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The Quest for the Qualitative: New Directions in Planning Theory and Analysis

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Introduction

"The main role of models is not so much to explain and to predict - though ultimately these are the main functions of science - as to polarize thinking and to pose sharp questions"
Mark Kac's, 166, 1969, p.699.

The main thesis of this essay which is embodied in Kac's quote involves a reinterpretation of the traditional role of models in planning. In essence, what began some two decades or so ago as a quest to develop mathematical models able to predict various characteristics of urban structure is no longer central to the concerns of urban planning. The hope which was held out that such models might enable urban problems to be understood and at least alleviated has faded as plan-making has changed in focus from technical towards political, from macro to micro, from idealist to realist concerns. Yet contained within this reorientation lie the seeds from which new goals for modelling in planning might spring and it is this history of learning about the limits to modelling which serves to refocus the field. It is proposed to explore these possibilities in this paper by showing how the history of this field has engendered a new understanding concerning the role of theory and models in planning, a history which is referred to here as the evolution of planning models.

It is a *sine qua non* of modern philosophy that our approach to abstract knowledge is a function of the times in which we live, and that social problems and aspirations guide the development of reliable and useful knowledge. That we live in an age of uncertainty in which everything seems connected to everything else in diverse ways is becoming a widely accepted assumption in social problem-solving as well as widely accepted experience, and this accounts for the dramatically changing problem focus in urban planning in the last 20 years. Mathematical models of urban structure were first developed at a time when it was felt that a more abstract approach to spatial structure could lead to plans which improved the efficiency, and hence the 'wealth' of our cities. Furthermore the tacit assumption was made that these spatial dimensions of urban structure could be understood in relative isolation of more micro factors which underpinned them, and moreover that manipulation of certain spatial chracteristics in cities could achieve certain commonly held social goals relating both to efficiency and equity. The assumptions were unrealistic, naive as they must always be in hindsight, for urban planning problems appeared to have a chameleon-like quality as efforts to understand their causes were intensified. Other difficulties such as those concerning the logistics of making models work clouded these issues but nevertheless led to similar conclusions, and thus modelling today is largely an academic preoccupation.

Many critiques of this experience have been written (see for example Batty, 1980) but a few have sought to explore the difficulties of developing hard knowledge of urban systems in more philosophic terms, and none have really tried to identify the new challenges which have emerged within a field which has become highly institutionalised. In this essay the emphasis will be on the more positive aspects of the modelling experience and on limits to explanation and prediction which have been learnt by modellers. It is hoped to show how these realisations have led to a new technical synthesis within the field and to a burgeoning concern for 'relaxing' the assumptions of modelling in the quest to explore current problems of planning from this vantage point. As much as anything, these developments are contained within notions about qualitative rather than quantitative modelling which tend to emphasise speculation rather than prediction and soft rather than hard approaches. It is proposed to illustrate these ideas using the now well-known idea of catastrophe theory and more generally to embed these ideas in concepts relating to discontinuity and crisis set against a background, it might be added, of a fairly minimal understanding of the problems involved. This reveals another theme of this paper; that to be useful models of urban systems should not assume a coherent or even necessarily consistent theoretical base.

In the next section we will begin with a brief sketch of the conventional uses of models in planning, illustrating the origins and progress in the field over the last 20 years. The British experience will be discussed as 'a dream turned sour', an experience in which problems began to shift and a reaction occurred against the conventional wisdom. Questions of prediction, in particular of the predictability of urbam systems, will then be addressed and certain logical limits to any modelling activity in the social sciences will be mentioned. The emergence of new modelling ideas will then be presented, the remarkable technical synthesis of conventional models will be examined and then the quest for qualitative modelling emerging from mathematics will be followed.

Abstract
This paper argues that new methods of understanding current planning problems might be found in recent advances in qualitative structural analysis. The case for qualitative rather than quantitative analysis per se is presented in terms of the history of systematic modelling in plannning, and these ideas are illustrated using the popular development of catastrophe theory applied to problems of urban riots, and land speculations in the central city.

Keywords
qualitative; prediction; models; catastrophe; theory

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Catastrophe theory will be illustrated using the analogy of urban riots and finally a preliminary application of these qualitative concerns will be described in a model of property speculation and community action in an area of inner London. Finally future directions for the evolution of planning models will be sketched.

Models in Planning

The word model has fast become part of our popular vocabulary and therefore it is rather important to define the term as it is used in planning. Models are necessarily simplifications as is all articulated knowledge. But it is their use in the process of producing abstract knowledge which defines them best. Harris (1966) says:

'A model is an experimental design based on a theory'

which really emphasises the notion that a model is a translation of a theory into a form which can be used for prediction. Others define models through their role in science. For example Greenberger, Crenson and Crissey (1976) say of a model:

'It is an instrument for the intellectual management of multiple relationships among complex phenomena'

and this is also consistent with Harris's definition.

