Mad, Bad and Dangerous To Know?

The evolution and limitations of the 'generic structure' concept in system dynamics

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Abstract

This paper traces the evolution of the 'generic structure' concept in system dynamics, and discusse the different practical uses to which they have been put. By reviewing previous work on the concep we have identified three different views of what a generic structure is and, hence, what transferabilit means. These different views are distinguishable in practise as well as in concept. Examination c these interpretations shows that the assumptions behind them are quite dissimilar. From this analysi we argue that it is no longer useful to treat 'generic structures' since a single concept as the unity : implies is only superficial. We conclude that the concept needs unbundling so that differer assumptions about transferability of structure can be made explicit, and the role of 'generic structure: as generalisable theories of dynamic behaviour in system dynamics theory and practise can b debated and clarified.

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§1 INTRODUCTION

From its inception, system dynamics aspired to offer an integrative theory of the separate processes of management which would make it possible to evaluate and reinterpret specific cases and experiences, so producing generalisable insights. In the last three to four decades the creation and evolution of 'generic structures', as vehicles for storing and applying these insights, has been one of the ways in which this aspiration has advanced.

Despite the important role that generic structures are seen to have within system dynamics there is no agreed or even precise definition. Paich in his 1985 review of the status of generic structures in system dynamics offered as a tentative working definition; generic structures are "dynamic feedback systems that support particular but widely applicable behavioural insights" (Paich, 1985, p. 127). Senge suggested "generic structures are relatively simple models of dynamic processes that recur in diverse settings and that embody important management principles" (Senge, 1985, p. 791). John Sterman was heard at a conference in 1993 saying "I don't know what one (a generic structure) is but I know one when I see one".

Generic structures also appear to be closely related to several other concepts in system dynamics which we might list. Generic models; "case studies converted to explicit dynamic form" (Forrester, 1980, p. 18) or "a self-contained behavioural theory of the dynamic processes it illustrates. They are a way of storing knowledge and feedback structure of social and business systems" (Morecroft, 1988, p. 314). Elementary structures, simple feedback structures, which can be used "to approach understandings of real-world problems" (Andersen and Richardson, 1980, p. 101). System Archetypes, which Senge identifies as being generic structures; "patterns of structure that recur again and again" (Senge, 1990, p. 94).

The purpose of this paper is to trace the evolution of the generic structure concept and to try to tease out the different strands of thought which have been associated with the concept. In doing so we will examine the different roles which have been proposed for generic structures and the extent to which generic structures have lived up to expectations. We will find that the concept has been overburdened with so many subtleties of meaning and has been used in so many diverse ways that it is no longer helpful to regard generic structures as a unified, or even unifying, concept. We consider it is time to try to unbundle the concept and suggest ways this might usefully be achieved.

§2 THE EVOLUTION OF GENERIC STRUCTURES

Generic structures were not invented but evolved gradually. The twists and turns of this evolution are such that it is helpful to identify at the outset three different facets of the concept which are prominent at different times. Generic structures are models, and as such are theories of dynamic structure and behaviours. Beyond this central question system dynamicists have variously stressed; the relationship between the dynamic structure and the application domain in which it was found, which we have termed **canonical situation models**; the mathematical structures which generate dynamic behaviour, **abstracted micro-structures**; and the behavioural characteristics which are commonly apparent in complex systems, **archetypes for behavioural insight**. The different emphases which have been put on these facets have created three different interpretations of generic structure which are highlighted throughout the evolution story.

Firstly we will discuss the earliest interpretation of generic structures, canonical situation models. Secondly we will summarise a debate on the basis for classifying systems and what is meant by the term generic or general in the context of generic structures. Thirdly we will discuss abstracted micro-structures, an interpretation which arose out that debate. Fourth we will revisi Mark Paich's 1985 review of generic structures. Fifth and last we will discuss the lates interpretation of generic structures, archetypes for behavioural insight.

2.1 Canonical Situation Models

The term 'generic structure' itself evolved from the term 'general model' which was first used b Forrester in 1961 to describe the generalisation and simplification of case study models so as t "represent a wider class of industrial situations" (Forrester, 1961, p. 208). The early emergenc of the concept of a generally applicable model and the need to transfer behavioural insights fror one situation to another are bound up with the original ambitions for system dynamics.

