Modelling, myth vs reality, map vs territory

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modeling, representation, analysis

Model making and manipulation, conscious or unconscious plays a major role in all of our lives. All of us perceive the world and the day to day problems we need to solve through the filters of internal models, and for better or worse, these filters affect all aspects of our interactions and our decision making. Externalising those models, either formally or informally as tools for communications and decision making is an important part of many management and engineering processes, even if the process is often implicit rather than explicit. This paper discusses the role of abstract models and their uses in the context of technical and business decisions within Hewlett Packard. The purpose of the paper is to set a context for the model based research within the SSRC, explaining what can and what can not be achieved through the use of abstract models, as well as exploring the myriad shades of grey between the two.

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Summary

Model making and manipulation, conscious or unconscious plays a major role in all of our lives. All of us perceive the world and the day to day problems we need to solve through the filters of internal models, and for better or worse, these filters affect all aspects of our interactions and our decision making. Externalising those models, either formally or informally as tools for communications and decision making is and important part of many management and engineering processes, even if the process is often implicit rather than explicit. This paper discusses the role of abstract models and their uses in the context of technical and business decisions within Hewlett Packard. The purpose of the paper is to set a context for the model based research within the SSRC, explaining what can and what can not be achieved through the use of abstract models, as well as exploring the myriad shades of grey between the two.

1 Introduction

What are models and why do they matter? The Performance Engineering Group within HP Laboratories spends a great deal of its time creating and analysing abstract representations of systems that our businesses care about - business processes, electronic services, computer architectures and measurement systems to name but a few. However the perception of what a model is, why you construct models and how you construct them is often at odds with the reality. This paper has been written to summarise our understanding of what the types of models we research and develop can and can not do for organisations.

There are two approaches to the use of models within a project. In the idealised world of Jain [1] a modelling project is undertaken in the same manner as a software engineering project. This starts with well defined scope and goals, the system under consideration is well understood and the scope and limits of the modelling exercise given. In reality, many of the questions to which Jain needs an answer would often require a considerable amount of the system to be constructed. The ‘electronic prototyping’ approach is that it is far easier to resolve these questions when an executable analogue of a system exists. Often the greatest value of a modelling exercise is to clarify the need for definition and measurement within very poorly defined and envisioned systems.

By modelling early we can gain insights into what should matter and what should not! This information is invaluable in identifying and subsequently exploring the parts of the system where greater clarity and definition are required. Simply measuring elements of a putative problem system is very costly and often does not deliver the critical data needed to resolve engineering/business questions. Furthermore during the initial phases of a project there will be many competing forces trying to direct the project to their needs. With little or no knowledge of the effect of trade off between these groups, decisions are often made that have a disproportionate cost/benefit within the final system. Early models can clarify the requirements of the various competing groups and give insight into the trade offs that will be required.