The role of prediction is very strong in conventional uses of models in planning. Some 20 years ago, articles and comments proclaiming the need for models continually stressed the idea that models represented 'artificial laboratories' where predictions could be made, and 'model' cities could be rearranged without any effect on the real thing itself. The ethical point concerning the undesirability of social experimentation underlies this notion but the fact that such models could be manipulated in their artificial laboratories - the computer - was tacit recognition that such models could be used prescriptively. In one sense the use of models in physical science is based on the same logic although the need to make predictions in laboratory settings indicates more that the real world may be inaccessible for making such predictions, rather than predictions on the real thing being undesirable. Of course this boundary is blurred within the biological sciences.

The development of models in planning was (is) coupled to ideas concerning the planning process and in particular to the development of the systems approach to planning. The concept of a system and a controller, the two being juxtaposed so that a system may reach a goal, is central to this approach. Within planning it has been assumed that models represent caricatures of the system whilst the planning process represents the controller. Although controllers usually exist inside systems in an engineering context, from the viewpoint of planning models are considered as existing within a more loosely structured process of control or planning. Thus within the planning process models can be used at any point where reference to the existing, predicted or prescribed system is made. That is to say models can take on purely passive roles a descriptors of the system, thus aiding understanding or analysis, or they can take on more active roles in prediction or prescription.

In fact most models in planning have been developed for predictive purposes, predicting the system of interest under various conditions. This use however has often been within the prescriptive or design phase of the planning process. A favourite strategy has been to generate alternative plans through *ad hoc* or semi-system means on the assumption that these designs contain both 'inputs' and 'outputs' consistent with those required by various models. These models have then been used predictively to assess whether the planned 'outputs' are *consistent* with the inputs. In certain cases only input levels have been designed and in such cases models have been used to predict directly the consistent output levels, thus 'elaborating' the plans (Boyce, Day and McDonald, 1970).

There is however another class of models which are essentially design models. These are based largely upon mathematical optimisation theory and invariably pay only scant regard to their consistency with any underlying urban theory. Such models are entirely presriptive and have not been widely developed in planning owing to the intrinsic mathematical difficulties of representing the objectives of and constraints on planning in acceptable ways. Moreover their use has also been hindered by the lack of logical procedures involved in the solution of such models, yet there have been some interesting developments. Perhaps the most fruitful has been the quest to embed such optimisation ideas into more conventional predictive models although the narrowness of the optimisation in question has always inhibited their practical use. Nevertheless some remarkable synthesis of scientific and design modelling in planning has occurred and this will be referred to later.

The Origins of Urban Modelling: The Problem-Orientated Focus.

The increasing scientisation of social science on the one hand and the development of the systems approach on the other are well-known to most planners and now form part of conventional planning history. But the rudiments of these stories are both worth retelling in so far as they will guide the ideas introduced here. There are many origins for the systems approach in general, the need for some unification within the sciences was a prime motivator, but the application of these ideas in the urban realm was largely due to an awakening of consciousness on the part of planners, with the realisation that cities were (are) enormously complicated artifacts. Moreover spatial, economic and geographic theory suggested a visible order to such complexity, hence the possibility of a useful theory of the city for planning. Models originally emerged from those aspects of urban structure which exhibited the most obvious order - traffic - but during the 1960's a variety of extensions were made to other spatial and aspatial domains.

The increasing scientisation of social science had a rather different impact. The social sciences have always lived in the shadow of the physical sciences, particularly of physics and mathematics, and the immense progress in these areas at the turn of the century had an accelerating effect on the process of scientisation. A logical and perhaps inevitable consequence of these developments was the growth of applied social knowledge in the form of policy science which became significant in North America from the 1950's. But it was developments in computer technology which really made modelling possible. From traffic models in the 1950's came land use models in the 1960's. A reaction occurred in North America in the late 1960's as anti-technocratic, anti-political movements were formed. In the United States, this reaction was polarised in Mel Webber's immortal phrase: 'If we can get to the moon, why is it that we can't get to the airport'? The 1970's saw a slow revival of modelling activity which had become quite widespread again by the end of this decade.

Elsewhere the history was similar. Massive enthusiasm for modelling at first, followed by disappointment when it was realised that models could not produce instant answers. The myth and the magic were quickly dispelled, a reaction set in and modelling was confined to the universities and the think-tanks. This is the situation in Britain today. After the great euphoria of the 1960's and the development of optimistic planning legislation, a reaction set in as planning problems were increasingly linked to the collapse of the economy and associated increasing economic inequality. Similar sorts of histories can be found in Australia, South America and continental Europe (see Simmonds, 1981).

The types of model which were developed provide an instructive and illuminating portrait of the reasons for their initial development and subsequent application. Models by their nature represent formalised abstract knowledge and in this context are mathematical in their structure. In essence such models were developed according to the usual scientific process in which some attempt at their validation is made before they are used in prediction or prescription. Mathematical validation implies statistics and statistics are built around the law of large numbers. It is a simple step to accept the point that such models were invariably macro in theoretical scope, concerning spatial and other structural configurations of urban land use and economic activity. Micro-models have rarely been developed although there are now consistent links to micro-theoretical foundations for many macro-models. Thus the models which have been developed can only address a narrow range of problems in planning, at the strategic land use-transport level and regional levels but seldom at the more local levels.

