Can We Have Confidence In Generic Structures?

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Introduction

Generic structures are central to the aspirations of our field. System dynamics has an explicit goal: to create integrative theories (= models) of different social systems which then make it possible both to understand specific situations and to produce generalisable insights (Forrester, 1961). To a large extent progress towards this goal has involved the use of generic structures as vehicles for storing and applying these insights. However, the concept of generic structure causes some confusion because of the range of model types to which this term is applied. Recently the concept has been divided into three sub-definitions, a troika of interpretations of 'generic structure' which aims to offer a sharper statement of style, purpose and application (Lane & Smart, 1996). This work leads directly to the question of confidence. How can a group have confidence that a generic structure can be of use to them? How should researchers judge whether something qualifies as a generic structure? This papers attempts to advance debate on both of these questions. The aim is to explore the extent to which we can support our current confidence in generic structures and to indicate means of improving that confidence.

Practical Criteria for Confidence

We extend this previous analysis by asking: how can we be sure that we have the right generic structure, that we are using it correctly and that it will be useful? Such questions connect with concepts of model validity and, in its broadest sense, the reasons why a user might have confidence in a model. In assessing the troika of generic structure definitions we shall employ the following concepts that intertwine to engender confidence in a model user (Lane, 1995):

- Perceived Representativeness of Models (PRoM): involves the descriptive realism of a model. The concern is whether a model's structure, data and (if relevant) behaviour represent the system that the users wanted to consider. PRoM has four elements; conceptual (Does the model draw on the mental models of the participants and so express their understanding of a situation?), formulational (If there is a simulation model, does it conform to the necessary rigours of computer code whilst still relating to the situation?), data (Is the data in the model reliable?) and experimental (Is the model structure confirmed by examining its behaviour?).

- Analytical Quality of Policy Insights (AQ): is judged by the answers to four questions. Does the model generate any insights? Are they innovative and important? Are they rigorously generated and shown by sensitivity analysis to be robust? Are they qualitative or quantitative?

- Process Effectiveness of the Intervention (PEI): relates to the participants' response to the modelling process. How costly was the process? Was it brief, or drawn out? How much did the group trust the modellers? How transparent were the models? Was it easy to explore the model and its runs? Was it fun to do so? How much did the relevant actors participate in the building of the models and the uncovering of the insights?

In the following section we consider each of the three forms of generic structures and relate them to the system dynamics literature on validation and confidence generation as it applies to practical interventions in organisations (see Forrester & Senge, 1980 and Lane, 1995).

Practical Consideration Of The Three Generic Structure Forms

The first sub-definition of 'generic structure' concerns general models of a particular situation which yield significantly different modes of dynamic behaviour (Lane & Smart, 1996). These are called 'canonical situation models' and they are case studies reduced to their essentials in order to make explicit the causal explanation (or theory) of the dynamic behaviours that the structure generates. These are therefore pre-existing models which one adapts to a particular situation. Since these are fully-functioning simulation models, their AQ will be high. However, the discipline that computer modelling brings might well reduce the PRoM to a middling level

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and, depending on the nature of the group, the PEI will vary. So can one have confidence when using a canonical situation model? Yes, a modeller can be confident that it will be well constructed and will generate interesting behaviour. But we might have reduced confidence that users will accept that such a model represents their system and fits in with the way that they think about their problem.

In the second view, generic structures are relatively abstract combinations of system dynamics components each of which generates a commonly observed behaviour mode. These 'abstracted micro-structures' are used as building blocks of larger models. Generally speaking the same comments apply here as for cannonical situation models; the discipline imposed by rigorous computer modelling delivers better quality analysis but may draw the model away from the understanding of and acceptance by any clients. Can one have confidence when using abstracted micro-structures? Yes, because they are well-crafted pieces of structure that have been shown to be useful elsewhere. However, one again needs to be aware that clients may be pushed away by the rigours of the model building approach, even though it will deliver a more analytically powerful inquiry.