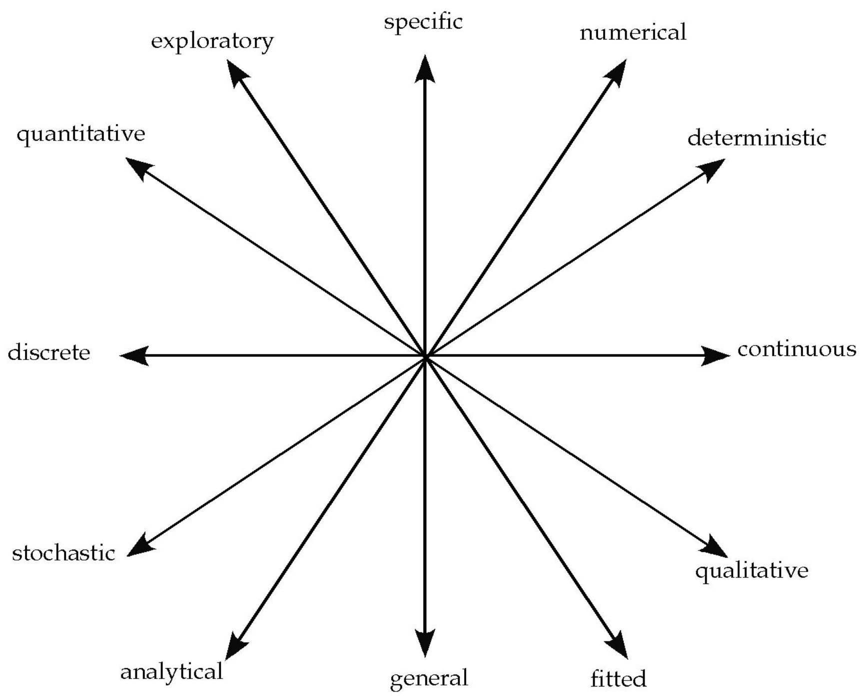

Figure 1: Discriminating between models: there is a wide spectrum of possible model representations, from those that are intended to explain phenomena (exploratory) through to those that are intended to predict behavior with little of no concern for the underlying phenomena (fitted). In addition, the form of the model (analytic vs. numerical, discrete vs. continuous), and its solution (deterministic vs. stochastic, qualitative vs. quantitative) will determine its suitability of application. Some of the choices are binary. More often than not, the axes represent continua. The model profile is likely to differ, both with system and with time as models are created, revised, rejected or augmented.

2 What is a model?

The term 'model' is widely used and abused. One succinct definition is given as

> ...a model is a conceptual abstraction of an existing or proposed real system that captures the characteristics of interest of the system. Modeling is the process of building the abstraction (model) ([2], p. 80)

In our area, we will limit ourselves primarily to models of a formal or mathematical nature which enable them to be manipulated (possibly by machine) to derive numerical *and* structural properties. Such a definition still covers a multitude of possibilities (figure 2). The choices that are made by the model builder (some of which represent binary decisions, others simply a bias) should reflect the system being analysed, the ambitions of the stakeholders, model builders and the modelling budget both in time and cost.

3 Why use models?

The use of such models within businesses, at many levels, from business process through to system engineering is widespread, although there is good evidence that the role of models and the level of sophistication required to achieve useful results is poorly understood by many managers.

The benefits of models and modelling [3, 4, 5, 6, 7] can be summarised as

- the act of creating a model forces an organisation to consider and review the structure of the business, investment or product that they are proposing to create; such a model, even if it is never deployed in anger or formally analysed will often play an important role in the initial feasibility study (for instance early computer based modellers [8] found that the model rarely need to be 'run', the act of creation informed them as to where system problems would lie);
- a model can act as important documentation of a system, the evolution of such a model, if documented, is an invaluable aid in the audit of a project (for example [9] provided an overall view of memory usage within printers, which was previously distributed over many different programmers);
- a model can act as a valuable communications aid, allowing discussions to be grounded in a common representation (for example [10]);
- models allow for rapid exploration of the decision space that an organisation is operating in, enabling multiple scenarios to be played out at low risk;
- models may be used to qualify and then check real systems; as the system runs, the behaviour of the model is compared with observations of the real system and discrepancies are investigated;
- models can demonstrate the sensitivity of a system to environmental changes, enabling users to design out (as much as is possible) potentially disruptive non linearities in the system behaviour;
- models can be used to check the correctness of particular approaches to problem solving;
- models permit the early capture of error, as they permit non-existant systems to be studied, with the well known benefit of capture time against value saved.

If models are such paragons of virtue, then one might ask the question why they are not more widely used?

4 Map vs territory

A common confusion relates to the goals of modelling, the results that might be achieved, and the reliance that can be placed upon the insights that a model might bring to its users. What must be understood is the *the map is not the territory*[11]. The only model that will behave, in all ways, as the original system is that system itself. When this observation is coupled to the fact that real systems are often complex (indicating an extreme sensitivity to initial conditions, sometimes referred to in the literature as 'chaotic'), many observers appear to conclude that any sort of modelling is therefore of very limited value and can essentially be ignored for all practical purposes. Maylor for example in [5] essentially dismisses numerical methods for business prediction on the grounds that small changes in initial conditions will invalidate models so rapidly as to make them virtually useless. He is not untypical of one school of management science, and taken simplisticly, he is obviously correct. Interestingly this view of the use of models is essentially contradictory to that used by modellers. The expectation that numerical results will be exact rather than used to demonstrate better/worse situations leads to erroneous use of models and consequently an erroneous view of their applicability. The problem with this view is that models, the managers 'finger in the wind', are still being used they are simply not being externalised. The immediate consequence of this approach is an inability to share understanding of a (business) system with the results that an individual cannot learn from others mistakes or share their competence.