Another set of characteristics defines the types of model produced and these relate to size. To develop such models in the first place strong and often untenable assumptions had to be made and the resulting models were frequently large, rambling, certainly inelegant structures characterised by brute force computations. Lee (1973) in his famous critique develops these points to a degree but critiques based on size involving the overambitious nature of models always tend to obscure the central point that such models are usually built in a theoretical vacuum. The historical origins of urban modelling clearly lie in problems rather than in theory; that is to say, such models were initially motivated by a concern for developing new tools to handle complex issues and the fact that such issues were seldom explicable in terms of well-tried social theory meant that the models which resulted were based on a mix of commonsense and that rudimentary theory which seemed applicable at the time. Of course what has happened in modelling is that the problems, or rather their perception which originally motivated the field, have now changed but once the field was started it soon became institutionalised. Thus work has continued in the confines of academia.

The institutionalisation of the field is to be seen in a number of developments - the critiques and counter-critiques which have flowed freely over the years, the growth of research articles, and later of text books, the development of courses devoted to the dissemination of such knowledge, and the establishment of a technical research focus. All these developments indicate a community of researchers who look at cities through the 'eyes' of their models, although it must be said that the field is not now wedded to problems in practice which originally motivated it.

The British Experience: A Dream Turned Sour.

If you accept the idea that any distinct body of knowledge is a function of its social context it is not surprising that a field which was initially so problem-orientated is left high and dry when the tide turns - when new problems and new perceptions fire the emotions of those empowered to change society. Sometimes such changes are cynically dismissed as fashion but a closer analysis of the phenomena reveals that it is an intrinsic characteristic of all ill-defined areas of knowledge. The 1960's in Britain represented a time of relative prosperity and although there was a sense of the impending economic catastrophe, the notion that prosperity would continue to increase was widley held as long as society developed more efficient organisationally. Part of this attitude was also the idea that society was becoming more complex and the usual bureaucratic response to information overload - the creation of new rather than the re-creation of old institutions - was dominant. In planning such complexity was hailed through new planning legislation introducing several fairly abstract notions such as 'Structure Plans'. Models fitted well into these new ideas for such plans depending upon broad locational strategies, and models could thus provide such predictions while at the same time recognising a level of complexity and order greater than existing techniques. But as with models, such plans were built largely on shifting sands for there was little substantive or procedural theory to guide their preparation.

Almost as soon as this new style planning came to be implemented problems arose. Strategic issues invariably could not be phrased in spatial terms, and although the situation with regard to accepted spatial theory was rife with ambiguities, aspatial or non-spatial theories of the city were virtually non-existent. Planners were pushed back on their experiences once again, and their working environment, which was dominated by political issues, became the central force in guiding plan preparation. Moreover as the economy worsened, planning began to change from its focus on allocating growth to one of managing decline, from a positive, idealist force to a negative, realist force, from a concern with prescribing for change to one of managing such change.

As the drive for economic growth of the 1960's changed to the management of economic collapse, questions of spatial equity were heightened. Spatial efficiency no longer seemed important and in any case it had never been as easy to measure such issues as those of equity. This involved a shift in scale too. Problems of equity were postulated at the individual level in contrast to questions of efficiency which were always posed in more macro terms. A concern for seemingly more tractable local issues was once again voiced by the planning profession although much more in terms of the politics of local change and the management of resources rather than in terms of the traditional concerns of design. Moreover this emphasis was reinforced as cuts in public expenditure were greeted first by the abandonment of the more abstract, less manifestly useful branches of planning.

During the 1970's, a new theoretical approach to urban issues emerged. Planning as a subject of study became less and less technical, and more and more a branch of social science in which planning as an activity came under scrutiny. Design in the physical, architectural sense was lost in the late 1960's but now the broader, spatial type of design was threatened. The IN(39)treatment in planning schools became more macro-scoiological with a concern for the political economy of cities in the broadest sense. Cities were seen as conflict generating structures and planning as essentially a political game. The emerging focus on land emphasised the imperfect nature of the local economy and local state and the idea that cities could be treated as market economies was quickly forgotten. All these cemented the reaction against modelling. Those agencies who did build models conveniently laid them aside while the model-building community noticeably aged as it failed to attract new recruits to the cause.

With respect to the models themselves, the types of problems mentioned by Lee (1973) were in evidence but the effort in Britain was clearly more modest. Nevertheless, there was a credibility gap. Model performance was generally poor (Openshaw, 1978) and problems of data inevitably were present. Many models never reached the design phase of the planning process, the effort in calibrating and making even simple predictions with them seemingly too great. In fact the field turned in on itself. More than enough technical problems had been generated along the way to provide a lifetime of research for many modellers and thus the field began to look towards geography and regional science rather than planning for its base. In short although a remarkable technical synthesis has been achieved with conventional models in research terms, the field has not responded to new 'practical' problems. Others have responded but modelling has not featured. The thesis to be promoted here is that the field could in fact have done so and indeed there are now signs that at last it is so doing, but during the 1970's when the going got rough, modellers moved towards more technical concerns and away from policy, at least in Britain.