The third interpretation involves 'counter-intuitive system archetypes'. They tell a story about the behaviour of a system and indicate that an unexpected consequence may flow from a policy. Each is illustrated by a simplified causal loop diagram and a story. As these are only qualitative maps of systems, the AQ that results can only be very low. However, despite the lose formulation of these models, the PRoM is deemed by users to be quite high. Similarly, the use of these maps can be very effective in groups; PEI is very high. Should we be confident of counter-intuitive system archetypes? It depends. These are very weak forms of system dynamics models. Only qualitative insights are available and are not grounded in simulation. The real links in a system are not developed in a rigorous way. Nevertheless, they do seem to be a compelling way of expressing people's ideas and drawing them into a discussion about social systems whilst introducing the idea of feedback.

Two Theoretical Aspects of Confidence

We should note that so far generic structures have been assessed as practical tools which are used actively with groups. We might also view them as theoretical concepts which extend the knowledge base of system dynamics. For this purpose, we might decide that too much importance was attached to the response of a client group in the description above and that our judgments veered towards the lenient. Two theoretical considerations should then be considered; the representativeness of generic structures and their completeness/exhaustiveness.

Representativeness

In judging representativeness we must discriminate between analogies and isomorphisms. A model is an analogy of a system if there is only a lose connection between the scientific ideas in the model and the phenomena in the real world. However, if the attributes of a model can be tightly compared one-to-one with the attributes of the relevant system then we have a more rigorous link between the two, an isomorphism (Beer, 1966).

With canonical situation models and abstracted micro-structures it is clear that an isomorphism concerning structure is being tested. A judgement on the correspondence between the structure of the model and that of the real world system is made in both of these cases. This is pressed forward by the discipline of simulation modelling. The expression of ideas in stock and flow terms and the creation of precise algebraic relationships leads to structural isomorphism. Similarly, by rigorously deducing behaviour with a simulation model, tests such as 'behaviour reproduction' and 'surprise behaviour' can be used and a judgement can be made regarding a behaviour isomorphism.

With canonical situation models a further judgement must be made concerning their representativeness. Since many real world systems are being mapped onto a single model, one is now studying a homomorphism and seeking external validity of the model. This may not be unproblematic, since it is necessary to have a clear definition of the range of phenomena that the model addresses. Nevertheless, testing the quality of an homomorphism is at least a possibility when there is a rigorous statement of the form of the model.

In contrast, counter-intuitive system archetypes cannot have an isomorphic relationship with real world phenomena. The structure of the maps in this form of generic structure is vague and badly posed when compared with other system dynamics models (the polarity of the causal

links is not given and the variable names frequently discourage the application of numerical values). It can be difficult to deduce which variables should be viewed as stocks and what the precise relationships between some variables are. Counter-intuitive system archetypes therefore have a much weaker structural mapping to the real world. In addition to this, with counter-intuitive system archetypes there is no rigorous linkage between system structure and system behaviour: the user is called upon to make an inference rather than a deduction. But this is known to be a highly perilous process and the implied use of such mental simulation arguably constitutes a rejection of one of the core assumptions of system dynamics. There is therefore no isomorphism between models and the real world in the case of counter-intuitive system archetypes. They are merely analogies which may 'feel right' and which seem to offer some illumination. This seems to be essentially the only basis upon which they might demand confidence of users. Now one can logially argue for validation by such an approach (Checkland, 1995) but this involves a substantive withdrawal from aspirations of descriptive realism. And that is a move which most system dynamicists would find alien and shallow.

Completeness/exhaustiveness

Is our current list of generic structures complete? Have 40 years of system dynamics research exhausted the complex structures and behaviours that social system present? A cautious person might immediately answer 'No' from a simple fear of hubris. However, there are sound reasons why this is the correct answer. Furthermore, these reasons indicate some of the research directions for generic structures.

Forrester has suggested that, "probably twenty basic structures would span 90% of the policy issues that most managers encounter" (Forrester, 1980, p. 18). Do we have the 20? This is hard to say because there is no published list of general models (though it exists in the minds of many system dynamicists). We would suggest that this is the case because of confusion over the form of a generic structure. We believe that Forrester's comment applies to canonical situation models. What is needed then is more work on criteria for establishing confidence in the homomorphism that lies at the heart of these models. From this will flow both a list of accepted models and criteria for accepting new ones. Might that list be complete? We are unsure. Forrester's comment is a characteristically bold statement, combining outrageous confidence and shrewd insight. We should see his remark less as a prediction than as a challenge for the field. Whether we can operate in 90% of situations with 10 or 30 canonical situation models is not the point. He is re-stating the notion that there are deep similarities between superficially dissimilar situations and that system dynamics can unearth them. He is not saying that the list is 20 items long. Rather, he is saying that the list is short and that whenever we have built a model we should try to generalise it as much as possible because the insights that it offers may be even more useful than we suppose. This is surely an inexhaustibly useful way of trying to understand the world.