If we accept that the model will never completely represent the system under consideration (for any interesting system that is), then what is the point of modelling in any formal sense?

The observation of real systems indicates that many have properties that make them amenable to modelling, or at least parts of them, specifically

1. many business systems, while complex in particular regions, have large operating spaces that are essentially linear, i.e. next state can be reasonably accurately and straightforwardly predicted from current state plus a known change in the environment, and if the environmental changes are not completely accurate (there is some noise for example), the changes in the predicted outcome will reflect that noise. For these systems, both numerical output and trend analysis (up, down, stationary) are likely to be of interest to the business planner;

2. the conditions under which a business enters a chaotic or complex region, may themselves be of considerable interest. While the precise behaviour of the system under those conditions may be impossible to determine, early warnings of, or a determination of the approximate probability of, complex behaviour can be extremely valuable. Models of this type are widely used to assess risk in poorly understood markets - for example [12]. Their inability to predict absolute performance, while regrettable, does not prevent their application.

3. many business are not 'open loop' - that is to say, a business has some control over the stimuli to that business (crudely this might be related to marketing, costing or supply chain management for example). By manipulating these stimuli based upon predictive models, an organisation might hope to reduce the probability of either moving to a complex or otherwise undesirable part of the operating space (figure 2);

4. most businesses that rely on information systems that are largely deterministic in operation and cost (at least for their gross properties) or can be designed to be deterministic; without a model of how the business will interact with the IS, specifying and managing it to meet requirements will be difficult;