The Ambiguity of Prediction.

In one sense the demise of modelling in practical planning can be traced to a lack of a thorough appreciation of prediction in the context of social systems. Some would say that this failure to appreciate the nature of social prediction shows naivety, perhaps technocracy, but this cannot be so. The nature of social prediction is barely understood and the disarray in which social science finds itself is sufficient testament to this. On the other hand in the philosophy of science, good theory is invariably regarded as being predictive as well as descriptive. Some go as far as to say that theory is only scientific if it is predictive but others argue that as prediction does not constitute explanation this can never be the sole criterion for science. Nevertheless the ability to make accurate predictions is widely regarded as a hallmark of science.

In attempting to assess whether or not models in planning can ever hope to achieve the predictive power of their counterparts in say physics, it is important to examine scientific prediction in some detail. In fact it can be easily shown that good scientific prediction is a highly localised affair. Nobody for example could hope to predict accurately the crash of a particular wave or the impact of throwing a particular stone into a particular pond - there are just too many factors involved. But it is possible to go a long way in science with simplified models of such systems. Indeed if the problem is sufficiently tractable in that it can be effectively isolated from the myriad of natural influences, it is often possible to build models which give almost perfect predictability.

Most physical systems do not meet the strict requirements posed by a model with perfect predictability. For example, Popper (1963) argues that accurate prediction is only possible in physical systems which are isolated stationary and recurrent. He says: 'Contrary to popular belief, the analysis of such repetitive systems is not typical of natural science'. Clearly if the predictability of physical systems of any complexity is in doubt, the variation in phenomena such as urban activity is likely to be such that only the most narrow types of prediction are possible. Relative independence of the activity being predicted from its environment, its context, is almost impossible to secure in urban systems and thus predictive modelling is unlikely to be particularly impressive. An excellent example of such notions is contained in the use of retail models to predict the impact of hypermarkets. Such retailing behaviour is relatively well-ordered but a variety of studies have shown that such behaviour is not independent of the configuration of retailing activity to which it relates. Thus when new facilities are introduced, retailing behaviour changes, adapts.

This is the crux of quantitative prediction in planning. The system must be sufficiently closed for a good approximation of its behaviour to be possible, and the behaviour in question must be a sole function of the input variables to the model. This is invariably never the case for it is well-known that prediction itself is a function of the behaviour being modelled, i.e. that predictions of behaviour influence the behaviour itself. Statistical models for example will always fail on this criterion for their essence is the selection of a model which is based upon the most limited set of variables possible. However in social systems it is *always* possible to suggest a facet of behaviour, a variable, which could influence the model but is excluded from the model. Of course such a variable may not have had any effect upon the behaviour in question so far, but the fact that it could have is sufficient to indicate the fundamental weakness on which all social theorising and modelling rests. Most models should be tested for closure in this sense to ensure that additional variables could not effect the prediction in any future as well as past context. Even in physical science this is an impossible criterion to meet but nevertheless there it is possible to meet it to a degree.

In a sense these difficulties are known but it is often difficult to act upon them. The obvious conclusion is to begin to use models in a rather different way from their sole use in prediction; to use them to inform what appear to be the most critical issues influencing a situation, in Kac's words, 'to polarize thinking and to pose sharp questions'. For example, the idea that qualitative rather than quantitative invariance may form a more useful focus for urban models is very much in this spirit of developing models for exploration, by qualitative invariance meaning a broader form of invariance than quantitative in that it is the characteristics of the system which must be preserved by any prediction. Some define qualitative as direction without magnitude, others define qualitative change as fundamental change in a system's characteristics. There is no standard definition.

Moreover the sense in which qualitative prediction implies a relaxation of hard measurement also poses problems. Rutherford's dictum: 'Qualitative is nothing but poor quantitative' echoes down the years and certainly in physics has a 'prejorative ring' (quoted in Thom, 1975). Qualitative is often regarded as an uneasy aggregation of quantitative, and this is clearly seen in those developments of models which represent structure in binary terms for example. Nevertheless although difficult to define, qualitative modelling does suggest a range of problem applications in planning more relevant to curent concerns. Therefore in the rest of this paper some examples of these developments will be indicated.

New Techniques of Modelling.

The changing focus of British planning and its effect on urban modelling has been briefly alluded to in that the problems which initially motivated modelling have long since disappeared, or at least been put aside. Problems of economic efficiency in land-use/transportation terms gave way to a focus on inequality, on problems of housing and income, on the poverty trap, on land speculation and ownership, on local unemployment and deindustrialisation. In short, the collection of problems loosely referred to as forming the 'Urban Crisis' found little use for traditional models, with perhaps the exception of problems involving energy. The focus in planning is clearly now more micro, more local, more sociological and political in emphasis with little feeling that the technical structuring of such issues is desirable even if it were possible.