With abstracted micro-structures things are similar but a little more simple. As new situations arise and are modelled using system dynamics, a structure will be shared around the field. Again, clear criteria for acceptance will be needed but if the initial model is accepted as well posed and is then adapted to a handful of other situations and found to be useful also in them then it is worthy of consideration. However, it is hard to imagine the list of such models being complete. It is much more important that we ensure that all of its members are good pieces of modelling, to be picked up by future workers in the field.

Do we have a complete list of counter-intuitive system archetypes? This depends on how we view their purpose. As a way of getting people interested in feedback they seem to offer a rich enough selection. However, we can think of two means of judging the incompleteness of the list. Firstly, if we see counter-intuitive system archetypes as a simple means of summarising the behaviour of a complex model, of expressing the insights that system dynamics has generated regarding the behaviour of complex social systems, then the list is clearly incomplete. We need only glance at Chapter 6 of *Urban Dynamics* (Forrester, 1969) to see that we have no 'summary' of the 'insensitivity to parameter changes' observation. However, it is hard to see how a counter-intuitive system archetypes could convey what is essentially a quantitative insight. Extending our net wider, the same comment applies to 'system compensation effects', by which the introduction of a new flow to a negative feedback loop shifts the equilibrium state away from the explicit goal (Goodman, 1974). This perhaps indicates the limited nature of counter-intuitive system archetypes: their very form restricts the

insights that they can convey. Alternatively, if we see them as simple configurations for causal loop diagrams then we have by no means exhausted the possibilities with our current set. We could generate candidate counter-intuitive system archetypes by a purely topological approach, combining balancing and reinforcing loops, varying the position of delays and permuting the loop which is dominant and then trying to interpret the resulting abstract causal loop diagrams in terms of real world phenomena. Some may make little sense but others will result in new explorations and may prove to be useful additions to the list.

Conclusions

If we consider generic structures from the point of view of organisational interventions, it is clear that the effectiveness of the three different types is constructed in different ways. In some situations there seems to be an argument for trading-off precision of model and analytical quality in favour of simplicity and ease of use. In this respect the task for the future is surely for those using the different forms to state clearly the type of confidence to which they aspire (Lane, 1995). An extension of this would be to probe the same situation using the three different interpretations of generic structure. This will be impossible in a strict sense. But the departure that counter-intuitive system archetypes make from previous forms of system dynamics, the questions concerning representativeness and precision of definition that they leave hanging and the popularity that they have achieved indicates an urgent need to make judgements of this kind. We need to look at broadly similar situations that have been studied using the different forms. We then need to get a sense of how effective the interventions have been and to what extent this can be attributed to the form of modelling used.

A more theoretical line of attack indicates that we need to develop further our understanding as a community of what we mean by 'generic structure'. The troika used here may prove useful but it is clear that we need clearer definitions and tighter criteria to make judgements. In our 40th year this author is emboldened to hazard the following guesses:

- We need more discussion on what we mean by canonical situation models, how we define an isomorphism and how we extend this to a homomorphism. But having done so, we will be able to compile a sound list of previous achievements and understand how to extend it.

- Bringing together our communal understanding of what we can now see as abstracted micro-structures, we will be impressed by the creativity of past modellers and will see the richness and flexibility of the technique that we have to pass on.

- If we engage in a debate regarding counter-intuitive system archetypes, there will be much criticism of their role and much comment on the dangers of their usage. However, with perseverance we will be able to hammer out a clear theoretical status for them and also understand how they can be used in practical interventions to interest more people in the importance of system dynamics.

So, more thinking must be done and more clarity created. We need to take stock - but may well be pleased with the achievements so far. And there is more exciting work to be done in the next 40 years. This is a healthy state for our field to be in.

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