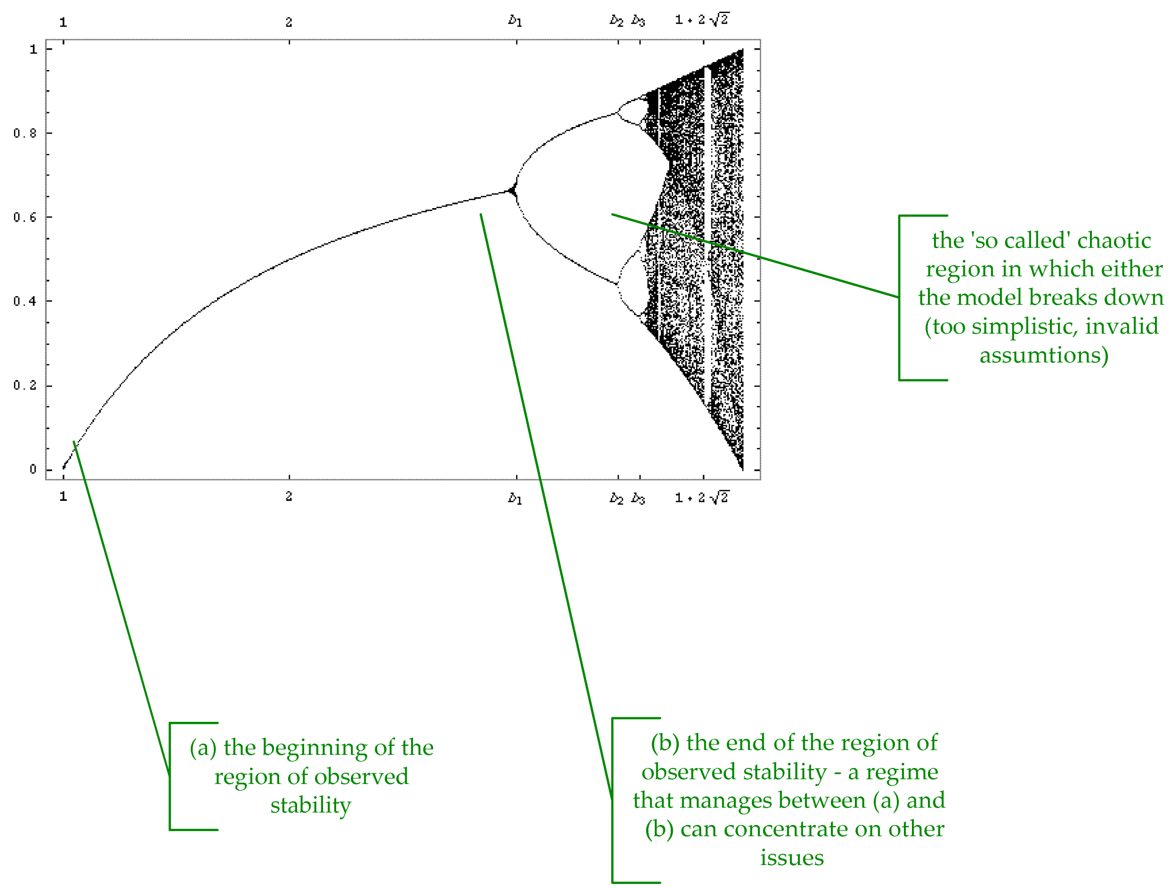

Figure 2: The relationship between control and modelling :- any business that has the capacity to effect its environment can make use of this control to reduce the probability of moving from regions of stable behaviour and those of either chaotic, or complex behaviour. This form of analysis does not guarantee that this movement will not occur, but is a relatively cheap mechanism for reducing the probability that it will and allowing managers to concentrate on the difficult parts of the system, those for which hard numerical or empirical data is not available.

5 What models are of practical value to a business?

Models are used every day by everyone. In most cases these will be mental models [11], deeply ingrained assumptions about the relationships between the components they are trying to manage and stimuli that can be applied to influence their behaviour. Such mental models are obviously highly effective, up to the point at which they need to be communicated and shared. A very few individuals do appear to be capable of translating their own complex, personal mental models into forms that can be shared and explored by many people, but they are in the minority. Externalising such models, through pictures, textual descriptions and definitions, as well as through mathematics not only allows them to be shared effectively, but also provides a mechanism for documenting and auditing decisions. Furthermore, this externalisation of knowledge has the usual benefits such as permitting new decision makers to be trained and the possibility of augmenting models as a consequence of testing their predictions. The exchange of mental models and their validation is the foundation of the scientific approach [13].

5.1 A simple model hierarchy and its application

The application of analytic models in management, engineering and science is frequently misunderstood - people expect too much - 'the market will grow by 2.546% over the next four years' - or too little - 'the protocol is too complex to analyse, let's run 40 hours of simulation and hope for the best'. In the area of business process modelling and the interaction of business (or organisational) processes with information systems analysis and provisioning there are four distinct areas in which models we are concerned to develop and/or exploit could be (mis)applied and conclusions drawn

1. the economy : typically highly complex systems used to predict growth, the cost of borrowing, consumer 'confidence' etc. their application is largely limited to reducing the probability of grossly stupid investments[1].

2. the micro-economy : again, often complex systems that can be used to make predictions and experiment with the impact of decisions within a particular product or service space (consumer inkjet for example), application is a combination of reduction in unnecessary risk and informing the next layer of the stack about the likely uncertainties in investment requirements and returns within a limited economic space.

3. the organisation : a collection of interacting systems made up of individual groups within the organisation, for any reasonably sized organisation (i.e. pretty much any organisation with two or more distinct types of product or service) it is probably impossible to create complete detailed models that can be used to explore fine detail across the whole organisation. Instead, the construction of horizontal analyses (such as the impact on the overall organisation of bundling strategies for home PCs and printers as opposed to treating each group as independent non interacting entities) can be used to answer specific questions about the impact of business decisions. Testing models of this type and their underlying assumptions against

[1]As could have happened with the sale of radio spectrum for 3G services within the UK – even ignoring the value of projected services, the mobile operators could have used existing and well respected projections of growth to moderate their bids in the ensuing auction. If any of the larger operators had done, the competitive space might look very different now, instead, they all crippled themselves with exceptional debts.

representations of the IS flexibility allows an organisation to both plan what is possible with existing infrastructure as well as make rational statements on requirements for the underlying IS in order to support the type of business agility that the organisation believes it needs.