There is one obvious reason why models have not been developed to inform such problems, and this involves measurement. Usually such problems are quite difficult to specify and there is considerable ambiguity over the variables which might detect their key characteristics. Moreover, such problems are often seen as the outcome of rather intricate urban social and economic processes, and are less easy to 'isolate' in any systematic way. If it is possible to rationalise their structure, this can only be done in verbal/logical terms, rarely if ever in algebraic or even arithmetic terms, and thus these problems seem to resist a modelling focus. Nevertheless, such problems usually do have a structure which is amenable to systematic description and as more structural models which are clearly gross approximations to quantitative models become better developed, there are possibilities. Roberts' (1976) work on energy is indicative of what is feasible in this area.

Two major developments in modelling technique which have occurred in planning during the last decade are well worthy of mention, the first building on conventional ideas, the second coming from outside the field. The remarkable technical synthesis within conventional modelling already referred to is the first of these developments, and this has been achieved entirely with respect to technical problems defined from the models associated with land-use/transportation planning. In essence, this synthesis relates to the link between the development of scientific models and design models, between predictive and prescriptive models. It is a well-known mathematical fact that for any consistent set of equations, it is possible to find an objective function and constraints which will generate such a set through optimisation. The synthesis referred to uses this fact to link prediction to prescription. Many predictive models can be generated statistically using maximum likelihood, entropy maximisation and so on while certain economic models are based on utility maximisation. Frequently such optimisations are used only as a convenience in generating models but the synthesis referred to makes more literal interpretations of the optimisation functions and processes. Entropy and utility functions are thus seen as functions with a collective or global meaning and have been linked to more general issues of welfare. Moreover, there has been a related quest to link a variety of statistical models to their micro-economic foundations while at the same time developing such models at a degree of disaggregation appropriate to standard statistical estimation. These developments are also consistent with the synthesis through optimisation.

There have been developments in more qualitative structural modelling which in essence embody a relaxation of the quantitative, and these have found considerable application in the design phase of the planning process. However the really dramatic developments in qualitative modelling have come from outside the field of urban modelling itself, from mathematics in fact. It is perhaps a little sobering to reflect on the fact that the momentum of any field rarely continues for ever, and it is now clear that any new momentum in urban modelling is not coming from the planning problem focus which originally inspired it but from mathematical modelling in general. The drama which has been referred to originated from topology, that branch of mathematics which deals with the geometry of relationships or structure. In essence, this new approach to qualitative modelling is built upon a theory of change which emphasises discontinuity and in particular it marries the theory of change based on differential analysis to topology, thus emphasising classes of system which are qualitatively equivalent. Discontinuities, or catastrophes as the original innovator in this field, Rene Thom calls them (Thom 1975), occur when there is a qualitative change from one system into another.

Catastrophe theory, CT as it is called, can also be seen as the outcome of a dynamic optimisation process in which the state of any system is an equilibrium solution of a potential function with respect to a number of independent or control variables. Occasionally, more than one solution might exist and it thus becomes possible for major changes of state to occur for very small changes in the control variables, hence the idea of discontinuities or catastrophes. Thom argues that such changes in state represent qualitative changes which occur when the system moves across barriers between states which are topologically equivalent. Such changes are infrequent in comparison with the normal states in which such systems can be found.

The Quest for the Qualitative: Soft Urban Modelling.

One characteristic of catastrophe theory lies not so much in the view of change with which it is associated but in the way it has been developed. Here is a development which has not been inspired by practical problems but by science itself, initially by mathematics, then biology. Yet the theory shows all the signs of being immensely useful as a means of articulating real urban problems. It provides a magnificent example of Kac's point that models are primarily useful in polarizing thinking and defining sharp questions. And it is in such uses that new ways of examining the current urban problems of social and political conflict can be found.

As alluded to above, catastrophe theory is best illustrated using rather specific physical problems, for example those in which the state of any system can be found as the solution to the minimisation of a potential function, an energy function, with respect to its independent or control variables. The idea is that the dynamics of minimisation are rather fast in contrast to changes in the control variables. Thus for a judicious choice of temporal observation unit, the system may always appear to be in equilibrium. However multiple equilibria may exist and if so it is possible that a small shift in control could lead to a switch between equilibria of dramatic proportions, dependent of course upon a certain topology defining the set of solutions.

Thom's (1975) mathematical contribution has been to show that for any number of state variables, and up to four control variables, there are only seven topological types of discontinuity which can occur. These are known as the elementary catastrophes which correspond to points of singularity on the function associated with minimisation of the system's potential. Of course, more complicated catastrophes can exist for up to four control variables but these are built from the elementary ones. To illustrate the idea, let us look at the best-known catastrophe, the so-called cusp catastrophe in which the state of the system, variable x, is a function of two control variables u and v. Thom proves that the potential function V(x) for such a system is no more complex than a quartic equation of the following form:

$$V(x) = x^4 + ux^2 + vx \quad (1)$$

where u and v are control variables. Equation (1) is 'structurally stable' in that it meets certain mathematical requirements into which a large class of 'real' systems can be mapped. The equilibrium of the system is given by the solution to:

$$\frac{dV(x)}{dx} = 4x^3 + 2ux + v = 0 \quad (2)$$

for x, u and v, and thus equation (2) gives all possible states in which the system might exist. As equation (2) involves a polynomial of the third order, it is possible that it may have up to three real solutions for given values of u and v. Thom shows that these solutions are given by the set of values bounded by the set of singularities in equation (2), that is by:

$$\frac{d^2V(x)}{dx^2} = 12x^2 + 2u = o$$

and the so-called bifurcation set which is associated with the singularities given by equation (3) can easily be shown to be those values of x for which $8u^2 + 27v^2 = 0$ holds.

