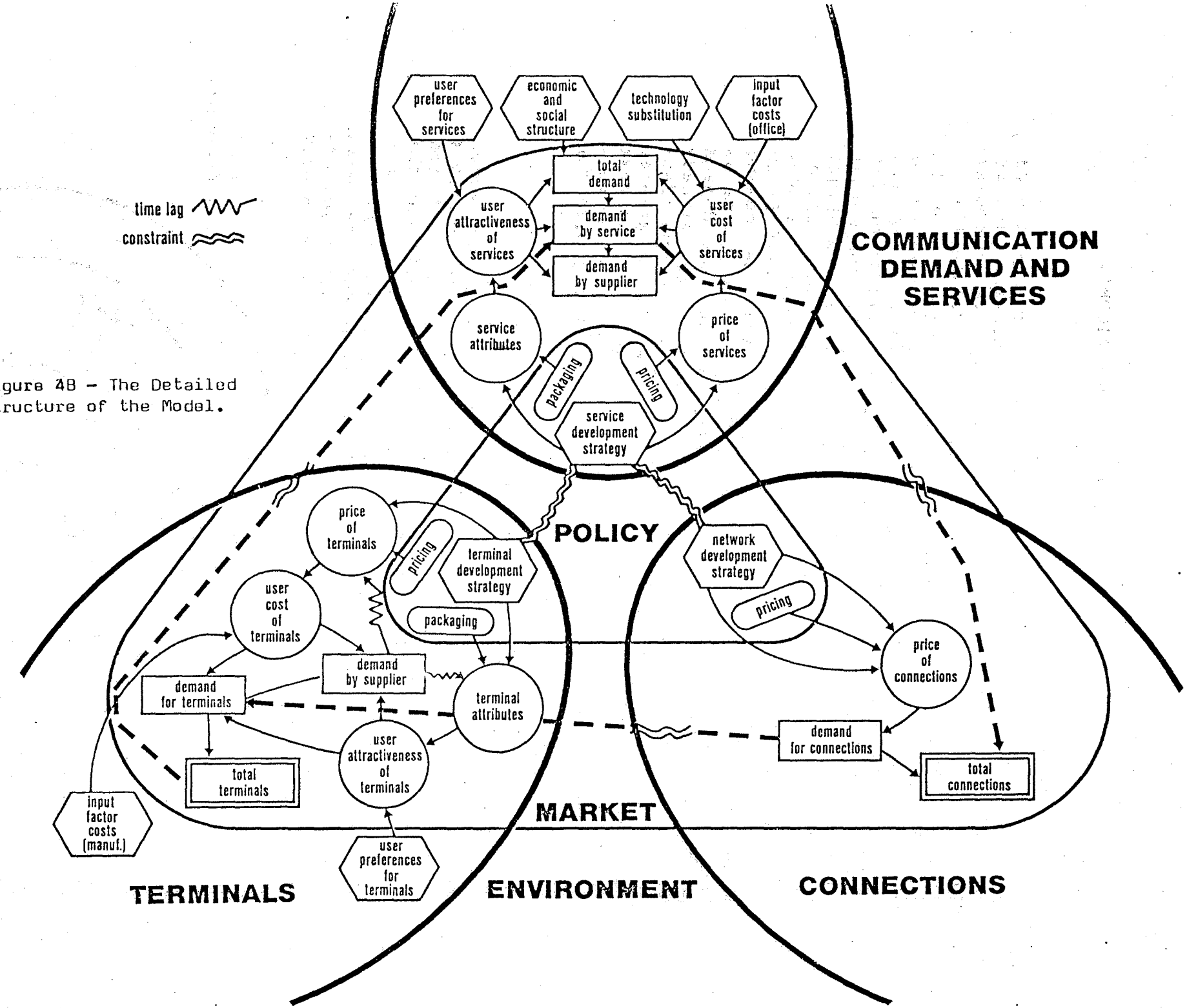


Figure 48 - The Detailed Structure of the Model.

