Integrating Archetypes and Generic Models into a Framework for Model Conceptualisation

David A Corben
Department of Management Science
The School of Management
University of Stirling
Stirling
FK9 4LA, UK

Abstract

Model conceptualisation is the most difficult system dynamics skill to acquire, practise and teach. The advent of user friendly simulation tools; STELLA and **ithink**, have made the task of model construction and use much easier. Model conceptualisation by contrast remains as difficult as ever.

Experiences in training managers in system dynamics show that it is a relatively simple task to turn complete beginners into competent and confident simulators. The capability to recreate a model from an **ithink** map and a written description of operating policies is quickly acquired, as is the ability of modifying that model to test out possible solution to problematic behaviour.

The problem arises when these proficient simulators are asked to conceptualise a simple two loop model from a problem description, presented in the form of a newspaper article. This task is found very difficult by most course members.

This paper describes the development of a new technique to assist with the model conceptualisation process. The method integrates archetypes and their corresponding generic Models into a framework that helps modellers move from a problem description to a first pass **ithink** model and/or causal map.

An application of the method, to aid the conceptualisation of a model of Government funding of housing associations is described.

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Introduction

During last two years, the author has been involved in the delivery of a number of three day training courses in systems thinking. These courses aim to develop both qualitative and quantitative modelling skills in parallel, they are "hands-on" in nature; the emphasis is on learning by doing.

The majority of these courses were conducted for small groups of managers or mixed groups of managers and analysts. Some of the courses were run as public workshops, which were open to participants from different organisations, but the majority were "in house" courses run for a specific organisation. The background of the participants and the organisation from which they came was highly varied. This has given the author a chance to observe a representative cross-section of both managers and organisations that have shown an interest in adopting system thinking in the UK.

Training Course Structure

This brief overview concentrates on the model building elements of the training course. These exercises are designed to form a progression in which participants are required to increase their own contribution to the modelling process. In the first exercise participants are given explicit instructions, the final exercises involve freeform modelling.

Exercise 1

In their first exposure to the **ithink** software managers are talked through a "hands on" exercise that builds a simple two stock model of staff turnover. (Wolstenholme 1990). This task introduces the main features of the **ithink** software and highlights the nature of the modelling process.

Exercise 2

This exercise requires the construction of a model from a given **ithink** map and equation listing. The model is based on a real case study (Wolstenholme 1993) and participants are taken through the background to the model before they start to build the model. The aim of this exercise is to reinforce the managers' skills with the software and provides the opportunity to perform "what if' simulations with a larger and more realistic model.

Exercise 3

The third modelling exercise is a major case study, based on the market growth model (Forrester 1968), that takes up most of the second day of the training course. The case study consists of two parts. The first is a qualitative mapping exercise, participants work in small groups to create a causal map from a problem description and they are also required to suggest a possible solution to the problem. A facilitated debriefing session follows in which the problem and proposed solutions are discussed.

The second part is a quantitative modelling exercise. The **ithink** map is provided as are the parameter values, but participants are required to create their own equations, but a written description of operation policies is provided to assist with this task. When the model has been built, the managers are required to modify it to incorporate the solution that was identified in the qualitative exercise, but no additional help or information is given.

Exercise 4

The final day of the course is devoted to freeform modelling of participants own problems, but first some additional practise in conceptualisation is provided. Participants are given a series of modelling exercise, that require participants to produce causal maps and/or **ithink** maps from written descriptions. Some of these are reasonably transparent descriptions of simple models, but others are based on problem descriptions taken from newspapers are much more open-ended in nature.

Evaluation of Participants Performance

It has not been possible to carry out a quantitative evaluation of performance, but the author has observed a large number of managers over the course of the last two years and the following insights have been gained.

Use of Software

Teaching managers how to use the **ithink** software is relatively easy. Most managers can be taught how to "fly" the software in a couple of hours.

Model Conceptualisation

This is the most difficult modelling skill for managers to acquire. Participants often stated that they found conceptualising the hardest part of the workshop and this was confirmed by their actual performance.

Participants find conceptualisation easier if it is carried out within some kind of framework. A good example of this, can be found in the second day case study (exercise 3). The task of incorporating the qualitative solution into the base case quantitative model is usually carried out very successfully, with little need for facilitator intervention. In contrast the less transparent of the conceptualisation exercises and the freeform modelling, are found to be much more difficult (exercise 4).

Participants confronted with a blank sheet of paper, find it difficult to start the modelling process going. If however they can be facilitated to build a working first pass model (this can be a very simple model), then they usually have the confidence to incrementally develop this model, with only occasional need for facilitator assistance.

Use of Models

Experimenting with a model comes naturally to most managers, but some need some prompting to experiment methodically and interpret simulation output.

A number of participants were motivated to conceive and implement their own extensions to the model used in exrecise 3. It was noted with some interest that it was the managers who were most likely to want to extend the model, analysts tended to regard the case study simply as an exercise to be carried out and soon lost interest in the completed model. However the analysts were in generally better at implementing such extensions.

This suggests that it is best if workshops are attended by mixed groups of managers and analysts. This has been confirmed by experience, the workshops where managers and analysts worked together, were all very successful and useful models of the managers own problems were developed on the final day.