The basic ambition of system dynamics was clearly and forcefully stated in the first publicatio on the subject "to become a basic theory of behaviour" (Forrester, 1958, p. 37). The way th theory would be applied was to be by using "case studies to enhance theory, to use theory as guide for solving problems" (p. 37.). The means by which case studies and theory would b interrelated in this way are not described but a clearer picture emerges with the publication c 'Industrial Dynamics' (Forrester, 1961).

In 'Industrial Dynamics' Forrester enlarges on the ambition of system dynamics to become theory of behaviour as a "common frame of reference to enable transference of experience (Forrester, 1961, p. 3), setting out the need for not only a general theory and method fc understanding and modelling dynamic systems but also for some means by which the lesson learnt studying one situation could be interpreted and applied in other situations. Althoug Forrester does not explain what he means by "experience" or explicitly identify ways by whic transference of experience is to be achieved, he extracts general principles from the case studie: e.g. "worse before better" (p. 348-349) and repeatedly asserts that a dynamic model of th fundamentals of a class of situations, a general model, can be built which is suitable for an member of the class being represented (p. 311-343). The examples given of situation classes ar described in terms of the application domain, e.g. market dynamics (p. 313) and product lif cycle (p. 320). The customer-producer-employment model, which Forrester discusses in deptl has been simplified and generalised from an actual case study to represent a wider class c industrial situations without "any major effect on the nature of dynamic behaviour nor on th conclusions drawn" (p. 208). The inference which can be made is that significant dynami behaviour and the important lessons to be learnt are those which are common to a class c application domain situations rather than those which are unique to a particular instance.

In 1968, Forrester presented his general model of market growth (Forrester, 1968a), a mod which has subsequently been regarded as an exemplar of generic structures. Forrester's conclusio from this study is that market interactions are so complex that an understanding of th underlying feedback structure is necessary to organise knowledge about the system, and calls fc increased research on "conceptualising the structures which produce typical classes of mark behaviour" (p. 102). This conclusion highlights that within an application domain the situatior that a general model can represent can be classified according to the underlying dynamic structu and its associated behaviour modes. The presentation of the market growth model is far simpl than that of the models in 'Industrial Dynamics', focusing on the causality and interactions of tl feedback loops and the nature of the dynamic behaviour generated rather than the detail of quantified operational model. This distiled form of general model emphasises the dynami fundamentals of the class of situations and so reinforces the explanatory qualities of gener models.

In the next decade a number of general models of much greater complexity were published. I 1969 Forrester published a model of growth processes in urban areas (Forrester, 1969). Unlik previously published general models which were distiled from real-world case studies and data, tl urban model was a hypothesis based on carefully argued assumptions, and in publishing the mod Forrester was inviting the methods, assumptions and results to be evaluated. In fact Forrester ha always advocated building a general model or theory first, and then modifying it to fit tl particular situation under study as the preferred method for building any system dynamics mod (e.g. Forrester, 1961, p. 318), but he had usually reported that a general model had been evaluated against a real-world case study before publication. The scale and complexity of urban situations, however, does not allow for easy evaluation of a theory of urban growth, and Forrester's purpose was to present a method for social analysis, in which general models have a central role. A similar approach was taken with the 'world model', a model of the basic factors which determine growth on this planet (Forrester, 1971). This model was adopted by The Club of Rome, purportedly eminent domain experts, who modified the model and attempted to validate its assumptions and findings (Meadows et al, 1972, 1992). While these models are of far greater complexity than earlier general models, they are conscious attempts to define and understand the fundamentals of dynamic structure and behaviour of a class of situations.

2.2 A debate on the meaning of 'generic'

In the same year as he published the market growth model, Forrester reviewed the first decade of system dynamics (Forrester, 1968b). The tasks ahead that he identified for the field included the cataloguing of 'system examples'. Forrester comments that system dynamicists approach problem situations by drawing on a mental library of previously studied systems. He advocates assisting others to do the same by putting these examples into written form, which as a series would identify common relationships in industry. These examples should "concentrate on the minimum structure necessary to create a particular mode of behaviour" (p. 412) and be supplemented by data which would indicate the circumstances under which a particular subsystem will be dominant. These 'system examples' are clearly a form of general model with the distinction made between the dynamic structure which generates the behaviour modes and the application domain data which will help reason about the causation of the problem being experienced.