The ideas underpinning this example are profound although the mathematics are very simple (Saunders, 1980). Indeed the geometry of the problem is highly illustrative and to fix ideas let us consider a rather topical problem to which this cusp catastrophe can be applied. Consider a poor area of a city, the inner city for example, where the level of civil disorder x is regarded as a problem. It is hypothesised that there are two variables influencing the level of disorder - v, the degree of tension in the community measured by the level of policing, and u, the degree of alienation measured by the level of unemployment. We will also assume that the function relating these variables is of the type V(x) in equation (1) and that the system always attempts to minimise the level of disorder for any combination of control variables as shown in equation (2). These are brave assumptions, perhaps untenable, but they do illustrate the point that such a model of civil disorder is consistent with the occasional outbreaks of rioting in such areas of the city. The model was originally suggested by Zeeman et al. (1976) and applied to the 1972 Gartree prison riots.

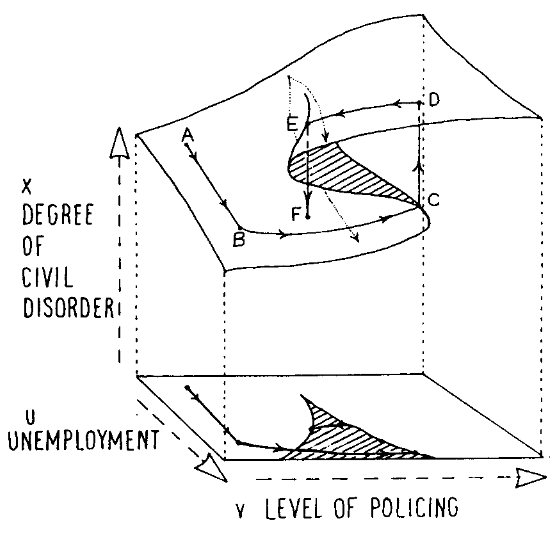

Figure 1: A Cusp Catastrophe Model For Urban Riots

The idea that such models generate catastrophes can be dramatically illustrated by showing the form of the solution set to equation (2). In Figure 1, the vertical axis represents the state of the system, the level of civil disorder, while the two horizontal axes u and v represent the control variables. The graph of x as a function of u and v is clearly double sheeted, for certain combinations of u and v given by equation (3), 3 solutions for x are possible. Two of these, the largest and smallest, are stable in that these correspond to minima of equation (1), and the third is a local maxima which is unstable for potential minimising systems. The bifurcation set (where multiple solutions exist) is projected onto the control plane in Figure 1 and its cusp-like shape indicates the origin of the name of this catastrophe.

A number of points can be made. The axes of this graph have no quantitative meaning, only the order of points is important; that is to say, whatever the values of u and v, the behaviour manifold (x in terms of u and v) will be double sheeted as in Figure 1. Moreover a path traced on the manifold or on the control plane indicates a succession of u-v values or a behaviour of the system. This is the slower dynamics of the system which represents a succession of equilibrium states. v is often referred to as the normal factor while u is a splitting factor in that changes in u for fixed v in the region of the cusp or fold can lead to a divergence of behaviour onto the bottom or top sheet as indicated by the broken line in Figure 1 (Zeeman, 1976). There are other aspects to this model. The area linking the upper to lower sheets is often referred to as inaccessible, and the notion of bimodal minima in equation (2) has been exploited. These will not be further developed here.

It should now be fairly clear from Figure 1 how discontinuities in the state of the system occur for changes in u and v. Imagine an inner city area with a very low profile method of policing - community policing as it is called in Britain - but with a rising level of unemployment. With unemployment rising and many more people on the streets, the policing policy comes under review. A tougher line is adopted, perhaps with a new police chief involved and tension increases dramatically, up to the point where there is a riot. The behaviour of the system can be mapped onto Figure 1, starting at A then to B, and then to C at which the tension explodes the system in a riot. The system is then at a high level of civil disorder (D) and remains so until there is a dramatic reduction in the level of policing (to E) and quite suddenly the level of disorder drops back to its earlier level (at F).

This cycle of behaviour and the fact that the dramatic increase in disorder (the riot) occurs at a different point from the decrease in disorder, is called hysteresis, and it is the product of a delay convention in which the system is intrinsically conservative and takes time to respond to change. Moreover because the behaviour manifold maps out the set of possible solutions or states of the system, it is possible to use the model prescriptively to show how changes of 'control' can lead to 'riots' being avoided. Of course it is no accident that I have presented this model of inner city riots to illustrate the general idea for it is well known that similar riots took place in many British cities in the summer of 1981. The model does not provide an explanation, nor does it provide hard predictions or prescriptions. It gives only a framework in which one can continue to articulate the factors responsible for such riots. These are more elaborate catastrophe models which might be nearer the mark but nevertheless it does pose sharp questions.