4. the process : typically a single process (such as supply chain management) which can be represented by parameterised models (such as the depths of pipelines, required inventory levels and supplier volatility). The process often represents the critical path (i.e the primary functional goal) of individual sub-groups within an organisation. These types of parameterised models can be explored in the context of any assumptions set by the 'higher levels' - such as inkjet supply chains in the context of bundled sales in the context of a declining home PC market in the context of booming consumer confidence. Importantly, models of this type can also be cross referenced to functional models of the supporting IS to test capacity, response, agility (in the limited context of the process) and to plan investment to achieve functional goals.

At each point in this simplified hierarchy, different questions can be asked and the results of analyses fed both upwards and downwards. As we move up the hierarchy however, as more and more 'critical' parameters are lumped, our ability to distinguish between individual causes and effects is diminished.

5.2 Static complexity

Social models based upon informal description and hierarchical decomposition such as Hierarchical Process Modelling (HPM, [14]) and the Universal Modelling Language (UML, [6]) have a good record of allowing individuals to compare and merge their mental models at many levels of abstraction. Experience with these techniques however has demonstrated that while they are often very useful at allowing *peers* to compare and contrast models, they suffer from four major drawbacks [15]

1. the techniques, jargon, and processes are not simple to either learn or use. They require significant 'practice' to retain proficiency, and while some individuals within a business operation may well be able to retain such proficiencies, they remain in the minority. This has two implications :- (a) specialised modellers are required to help translate and explore stakeholders mental models of the system they are attempting to construct, which itself will be necessarily error prone and (b) they are probably unlikely to be used in day to day operations;

2. they encourage an informal refinement of the models that may well be misleading; assumptions about the coupling between different parts of the system, and potentially about the common components that such a system is likely to share can be difficult to isolate and analyse;

3. they discourage cross-competency exploration of the underlying systems, primarily due to the use of specialised and subtle vocabularies that are difficult to share;

4. automated abstraction and analysis is often impossible due both to the structure of the resultant models and the ambiguities inherent in such descriptions.

5.3 Dynamic complexity

The problems that we typically deal with can be characterised as a widespread failure to

1. understand the impact of systems investments on organisations;
2. manage systems investments so as to impact organisational goals;
3. exploit the unique properties of IS/e-service system structures - that is the ability to exploit flexible specifications throughout the lifecycle of the system;
4. deliver systems than reflect the needs of the organisation.

These problems often appear to be representative of two distinct types of misunderstanding

1. the cross-wise impact of decisions being made in one domain on another (marketing on operations for example);
2. the dynamic behaviour of the systems under construction;

Senge makes the point [16] that

> *the real leverage in most management situations lies in the understanding of dynamic complexity and not detail complexity*

and goes on to suggest that most systems analyses concentrates on detail complexity - very much the problem that UML and HPM attempt to solve.

The role of dynamic complexity in characterising qualitative system behaviour is well understood in management science. At a social level, *qualitative systems dynamic* models [17] have been demonstrated to improve the understanding of the dynamic behaviour of (largely, but not exclusively non-numerically represented) systems. Quantitatively, many commonly used economic models make use of systems dynamics principles [18] which have been developed extensively beyond Forrester's work of the early 1960's. The role of dynamic models within the management of integrated projects (market to operations) does not appear to be as well understood.