During the debate with Ansoff and Slevin, Forrester asserts that general models are theories of dynamic structure and behaviour and that "particular applications of industrial dynamics could become theories of behaviour of particular systems" (Forrester, 1968c, p. 604). Up to this point descriptions of general models have included features of the application domain. However, later in the same paper Forrester asserts "an industrial dynamics model is a theory of structure and dynamic behaviour for a particular class of systems" and "systems belong to the same class if they can be represented by the same structure" (p. 606). Forrester illustrates the meaning of a class of systems by comparing a simplified employment-inventory system with a swinging pendulum. He shows that both systems have the same underlying structure and generate the same dynamic behaviours, and are therefore both members of the same class. The commonality between these two examples rests not on features of the application domains but purely on the commonality of the components of dynamic structure, i.e. feedback loops, levels, rate equations, etc., and the relationships between them. This dynamic structure when abstracted from any application domain data defines the class of system.

In 1980 Forrester looked to the future of system dynamics and among the "missing links" called for a "library of fundamental dynamic structures that generate the difficulties with which managers must cope" (Forrester, 1980, p. 18). By way of example he gave the production-distribution model (Forrester, 1961), and suggested the model could be simplified and generalised further. These structures he terms 'generic models' and describes them as "case studies converted to explicit dynamic form" and asserts that "probably twenty basic structures would span 90% of the policy issues that most managers encounter" (1980, p. 18). In the same collection of papers Bell and Senge define generic models as models that "attempt to provide a general theory of the behaviour of a class of systems" (Bell and Senge, 1980, p. 66). It should be noted that a 'class of systems' here is described in terms of a class of application situations, e.g. urban development, unlike the 'class of systems' defined earlier by Forrester purely in terms of abstract dynamic structure (Forrester, 1968c). Bell and Senge advance the cause of generic models as having greater potential refutability as each new specific model, as a member of the class, tests the assumptions of the generic model. A test for 'family membership' of a class of systems is described by Forrester and Senge (1980).

Forrester's assertion that a limited number of dynamic structures could explain the majority significant dynamic behaviours in such a large and complex application domain has had enormous impact on system dynamics. It has given generic structures widespread prominen within the field and restates the claim that system dynamics is a "general systems theory to ser as a unifying framework capable of organising behaviour and relationships in areas as diverse engineering, medicine, management, psychology and economics" (Forrester, 1968a). This clai can be substantiated by identifying a defined set of generic structures which do explain t significant observed dynamic behaviour in an application domain, and the search for the structures has become the system dynamics equivalent of the search for the holy grail.

2.3 Abstracted Micro-structures

In 1983 Forrester once again looked to the future and identified generic models a conce which needed further exploration (Forrester, 1983). In describing generic models here, Forrest appears to suggest that a deeper, more fundamental level of generic model is possible than h previously been discussed. Forrester states that "a model is a theory of the system that the mod represents" and that "the primary utility of a theory lies in its generality and transferability" (6). The examples he gives of useful theories are Ohm's law and Newton's laws of motio fundamental theories indeed. Forrester then goes on to suggest "we should be seeking gene theories of behaviour" and notes "a model can represent theories within theories" (p.7). I concludes that simpler more widely transferable structures (theories), which he terms gene structures, would strengthen dynamic theories of application domains, and by applying syste insights to theories strengthen the ties with other fields. From the line of argument taken l Forrester in this paper it is difficult not to infer some sort of link is being made between syste insights and generic structures.

As far as developing micro-structures is concerned, much progress had already been made. the theory of system dynamics became established, explanations of the field were made l elaborating from first principles. In 'Principles of Systems' Forrester explains how bas behaviour modes are generated from simple dynamic structures and their components (Forrest 1968d). This kind of treatment was extended by Goodman (1974), Coyle (1977), and Richards and Pugh (1981) to cover the principle types of dynamic behaviour explained in terms of the tv types of feedback loop. These structures were expressed solely in terms of abstract syste dynamics constructs.

Andersen and Richardson mapped examples of generic models to a similar sequence of theo generated structures, or elementary structures as they termed them (Andersen and Richardso 1980). Elementary structures are the building blocks of all dynamic systems including the gene models discussed earlier, and can be seen as one interpretation of Forrester's "theories with theories". This interpretation has its roots in Forrester's early assertion that system dynami models are theories of dynamic behaviour for classes of systems, where the class is defined terms of the underlying abstract dynamic structure (Forrester, 1968c).