There has also been considerable criticism of this somewhat cavalier approach to modelling. Sussmann and Zahler (1978) are adamant that applications such as the one sketched above imply a post hoc rationalisation of catastrophes, and they argue that such ideas are positively misleading. There is some dispute too between the originator Thom, and the populariser, Zeeman over the degree to which such models might be 'fitted' to real problems. There is considerable disquiet over the widespread popularity of the easily visualisable cusp catastrophe as used for example in the book by Postle (1980). But all in all, the great value of ideas such as these is in providing a framework for difficult-to-measure but nonetheless important variables in any problem. And there are even connections back to more mainstream urban modelling (Wilson, 1981) which illustrate the widespread influence of catastrophe theory.

Modelling Urban Crisis.

As a final illustration of these ideas and to emphasise the direction in which models in planning might evolve, let us consider using the cusp catastrophe to articulate a 'real' problem of property speculation and compulsory land acquisition in an area of central London. Between the late 1950's and the mid 1970's there were a series of crises concerning land speculation in the area of Euston known as Tolmers Square (Wates, 1976). A succession of attempts by the local authority, Camden, to bring this land into public ownership by compulsory purchase were rebuffed by central government due to the costs involved. However eventually a successful bid was made which was sanctioned by central government but only after massive political pressure at the community level and the election of a central government wedded to the idea of the public ownership of land. Essentially this succession of events to buy the land in question can be modelled as a succession of hysteresis cycles - a succession of attempts to induce a qualitative change in the system which eventually succeeded. To really appreciate the extent of this qualitative change, it is only necessary to compare the area's present redevelopment with the form it was originally developed in, which lasted by and large for some 80 years.

The cusp catastrophe has been chosen largely because of its easy visualisation, and because it seems the simplest model which captures the essence of the problem. It is by no means the only catastrophe model, and certainly there are other ways of modelling the problem (Batty, 1981). Two control variables are involved: u is the normal factor - the level of political pressure in the system, while v is the splitting factor - the ease with which the local authority, Camden, anticipates its getting loan sanctions from the central government to buy the land. The state variable x represents the anticipated amount of land in public ownership in Tolmers Square. It is unnecessary to be specific about the scale of values involved but high values imply most or all land in public ownership and low values imply hardly any land in public ownership.

The argument runs as follows: for low levels of political pressure and increasing ease of obtaining loan sanction, the land passes 'smoothly' into public ownership. For low levels of anticipating the granting of loan sanction to purchase the land, and an increasing level of political pressure, the desire to take the land into public ownership drops, and there is increasing likelihood of 'deals' between owners and the local authority over development for the area. For the very easy granting of loan sanction, the level of political presure makes little difference and there is a high likelihood of most of the land passing into public ownership. Finally for a high level of political pressure and increasing ease of loan sanction, the reluctance of the local authority to purchase the land is suddenly accompanied by the possibility of purchasing the land. This could be due to some of the members of the local authority sticking with the old policy, others supporting the new, but due to the inevitable delay in switching from one policy to another, there is a bimodality in behaviour. In fact the inaccessible region means very little in this example, so it could be omitted from the diagram of the problem shown later. Also note that hysteresis cycles in such a model can be interpreted as a request for loan sanction followed by a rebuff.

To ground the analysis, the various events involving requests and rebuffs over the period from 1957 to 1977 have been ordered in terms of their assumed level of political pressure and ease of loan sanction, using the descriptive account provided by Wates (1976). From this account, it is possible to order the events according to the u-v values in sequence using a variety of standard methods. This has been done using Saaty's (1980) procedure and the results of this process are plotted on the control plane shown in Figure 2. This diagram in which the points are connected by straight lines shows a map of the behaviour of the system over the period in question together with a description of the various events. It is also possible to order the events over all combinations of values although this would involve a massive exercise unlikely to yield a radically different pattern of behaviour and has thus not been attempted here.

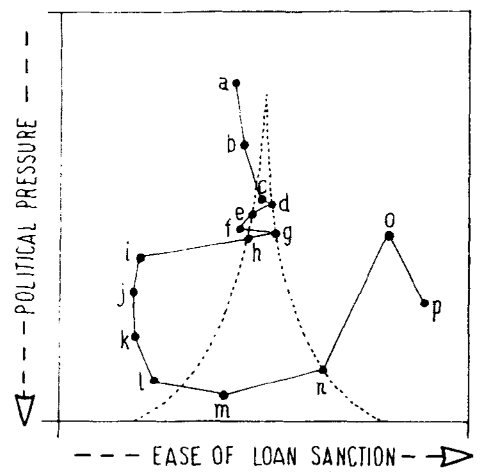

Figure 2: Behaviour of 'Events' in the Control Space for the Tolmers Square Issue.