5.4 Misconceptions

There is a common misconception that mathematical models must involve both highly complex representations of the system they represent, and must also be capable of producing *numbers* as their output[2]. This 'misunderstanding' of what mathematical modelling represents and its applicability

[2] Ignoring for the moment the need for visualisation when many sets of results need to be compared

is apparent in many otherwise sound papers and texts - for example Maylor in [5], a popular project management text in Universities, distinguishes between two 'paradigms for handling uncertainty [page 231]',

> *The research literature on improving mathematical models for handling uncertainty is vast. Most requires the input of an expert statistician to be used effectively. This approach tries to impose a degree of certainty on the system, through treating the causes of the uncertainty. The alternative (managerial perspective) is to provide a basis for handling the effects."*
>
> *As an example, a company is about to launch a new product onto a market in which it has previously operated. It feels that there is a considerable degree of uncertainty as to whether the new product will be a success. There are a number of possible routes open to it:*
>
> - *first analyse, using the best data available, the possible sales patterns for this product;*
> - *second, do rough predictions and spend the rest of the time looking for options as to what will happen given various scenarios – both good and bad.*
>
> *In the former case, the managers are unlikely to have much input to the process by which forecasts are generated, nor faith in the results. In the latter case, the process is visible and the options given market conditions can be evaluated.*

The author goes on to briefly discuss a few modelling techniques, drawing upon a 1983 survey of the application of such by Forgionne [19]. These techniques are further discredited with a brief description of *chaos* or *complexity* theory and its implications, suggesting that because non linearities can dominate the behaviour of a complex system, forecasting is by its nature, a black art and should be left well alone. Intuition is king. This naive view of chaos is prevalent but wrong. Chaotic systems are not necessarily impredictive, they just have limits on how long trajectories can be trusted for. Currently detailed weather forecasting can be considered reasonably reliable for 5 days, and if this is a useful horizon then the system is predictable for ones purpose. To say that a system is chaotic with no mention over what time scale it becomes impredictive is of no use when considering whether a model will produce useful predictions. Even the 'intuition as king' approach assumes that the system is predictive and not chaotic, consequently it seems that either the intuition is vacuous or the choice of modelling approach flawed. The contradictory position of 'my intuition can model a system' but no external description can, is largely based on the mathematical naivety of certain groups [20, 21].

Maylor does go on to make some good points, specifically regarding the reliance that managers (and others) are prepared to put on models whose underlying assumptions are not obvious, but the overall tone is binary. If models are used correctly, then they can be used to identify the areas of maximum exposure and risk, explore alternatives (the business feature landscape), and explain the results within an appropriate context. A hybrid alternative to Maylor's explanation of the the use of models within the planning process might be

1. identify what is known, what can be parameterised, what are the risks (instabilities) within the data;

2. write simple [22] models that can be used to identify the points of maximum risk within the system being proposed (through a sensitivity analysis);
3. for the most sensitive parameters, use detailed models to determine what (if any) control the business can have over them;
4. use a large number of simple models (parameterised where appropriate) from the models derived in 3 above;

6 A management perspective on modelling within business

6.1 The Generic Industry Perspective

In his 1983 survey, *Corporate Management Science Activities: An Update*, [19], Forgionne reported on a survey of the use of 'management science methodologies' in American operated companies. Two sets of his results are relevant to this study, the range of methodologies and their area of application (tables 1 and 2).

Of the companies surveyed, a majority (more than two thirds) gave 'good' or 'excellent' effectiveness ratings to management science and operations research. 82% stated that a major benefit from implementing MS/OR was access to useful data, and other benefits identified included

1. helps define the problem (74.2% of respondents)
2. helps identify relevant policies (61.3% of respondents)
3. provides a useful test laboratory (37.1%)

Despite these positive findings however, substantial numbers (approximately 50% of the survey) described poor communications between analysts and management, and the lengthy completion times for such projects as significant barriers to their application. These findings back up those of other researchers in this area (for example [23]), that mutual understanding of analysts and management requirements are problematic. There is an important question of model 'ownership'? So long as models are seen as owned by operations research (OR) departments or a select group of specialised programmers then their value is limited. Just as spread sheets wars [24] obscure rather than inform, any model can be exploited for this purpose. It is important that the model is owned by the system stakeholders and not by a group of specialists. This place demands both on the decision making group and on the modelling system chosen. In particular openness and transparency within the model is vital, assumptions and causes within it being clear. The spreadsheet approach to modelling is in complete contrast to that of model as medium of discourse, it positively encourages assumptions and causes to be hidden within the definition of cells. As a consequence shared ownership of such a model is practically impossible.