2.4 Paich's review

In 1985 when Paich reviewed the status of generic structures within system dynamics, attempted to synthesise the different views on what is 'generally applicable' about feedba structures in his working definition of generic structures as "dynamic feedback systems th support particular but widely applicable behavioural insights" (Paich, 1985, p. 127). Within th definition he distinguishes between two main viewpoints. The first viewpoint "that gene structures are feedback mechanisms that are transferable to new situations within a particul field" (p. 126) is a direct descendant of the generic model concept, and the examples given, e. production/distribution (Forrester, 1961), market growth (Forrester, 1968), urban developme (Forrester, 1969), were all previously regarded as generic models. The second viewpoint "th there are structures that can be transferred across fields" (p. 126) is identified with approach similar to that of Andersen and Richardson described above. Paich is not attempting a preci definition of generic structures, but it is worth mentioning that the aspect of his definition whi is not discussed is the nature of the 'insights' which generic structures are held to suppo

However, it is clear that the differences between the two viewpoints hinge on whether the application domain or the abstract dynamic structure is the primary focus of interest.

2.5 Archetypes for Behavioural Insight

At M.I.T. the 'New Management Style Program' was exploring the role of generic structures in improving managers' understanding of dynamic behaviour in organisations (Senge, 1985). Senge defined generic structures as "relatively simple models of dynamic processes that recur in diverse settings and that embody important management principles" (p. 791). The generic structures are identified with a part or parts of a generic model, a generic model being the final form of a series of generic structures of increasing complexity. The management principles are identified with lessons of dynamic behaviour which can be learnt as the series of generic structures becomes more complex. Senge gives an example, based on the market growth model, of how a two-loop model representing market growth with fixed capacity reveals the management principle "no firm can sell what it doesn't produce" and the addition of variable production capacity reveals "imbalances between market growth and capacity expansion result in fluctuations in demand and sales" (p. 791-792). Within this definition, generic structures are restricted to an application domain, but unlike generic models and Paich's 'field dependent' generic structures which seek to be applicable to a class of systems. The primary focus is now on the lesson to be learnt; the management principle the structure reveals. Implicitly a structure is identified as generic because there is a lesson to be found within it; a structure defined by dynamic insight.

In addition to identifying and defining generic structures in this way, Senge also identifies a deeper level of insightful structure, which he terms archetypal structures. These archetypal structures are abstract dynamic structures which Senge claims are "the mathematical (sic.) building blocks of all systems" (p. 794), a view for which he cannot be said to have given a complete justification. Archetypal structures reveal system insights, such as 'shifting the burden to the intervenor' (Meadows, 1982). The roots of this concept is to be found in Forrester's characteristics of complex systems which he described in Urban Dynamics (1969, p. 107-114). From his study of high order dynamic systems, Forrester identified a number of principles or important behaviour characteristics of complex systems (Forrester, 1969, p. 107-114), e.g. "complex social systems tend toward a condition of poor performance" (p. 112). These principles encapsulate "generic insights" (Richardson, 1991), which help to understand the relationships between structure, behaviour and policy. Meadows (1982) represented these insights, and advanced her own, in the form of simple causal loop diagrams. This is the source of the actual form of half, and the style of all of the archetypes in 'The Fifth Discipline' (Senge, 1990). Forrester had presented his original behavioural characteristics as empirical observations. Senge, however, is claiming that these characteristics are caused by fundamental feedback structures which are the building blocks of all systems, a position which can be contrasted with a claim that these characteristics are the 'emergent properties' which appear in complex dynamic systems irrespective of the underlying structure; deep structure or surface structure. The assumptions behind archetypal structures have quite different roots to the 'elementary structures' discussed earlier which can be regarded as mathematical combinations of system dynamics components.

Archetypal structures reappear in The Fifth Discipline as systems archetypes which Senge, confusingly, now equates with generic structures (Senge, 1990, p. 94). Systems archetypes are presented as patterns of structure that recur again and again in all aspects of life, and that understanding and mastering these archetypes changes our perspective in a fundamental way, "For . . . only when managers start thinking in terms of systems archetypes, does systems thinking become an active daily agent, continually revealing how we create our reality" (p. 95). In this form generic structures, as systems archetypes, have broadened their primary focus of interest from being the means to understanding dynamic insights into 'ways of seeing'. Meadows neatly, if more prosaically, characterises these archetypes as "computer-free systems insights that any adult can carry in his or her head to deal with the persistent, system-dependent malfunctions of a complicated society" (Meadows, 1982, p. 98). In this presentation of system archetypes, Senge emphasises their role as templates or patterns of structure, and he does not stress his earlier claim that system archetypes are the 'building blocks' of systems. The all embracing nature of Senge's vision makes it difficult to engage with him at the same level o debate as with other views on generic structures. As a holistic concept you have to accept or den the premises as true or false; and if you accept that the premises are true then the consequence are necessarily true.