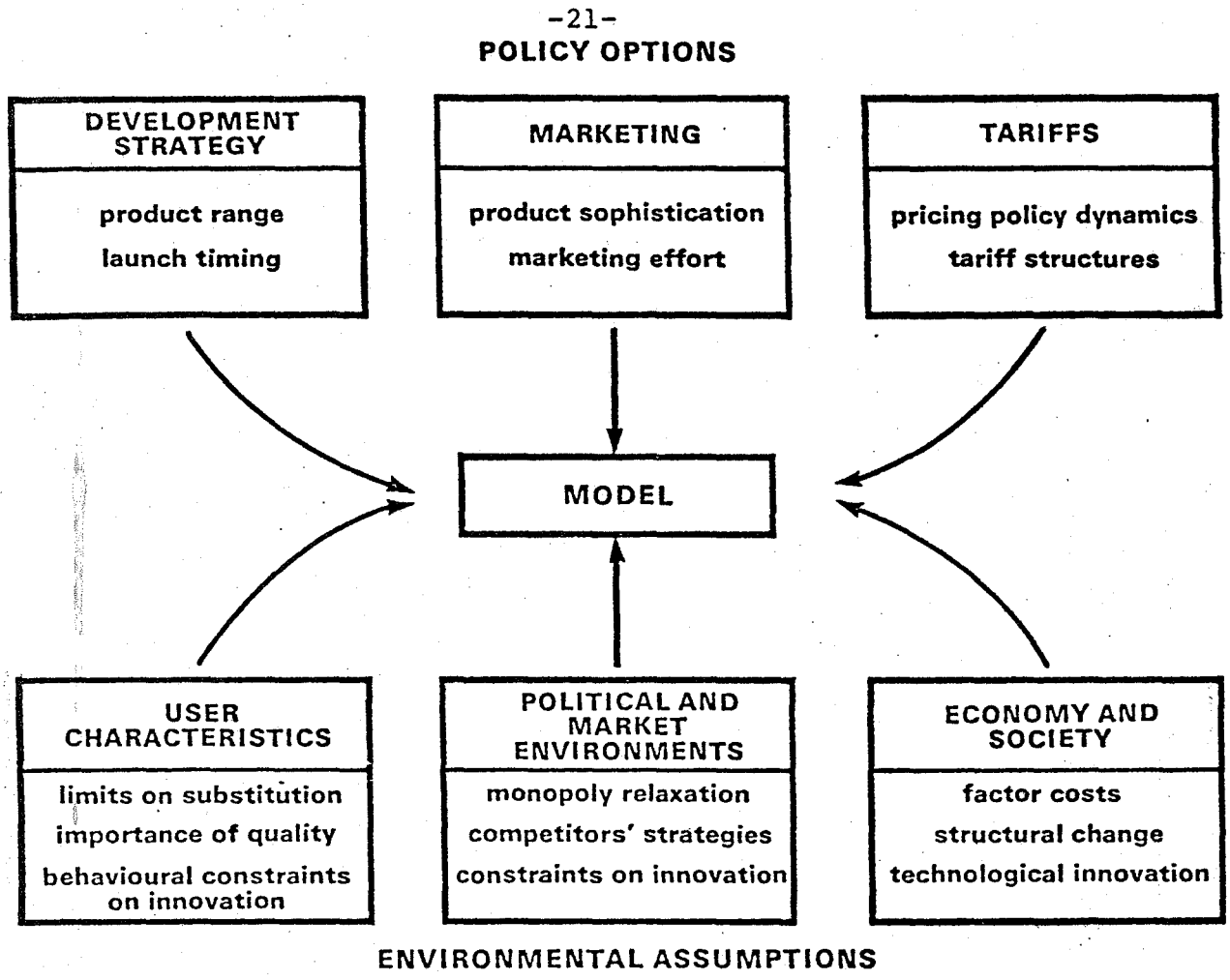