Table 1: The utilisation of management science and operations research methodologies, from [19]

Methodology	Frequency of Use (% of Respondents)		
	Never	Moderate	Frequent
Statistical Analysis	1.6	38.7	59.7
Computer Simulation	12.9	53.2	33.9
PERT/CPM	25.8	53.2	21.0
Linear Programming	25.8	59.7	14.5
Queuing Theory	40.3	50.0	9.7
Nonlinear Programming	53.2	38.7	8.1
Dynamic Programming	61.3	33.9	4.8
Game Theory	69.4	27.4	3.2

Table 2: Areas where MS/OR methodologies are applied, from [19]

Area	Frequency of Application (% of Respondents)		
	Never	Moderate	Frequent
Project Planning	33.9	45.2	21
Capital Budgeting	40.3	41.9	17.7
Production Planning	43.5	27.4	29
Inventory Analysis	48.4	30.6	21
Accounting	50	33.9	16.1
Marketing Planning	53.2	35.5	11.3
Quality Control	58.1	25.8	16.1
Plant Location	59.7	35.5	4.8
Maintenance Policy	61.3	30.6	8.1
Personnel Management	67.7	25.8	6.5

6.2 The Hewlett Packard Perspective

The Forgionne study is relatively elderly, being published in 1983. While figures for the use of modelling in different business contexts are often published in management science textbooks, they generally appear either older than Forgionnes, or lack either details of the protocols from which the data was generated, or even a source. Resources were not available to rework Forgionnes study in a more modern context (and Forgionne himself has not updated the work [25]), however it was possible to rework the study within Hewlett Packard.

Since 1983, the widespread adoption of the personal computer (there are more than two machines per employee on average within HP) was expected to have had some effect on the survey, specifically in the case of the spreadsheet.

Seventy five surveys were distributed to research and development, marketing, manufacturing and treasury managers. These were broadly based on Forgionne's study, however some additional categories were added and others removed[3]. Followed up by telephone or personal interview, fifty nine of these were returned, completed correctly and usable in the survey. Summaries of these findings are shown in tables 3 and 4.

The results were in many ways very similar to Forgionnes. A majority (more than two thirds) gave 'good' or 'excellent' effectiveness ratings to management science and operations research. 74% stated that a major benefit from implementing MS/OR was access to useful data, and other benefits identified included

1. helps document the problem (63% of respondents)
2. helps define the problem (68% of respondents)
3. helps identify relevant policies (71% of respondents)
4. provides a useful test laboratory (45%)

Again, despite these positive findings, substantial numbers (approximately 65% of the survey) described poor communications between analysts and management, and the lengthy completion times for such projects as significant barriers.

What is clear from this survey is that models and modelling is widely used throughout the company. These results are also very conservative. If we look at the number of respondents citing 'spreadsheets' in their teams, 97% are using them on a regular basis. What many respondents do not know (and should not need to in an ideal world) is that many of their spreadsheet models are built on the top of linear programming, simulation and statistical analysis. The wide acceptance of such techniques might make their application across multiple functional areas possible with an appropriate presentation style.

[3] Experience shows that few people care for surveys and their apparent relevance, combined with their length has a direct bearing on the probability that they will be returned

Table 3: The utilisation of management science and operations research methodologies within Hewlett Packard (2001), all quantities rounded up

Methodology	Frequency of Use (% of Respondents)		
	Never	Moderate	Frequent
Spreadsheet	3	40	57
Statistical Analysis	1	27	72
Computer Simulation	0	37	63
PERT/CPM	4	53	43
Linear Programming	45	27	28
Queueing Theory	53	40	7
Nonlinear Programming	60	27	13
Dynamic Programming	53	27	20
Game Theory	43	39	19

Table 4: Areas where MS/OR methodologies are applied within Hewlett Packard (2001), all quantities rounded up