2.6 Generic Structures: three views

By tracing the evolution of the generic structure concept we have identified three differen views of what they are concerned with.

In the first view, generic structures are theories of significant dynamic behaviour in a application domain; canonical situation models. These generic structures are closely related t general or generic models, being case studies reduced to their essentials in order to make explici the causal explanation of the dynamic behaviours the structure generates.

In the second view, generic structures are combinations of abstract system dynamic components which generate commonly observed behaviour modes; abstracted micro-structures.

In the third view, generic structures are recurrent patterns of structure which are associated wit a distinctive behaviour mode and exhibit one of the characteristics of complex systems, a systen insight; archetypes for behavioural insight.

We will now examine the applications of generic structures in system dynamics, in order to b able to discuss whether distinctions made here hold up in practise.

§3 GENERIC STRUCTURES IN ACTION

Generic structures may have acquired an important role in system dynamics' claim to be a integrative theory of dynamic behaviour, but they were generally conceived of for practica purposes. In this survey of generic structures we have identified four main application areas model construction, domain understanding, system conceptualisation and teaching devices. Th role of generic structures in each of these areas is examined in turn.

3.1 Generic structures as building blocks for model construction

The most direct use of generic structures for model construction is to employ abstracted micro structures as components of the model. System dynamics software user guides are emphatic i advocating their use. For example, the i-think user guide (i-think, 1990) identifies three levels o generic micro-structure, excluding elementary components, as generic flow processes, generi infrastructures and generic sub-systems. Many of the generic flow processes and the generi infrastructures (growth) are identical to the micro-structures discussed earlier, being simpl abstract structures which generate particular behaviour modes. In addition functional structure are described, i.e. generic infrastructures (functional) and generic sub-systems, which represen functions such as stock ordering with a delay or the finance sector of a typical company. Th rationale for using all of these structures is purely pragmatic; it is claimed that significantly bette models are built in significantly less time. These structures were identified by analysing a larg number of constructed models and extracting the stock/flow arrangements which recurred mos frequently. Some of the larger sub-systems, e.g. a marketing sector, have a superficial similarit with the general models discussed earlier. The focus here, however, is on the correct arrangemen of stocks and flows so as to be internally consistent, rather than the relationship betwee structure and behaviour in an application domain. Structures used in this way for mode construction, whether abstracted micro-structures or larger components, can be thought of a reliable de-bugged chunks of code which fulfil a particular purpose.

In the early applications of system dynamics, a general model is seen as being the precursor t building a specific model of the application problem (Forrester, 1961). However, it is not clea whether this general model is operational, with representative parameters, or a logical model use to 'home in' on the fundamental relationships in the application domain. The urban growth model (ibid.) on the other hand is an operational model representing a general theory of urban development, a model which could be taken intact and then specialised to a particular urban situation. Forrester and Senge (1980) suggest this course of action when discussing confidence tests for system dynamics models; "The general theory is embodied in the structure of the model. The special cases are embodied in the parameters. To make the (family member) test, one uses the particular member of the general family for picking parameter values. Then one examines the newly parameterised model in terms of the various (other) model tests to see if the model has withstood transplantation to the special case" (p. 221). To our knowledge, however, there are no published examples of this process being performed.

3.2 Generic structures for domain understanding

Generic models "attempt to provide a general theory of the behaviour of a class of systems" (Bell and Senge, 1980, p. 66). It follows that a 'good' general theory should be useful and ultimately be accepted in the application domain for which it is intended. The systems dynamics models which have gained widespread attention have also generated widespread controversy, e.g. the urban model and the world model. Perhaps because of this resistance, recent work on generic structures has concentrated on 'in-house' uses such as system conceptualisation (see section 3.3). Richardson, however, has shown that many of the important theories in social science are implicitly theories of dynamic behaviour, which can also be represented as situation-based generic structures, at least in causal loop diagram form (Richardson, 1991).