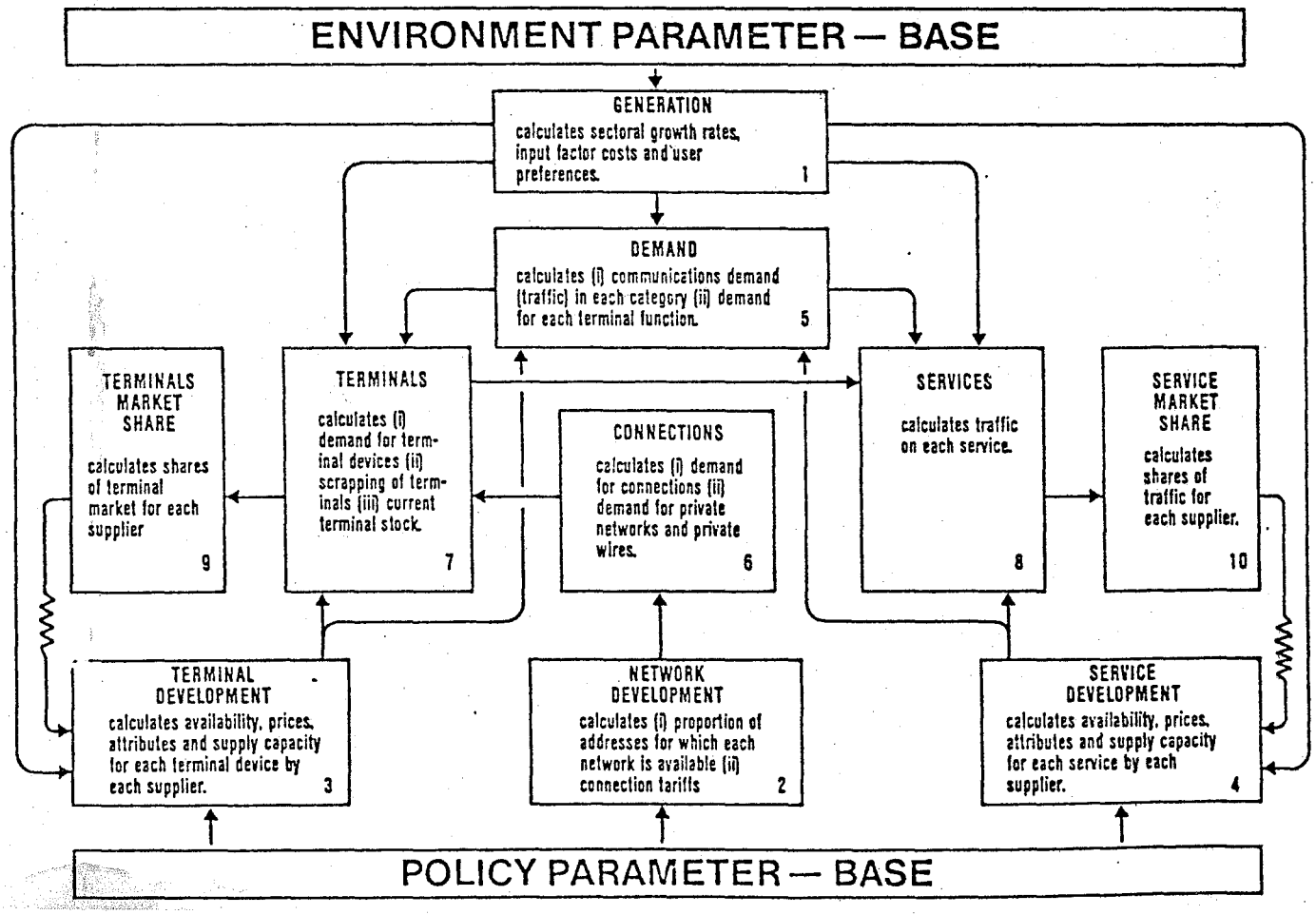