List of Events.
a. 1957 Rent Act: Tolmers Square Residents Association formed.
b. LCC reject application for office development 1959.
c. Euston Tower Campaign 1962.
d. Application by camden for compulsory purchase order 1965.
e. Loan sanction refused by Government 1966.
f. Camden start negotiations to purchase the land with developers.
g. Camden apply for compulsory purchase order 1968.
h-i Government refuse order; deal with developer 1970.
j. Labour Party opposition grows 1971.
k. Tolmers Square Crisis attracts public eye 1973.
l. New development (Claudius) proposal 1973.
m. Council reject private deal of any sort 1973.
n. Council apply for compulsory purchase order 1974.
o. Order is granted: pressure is off 1975.
p. Camden break agreement on type of redevelopment 1976.

From Figure 2, it is possible to sketch the bifurcation set, and from this it is a simple matter to project the control space into three dimensions to show the behaviour manifold. This method of working backwards, so to speak, results in Figure 3 which also contains a projection of the behaviour pattern of the system onto the sheet.

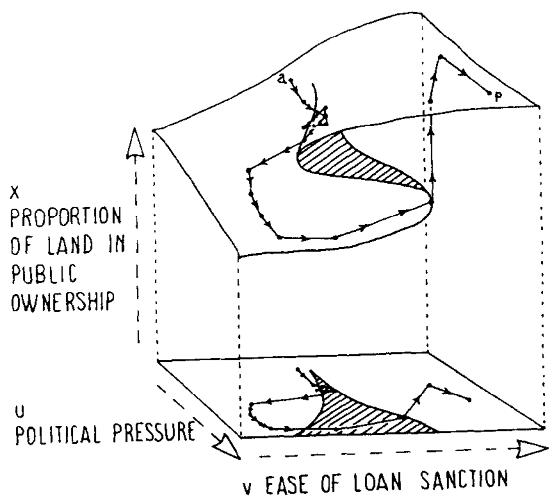

Figure 3: Plots of State Behaviour using a Cusp Catastrophe Model for the Tolmers Square Issue.

The effect of hysteresis is dramatically pointed up by this diagram: attempts to compulsory purchase land in 1965 and 1968 were met by rebuffs in 1968 and 1970 respectively but in 1975, the next attempt was not rebuffed for the central government was favourable to the request, and the system then changed qualitatively. One final point: it is quite clear that Figure 3 can be stretched in many ways as long as the fold in the sheet is preserved, without changing the order of behaviour, and this more than anything else illustrates the idea of qualitative modelling.

One cannot prove that this model is a valid representation of these events but it is certainly consistent with them and it serves to focus on the sorts of variables which appear critical. In a sense, it was constructed backwards and it does not meet the criticisms voiced by Sussmann and Zahler (1978) indicated above. The idea of a potential and its minimisation is speculative but none of this really matters. What matters is that this type of thinking sharpens up the problem where there is a great deal of confusion and ambiguity. In fact more complicated catastrophes in which this problem was embedded could easily be envisaged, for example involving switches of policy once the land had been purchased. Moreover there is also a sense of irreversibility to this set of events not captured by the catastrophe theory model displayed here. But nevertheless the imagery invoked is surely of interest.

Future Directions.

The evolution of planning models is dominated by a process of learning, learning the limits to social prediction, learning to respond to problem shift, and learning to develop new approaches to the problem of interest. A major reaction in planning and in modelling has been to recognise that simple ideas, no matter how elegant, might be positively misleading, and gradually the notion that prophecy rather than conditional prediction is possible is being abandoned. In the process the practical development of models in planning has come to a virtual halt and the field has turned in on itself. A useful technical synthesis has been achieved but there are now signs that the field is reawakening to practical possibilities - to the development of models of a much more qualitative, speculative kind which do not attempt to predict or prescribe for actual events.

This role of models, indeed any mode of analysis in planning based on controlled speculation, is difficult to justify in a practical context but it appears a necessary development for the art and science of planning. More speculation, more pedagogy, more exploration and more counter-modelling are required in planning for only then can problem shift be anticipated and expected. These ideas have also become possible because the constraints on modelling are gradually being lifted. For example, computation is no longer an issue, indeed it is now a positive force in releasing potential for qualitative modelling: graphics, group communication through computers, and the development of participant interaction with computers are all immediately available possibilities which change the way models can be developed and used.

We have entered a different era in which problems seem far too convoluted to be understood through the medium of the single model. Although it is a major aim of science to disentangle the world starting with the simplest problems first, the aggregation of simple to complex, of micro to macro has proven intractable in many fields, and thus it appears necessary to adopt different strategies. Catastrophe theory is one of several ideas which rest upon such assumptions. A more relaxed approach to modelling is sorely required and this is clearly consistent with these newer approaches emanating from mathematics and natural philosophy. Rene Thom (1975) sums it up admirably when he says: 'Finally, the choice of what is considered scientifically interesting is certainly to a large extent arbitrary. Physics today uses enormous machines to investigate situations that exist for less than 10^{-23} second, and we surely are entitled to employ all possible techniques to classify all experimentally observable phenomena'. It is the conclusion of the essay that this view should come to dominate the use of models in planning.

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