3.3 Generic structures for system conceptualisation

The first suggestion of using generic structures for system conceptualisation was made by Forrester when he noted that system dynamicists approach problem situations by drawing on a mental library of previously studied systems (Forrester, 1968b). These 'system examples' are situation-based generic structures, used as an initial 'hypothesis' about the important features of dynamic structure in a specific problem situation. Morecroft, Lane and Viita (1991) describe using Forrester's market growth model to generate "in-depth (sic.) questions for fuelling discussion and structuring information gathering" (p. 115). In using a canonical situation model to focus system conceptualisation, there are a two different views which can be taken on the role of the 'hypothesis'. In one view the 'hypothesis' is a scientific theory to be tested and verified. An alternative view, based on a proposal by Lane (1994a), is that the 'hypothesis' is similar to Max Weber's ideal types; "thinking aids, drawn from real phenomena, with which a situation is compared in order to understand its significant components and so generate explanatory value" (ibid.). In either case verification of the 'hypothesis' proceeds by analogy, testing the various assumptions in the generic structure for their equivalents in the problem situation. Although the philosophical assumptions behind the two views are quite different, the practical limitations of using canonical situation models for system conceptualisation are rather similar. Both views assume a sufficient number of suitable 'hypotheses' can be found to cover any specific situation that will be encountered. The risk is that using an inappropriate structure will mislead in the investigation of the problem.

Abstracted micro-structures have also been suggested as a tool for system conceptualisation. Andersen and Richardson (1980) advocated that students of system dynamics build their own catalogue of abstracted micro-structures and situation-based examples as an aid to understanding "general characteristics of structure and behaviour which transfer from one system to another, whatever their surface differences may be" (p. 101). A central premise of system dynamics is that structure generates behaviour, and consequently behaviour can help infer structure. Andersen and Richardson note, however, that the identification of structure from behaviour for real-world systems is suggestive rather than certain and that skill is required to recognise these elementary structures in more complex systems. Transferability of understanding using abstracted micro-structures comes from being able to make a hypothesis about the dominant elements of system structure from the reference mode. The main limitation of using abstracted micro-structures for system conceptualisation in this way is that only low order structures are of practical use. High order abstracted micro-structures are capable of generating so many different behaviour modes that inferences, beyond identifying the one or two most dominant feedback loops, becom impossible.

The whole thrust of 'The Fifth Discipline' is that systems thinking is a way of conceptualisin about the world, and as such its primary purpose is to improve our understanding of dynami systems in the real world. This approach has similarities with Morgan's description of the use c metaphors for understanding organisational behaviour, "For the use of a metaphor implies a wa of thinking and a way of seeing that pervade how we understand our world generally" (Morgar 1986, p.12). A metaphor, or any framework for conceptualisation, highlights certain aspects c the world and obscures others, producing a one-sided kind of insight. System archetypes as a integral part of the larger framework, systems thinking, are similarly one-sided. Senge attempt to justify this approach by drawing the analogy between systems archetypes and "archetypa personalities" such as the eccentric inventor, noting that they "lead us to subconsciousl categorize unique individual personalities, with the consequence that we often act mor appropriately to the archetype than to the person him- or herself. Might archetypal structure lead, in a similar fashion, to new perceptions and actions?" (Senge, 1985, p. 795).

At a more mundane level, system archetypes make a strong inference between a particula behaviour pattern and the underlying dynamic structure. Kim summarises the use of system archetypes in the following way; "Often, an event that is seen as a problem symptom can be th starting point. This may lead you to trace out the pattern of behaviour of similar events over period of time. The archetype can then help you identify the systemic structures that ar responsible" (Kim, 1992). This contrasts with other types of generic structure, and syster dynamics models in general, where dynamic behaviour is regarded as suggestive of structure, bu little more. The limitation of system archetypes, as archetypes for behavioural insight, is that b asking us to see the world through these structures, it is not possible to question th appropriateness of the structures.

3.4 Generic structures as teaching devices

Andersen and Richardson (1980) suggested a pedagogical approach to system dynamics in whic generic structures were seen as means of teaching system conceptualisation skills. The use of catalogue of elementary structures, i.e. abstracted micro-structures, they suggest students build ha been discussed earlier (see section 3.3). In addition they suggest a number of other usefu exercises, such as constructing and de-constructing example models, such as the market growt model, component by component, loop by loop, and observing how the behaviour change: Another method is to have students examine isomorphic systems such as the pendulum an inventory/workforce systems (Forrester, 1968c). The purpose of these exercises is to teac students of system dynamics about the possibilities and limitations of transferability of structure.