Figure 4C **Use of the model for strategic analysis.**



We shall now give examples of typical strategic issues:-

a) Marketing Strategy - What is the latest time that B.T. can enter a market and still gain a satisfactory share?
b) Development Strategy - How far should B.T. attempt to integrate office equipment with communication devices?
c) Tariffs - Should a loss-leading strategy be adopted to gain a high market share at the launch of a new service?

4.2.2. Environmental Assumptions.

We now give examples of some environmental assumptions:-

a) User Characteristics - Limits on the rate of substitution of physical communication by electronic media.
b) Economy and Society - Effects of major changes in the work/leisure split and the impact of increasing energy costs.
c) Political and Market Environments - The timing of the relaxation of the monopoly and the action of competitors.

4.3 The Modular Structure.

The conceptual diagrams discussed in the previous section do not give many clues as to how the model is actually implemented as a computer package, written in FORTRAN. So we now explore in a little more detail, the modular structure of the model in which the modules depicted in figure 4D are themselves made up of a number of subroutines. We have already found from our experience with the LRPM that this structure makes for considerable flexibility in enabling new dimensions of analysis to be included at short notice.

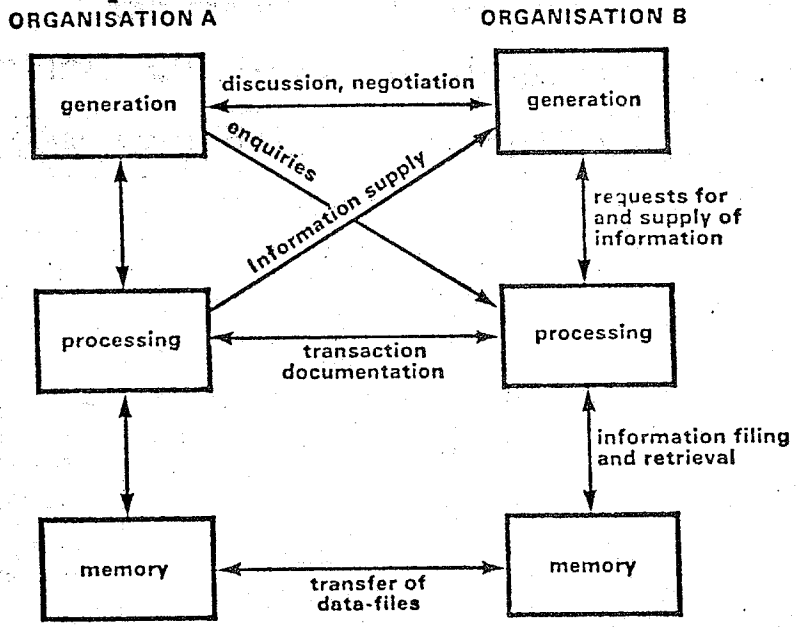


fig 4E **Information activities and communications.**

The demand module utilises categories defined both by economic sector and communication function in which 4E shows the basic flows between various organisational functions. The other domains of the model associated with terminal demand are depicted in figure 4F in which we have attempted to capture the generation of demand from several different perspectives. In particular we note that in many cases we

Tables 4F.

a) Economic Sectors.

1 Agricultural/extractive/manufacturing/construction.
2 Transport/post/distribution/personal services.
3 Insurance/banking/finance/business services.
4 Other information-based services (including government, law, medicine and education.
5 Télématique (telecommunications and computing industries).
6 Residential (A) - Domestic economy.
7 Residential (B) - Recreational activities.
8 Residential (C) - Social Activities.

b) Terminal Functions.

1 Audio Communication.
2 Video Communication.
3 Video Display.
4 Person - Person Data (Character-coded:- telex, teletex).
5 Person - Person Data (Content-coded:- facsimile).
6 Person - Person Data (Content-coded:- telewriting).
7 Person - Machine Data (Computer terminal).
8 Person - Machine Data (Electronic Funds Transfer-(EFT)).
9 Person - Machine Data (Videotex Information Systems).
10 Machine - Machine Data.
11 Terminal Intelligence.

c) Terminal Devices.

1 Basic Telephone.	2 Advanced Telephone.
3 Television Monitor.	4 Videotex Monitor.
5 Teletype Terminal.	6 Visual Display Unit.
7 Telex.	8 Teletex.
9 Word Processor.	10 Mini and Micro Computers.
11 Facsimile.	12 Advanced Facsimile.
13 Viewphone.	14 Telewriter.
15 EFT Point-of-Sale.	16 Telephone and Facsimile.
17 Viewphone and Facsimile.	18 Videotex and Word Processor.

Further categories include other multi-functional terminals.

d) Communication Services.

1 Physical Mail.	2 Printed Media.
3 Face-to-Face Meetings.	4 Broadcast Media.
5 Audio Communication.	6 Video Communication.
7 Electronic Mail (Messages).	
8 Electronic Mail (Documents).	
9 Electronic Information (Data Entry/Retrieval - Videotex)	
10 Data Communications.	
11 Electronic Funds Transfer Services.	

have the possibility of providing a new service either through terminal or network based intelligence. A further complication is created through the evolution of terminals from those with single functions such as the basic telephone towards more advanced multifunctional terminals which can act as a complete office communications workstation.

4.4 Extensions of Research into Communications Demand.

There are two natural directions in which we can pursue further research which are both currently areas of considerable interest within British Telecommunications.