Area	Frequency of Application (% of Respondents)		
	Never	Moderate	Frequent
Project Planning	19	40	41
Project Review	87	10	3
Capital Budgeting	15	17	68
Production Planning	1	41	57
Inventory Analysis	36	57	7
Marketing Planning	49	33	17
Quality Control	8	61	31
Engineering specifications	3	21	76

7 Issues

7.1 Model complexity

> *I should like to ask the same question that Descartes asked. You are proposing to give a precise definition of logical correctness which is to be the same as my vague intuitive feeling for logical correctness. How do you intend to show that they are the same? ... The average mathematician should not forget that intuition is the final authority.*
>
> *Barkley Rosser*

Within programming and programming like technologies (such as silicon design), there has been a long standing debate on the role of mathematical proof in the construction and validation of systems. What has become clear from the arguments that have raged backwards and forwards over the last thirty years, is that the process of proof is a highly social process, in which what is discussed and debated (in an appropriate vocabulary) is confidence in results [26]. What has also been comprehensively demonstrated is that it is trivial to build complex structures (models or programs) whose detailed behaviour is beyond both proof and, as whole, understanding.

These observations have lead to significant changes in the way that many mathematicians approach the problem of description, validation and modelling. Rissanen [27] has suggested an equivalent to Occam's Razor - the *minimum description length* principle - essentially stating that the best model is the simplest and the shortest[22, 28, 29]. Unfortunately in practice, this seems to be forgotten quickly, sometimes because users appear to confuse detail with accuracy, sometime because users do not have a clear idea of what they will ultimately want to use the model for. A model that describes and explores the effect of stage latencies within a particular form of supply chain is likely to be of a very different form than another which describes the variations in demand of a particular service based upon the general economic climate. While both may be simultaneously useful to the business planner, attempting to describe and analyse them simultaneously may well be intractable, at least for the non domain expert.

7.2 Model politics

The second issue that appears to reduce the exploitation of models within corporations is the politics that go alongside them, and the potential that models whose construction and behaviour are not transparent have to deceive. Schrage, in his otherwise undistinguished book, *Serious Play* [24], makes the very good point about the use of spreadsheets[4] - they have a short and dishonourable history as means of obfuscation. There is little doubt that other forms of model have the potential to play an equally opaque role in the making of decisions.

This suggests strongly that for a model to be trusted, both the assumptions and the means of creating and presenting models should be transparent to **all** users of the system.

[4] Spreadsheets are after all just a style of model construction and presentation. As many of the assumptions and calculations that occur 'behind the cells' are not made obvious, we could re-write Mark Twain's adage as 'lies, damned lies and spreadsheets'.

7.3 Desirable properties

It is clear from the discussions above, that many managers have problems in both understanding the models created and assessing their implications. There is also a suspicion that the assumptions implicit in the construction and manipulation of such models could hide important details. From this we can speculate on the properties that a successful representation and manipulation system might have. The models must be

1. easy to create and apply – preferably the mathematician should be taken out of the analyse, model, experiment loop, this has been achieved for programs;
2. believable – the results from these models must be obvious enough to be accepted by their users and clients;
3. widely applicable - if possible through the use of templates;
4. applicable across multiple domains of expertise.

8 Conclusions

Models are widely accepted within industry as tools in the exploration of business structures and processes. Spreadsheets - the most widespread presentation style are familiar to the vast majority of individuals surveyed as part of this work. At the same time, large scale models, while still respected, are generally considered to be expensive to develop and maintain. Sharing models, while common within functions, is not commonly used as a means of communicating across functions. Moreover, models do not appear to play a significant part in project reviews within Hewlett Packard, despite their recognition at the project planning stage. The primary obstacles to model use appear to be complexity, real or imagined, and perceived cross functional applicability.

The work within the Model Based Analysis team (possibly it should be called the systems exploration and modelling group) in SSRC aims to provide disparate groups with a means of constructing lightweight, useful models of systems, which can be manipulated, communicated and understood by a wide range of stakeholders. As well as tools and mathematical technologies for representing these systems, the team is also responsible for developing and testing processes (in particular the Rapid Systems Prototyping Methodology), as well as using these techniques for consulting within the extended company.

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