A more ambitious project was undertaken at MIT- the computer-based case study project, i which part of the educational objectives was to help managers gain a greater understanding (dynamic behaviour in organisations. Generic models, i.e. canonical situation models, were used a the basis for case study examples as they provided consistent and known generic problei situations. Graham (1988) in a paper which preceded development of the computer-based case identifies seventeen generic models representing common "problematic syndromes and behavio modes". While generic models may make reliable and repeatable teaching examples he note "The weaknesses of generic models for management education are first, requiring a highly-traine modeler to run the model and interpret its structure and behaviour, and second, even with suc guidance, substantial difficulties transferring insights from an abstract model to real situations" (p 2).

§4 CONCLUSIONS

In tracing the evolution of the generic structure concept we have tried to elucidate some of th subtleties of meaning which have been implicit in different variations of the concept. Gener structures in all their forms express the basic ambition to transfer experience and understandin from one dynamic situation to another. We have identified three different views of what generic structure is and what transferability means. These different views are distinguishable in practise as well as in concept.

In the first view, generic structures are theories of significant dynamic behaviour in an application domain; **canonical situation models**. They offer transferability of both dynamic structure and particular causal assumptions about dynamic behaviour in the application domain. These generic structures are, in a technical sense, indistinguishable from any general or generic model which has been reduced to its dynamic essentials. One of the difficulties for this form of generic structure is that there is no obvious means of defining them, except by their acceptance as a generic structure within the system dynamics community or as a useful theory within the application domain. Similarly there is no obvious way of validating or refuting a generic structure. As Barlas and Carpenter point out "Model validation is a gradual process of building confidence in the usefulness of a model; validity cannot reveal itself mechanically as a result of some formal algorithms. Validation is a matter of social conversation, because establishing model usefulness is a conversational matter" (Barlas and Carpenter, 1990, p. 157). Forrester's assertion that twenty generic structures would cover 90% of the policy issues that most managers encounter can never be proven. Greater confidence in using a canonical situation model for a particular problem situation can only come about when the structure is accepted within the application domain as a valid theory for interpreting a particular class of problems. This suggests that more effort should be put to engaging in debate about the use of generic structures in the application domains. Within the system dynamics community, canonical situation models have been suggested as being useful for model construction, system conceptualisation and teaching principles of dynamic behaviour. However, except for the MIT case study project, little has been reported about the success or failure of using these structures in practise.

In the second view, generic structures are combinations of abstract system dynamics components which generate commonly observed behaviour modes; **abstracted micro-structures**. They offer transferability of structure, pure and simple. Abstracted micro-structures are more easily definable, as any abstract dynamic structure can be classed as one. For system conceptualisation, however, only low order structures are of practical use because of the difficulties of inferring structure from behaviour in complex systems. For model construction their value lies in their reliability and predictability as model sub-systems.

In the third view, generic structures are recurrent patterns of structure which are associated with a distinctive behaviour mode and exhibit one of the characteristics of complex systems, a system insight; **archetypes for behavioural insight**. They offer transferability of insight about particular characteristics of complex dynamic systems. The validation of these structures is conversational within the particular community which uses them, as they are seen as equally applicable to all types of dynamic system. As an integral part of a larger conceptual framework, belief in their usefulness depends on acceptance of that framework.

By tracing the evolution of the generic structure concept and examining the way that generic structures have been used in practise we have shown that there are at least three distinct interpretations of the concept. As interest in dynamic systems increases and the scope of systems dynamics thinking grows to encompass different assumptions and even paradigms (Lane, 1994b), it is no longer desirable for different notions of what is generalisable and transferable about dynamic systems to be concealed by such an ill-defined and all embracing concept as the generic structure. We believe it is time to unbundle the concept so that these different notions can be debated, and that system dynamicists can critically evaluate the theoretical and practical uses of 'generic structures' with respect to the assumptions inherent in their problem solving and modelling approaches.

ACKNOWLEDGEMENTS

The authors would like to offer their thanks to Jay Forrester, Michael Goodman and George Richardson. Their observations on generic structures, particularly those offered to DCL during his visit to Boston and Albany in November 1993, were a valued contribution to our work. We are grateful for the time and interest that they gave.

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