4.4.1. Information Flows within Organisations and the Home.

We are intending to extend the demand and generation modules to include a far more detailed representation of the transformation of information flows within the office through the impact of electronic communications media. Over the last few years, a number of consultancies have undertaken market research studies in this area and we intend to develop a module which encompasses such results at a fairly aggregrate level. We shall then proceed to consider the possibly more difficult task of modelling the impact of information technologies within the 'Home of the Future'.

4.4.2. The Impact of Telecommunications on Society.

We are also exploring the possibility of enlarging the domains of the generation and demand modules to include a more complete representation of the role of information technologies within society as a whole. We are currently limited in achieving such a representation by a lack of data which gives us the detailed breakdown of information costs within the national accounts. What we wish to achieve is a dynamic representation of the transformation from the industrial economy to that of the information economy. Such a model would explicitly bring out the impact of new telecommunication services on industrial productivity within a wide range of economic sectors.

4.5. Links between the ICDM and the LRPM.

We now ask how we can use the ICDM as a detailed representation of the marketing module within the LRPM. We envisage having links both within the computer as well as through interchanges of ideas and insights between strategy analysts. We intend to use aggregations of results from the ICDM in order to aid us in assigning values to the LRPM, similar in concept to the policy levers previously described in section 2. Thus we can perform a detailed market share analysis and then explore the personnel and financial resource requirements through the use of the LRPM. In addition, there is no reason why the two models should not be run simultaneously with the ICDM replacing the current marketing module. Such experiments will be performed later this year. The colour graphics developed initially for the LRPM is now also used as the user interface for the ICDM, which considerably reduces our problems in 'marketing' yet another large integrated model to operational management.

5. Thoughts for the Future.

5.1 Distributed or Integrated Modelling?

The two dynamic models which have been discussed in this paper are relatively large, run on main-frames, and were developed using an integrated philosophy of modelling. However, with the advent of micro-computers and the trend towards distributed databases it seems that we should also explore the feasibility of "distributed modelling". We can envisage strategic analysts within each operational department of a corporation developing and running system dynamic models on micro-computers. These models could then communicate with each other over the telephone network whenever the analyst wishes his study to embrace a rather wider corporate viewpoint.

5.2. Dynamic Models as the basis for Business Games.

In BT we are currently exploring how dynamic models can be used by teams of staff each representing different interest groups such as customers, suppliers, BT staff, the Government, and BT competitors. In general, the models described in the literature have been used only by modelling specialists. Through creating the LRPM as the core of some Business game, we hope to enable a wider spectrum of BT staff to gain experience of the analysis of alternative strategic options.

5.3. Intelligent Models.

The question arises as to how much intelligence we should program into a dynamic computer model. It would be useful, for example, if the model could explain its own derivation of the results it produces since this would eventually lead to increased confidence in the model's structure. In a way we are asking for a means whereby a model can justify its validity to non-specialist users. Recent research into the design of expert systems has been pursuing such aims and it looks as if we can expect applications to dynamic corporate modelling within the next decade. Again, it is of little use increasing the intelligence within a package unless corresponding improvements are made in the user interface. Thus human factors research is also likely to assert its role in such extensions of the art of systems dynamic modelling.

5.4. Conclusion.

The aim of this paper has been to survey the dynamic modelling methodologies currently used within the Long Range and Strategic Studies Division of British Telecom. Space does not permit us to go into extensive detail concerning the structure and operation of the LRPM and ICDM, and for greater depth the reader is referred to the references at the end of this paper. The organisational turbulence both within British Telecom and its external environment will certainly result in our being confronted with a wide spectrum of new modelling challenges over the next decade.

6. Acknowledgements.

I should like to thank my colleagues in both British Telecom and at Cambridge University for the many ideas which they have contributed to this programme of research into dynamic modelling during the last five years. In particular, I wish to express my sincere thanks to Bernie Allenstein (BT), Chris Doubleday (CU) and Geoff Walsham (CU) for many stimulating discussions on the art of computer modelling and its implementation in a corporate environment. Finally I wish to thank Dr Jim Cowie, Head of Long Range and Strategic Studies (BT), for his active interest and support for this work, and also Donald Wray, Director of Business and Strategy, for permission to publish this paper.

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