Identification of Areas of Difficulty

The performance of participants clearly shows that conceptualisation is the most difficult system thinking skill to master. In particular it is the early stages of the conceptualisation process that causes problems. Once participants have a simple model to work with, they are capable of conceptualising and implementing enhancements to that model. The rest of this paper describes the development of a modelling framework that aims to help managers move easily to a working model as early as possible in the conceptualisation process.

Model Conceptualisation

Model conceptualisation is the most difficult stage in the modelling process, but is also the most rewarding, for it is here that the big leap in understanding occurs. Given the complexity of a typical managerial system it is possible to build any number of models of that system. The purpose of the conceptualisation process is to identify the model that will provide a suitable vehicle for understanding the behaviour that is of interest to the managers of that system.

In conceptualising a model, the following need to be decided; the basic feedback structure, the level of aggregation, the model boundaries and the time frame. It follows that the conceptualisation process is essentially qualitative in nature. Turning the qualitative conceptual model into a quantitative model is not a trivial task, much about the system will be learned along the way, but these will be incremental gains in understanding, that serve to enrich and the add detail to original insight, that occurred at the moment of conceptualisation.

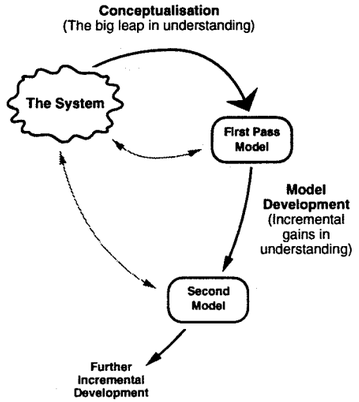


Figure 1 The modelling process

Current Modelling Frameworks

A number of techniques for the building of system dynamics models have been proposed. (Forrester 1961; Randers 1980; Richardson & Pugh 1981; Morecroft 1982; Wolstenholme & Coyle 1983; Wolstenholme 1985, 1990, 1992; Mass 1986; Richmond et al. 1987, 1993)

These approaches typically break the modelling process down into a series of steps (one of which is conceptualisation) and provide guidelines and suggest techniques for each step. These methods undoubtedly contain much useful advice, but the guideline approach to model conceptualisation does not provide enough support for novice modellers.

Some methods make use of modular building blocks (Wolstenholme & Coyle 1983; Richmond et al. 1987, 1993). This provides the modeller with "something to work with", but turning these building blocks into a working model is still a difficult task for the inexperienced modeller.

The novice modeller needs to be provided with the facility to conceptualise a model in terms of generic structures thereby providing a working model for experimentation, very early on in the conceptualisation process. In the next section generic structures and their use in the modelling process are reviewed.

Archetypes, Generic Models and Generic Structures

> There is at present, nothing close to an accepted definition of a generic structure: it is unlikely that two system dynamicists discussing the concept will be talking about the same thing.
>
> Mark Paich (1985)

This statement is, unfortunately, as true now as when it was first written nearly ten years ago. In an effort to clarify the situation, three different classes of generic structure can be identified. (Paich 1985) (see Table 1) The names have been applied by the author. The use of these structures in the conceptualisation process will now be discussed.

Table 1 Classification of Generic Structures

Generic Models	Structures generic to a specific problem domain.
Archetypes	Structures that are transferable between different problem domains.
Building Blocks	Sub-structures that are found as building blocks in many different models.

Generic Models

The use of an appropriate generic model can greatly simplify or even eliminate the conceptualisation process. The problems with this approach are; the need for a suitable generic model of the problem domain under investigation to be available, there is a danger that an inexperienced modeller will select an inappropriate model and finally the existence of a generic model may give the modeller a preconceived view of the problem.

Archetypes

Archetypes can be used a way of conceptualising more general problems, but for this to work, the modeller must have a good understanding of the full set of the archetypes and the totally qualitative nature of the archetypes may cause difficulties. The archetype approach to conceptualisation, shares with the generic model method, the problems of; structure availability, inappropriate choice of structure and preconceived view.

Archetypes were originally seen as fundamental building blocks (Senge 1985), but now they are seen as a set of more complex structures. (Senge 1990) There is still a degree disagreement over the constituents of this set. (Senge 1990; Kim 1992)

Table 2 The base archetypes

		Intended Action	
		Control	Growth
System Reaction	Opposition	**B/R** Fixes that Fail	**R/B** Limits to Success
	Competition	**B/B** Fighting for Control	**R/R** Success to the Successful

It has been shown that there is a reduced set of four "Base Archetypes", consisting of two loops, that can be used to represent managerial problems in terms of an intended action and a system reaction. (Wolstenholme & Corben 1993) (see Table 2) This simplified way of looking at a system provides an ideal vehicle for model conceptualisation.

Building Blocks

These structures are more useful in the iterative development stage of the modelling, when processes are being modelled in more detail, than in the conceptualisation stage.

A Framework for Model Conceptualisation

The method uses the base archetypes and generic models of those archetypes to ease the transition to a simple working model. The identification of an intended managerial action and a system reaction allows a base archetype and it's corresponding generic model to be selected. The modeller therefore only needs to identify two loops before they can begin experimenting with a working model, that can be used as an aid to clarify their thinking by exploring the chosen structure's dynamic behaviour.

The selected generic model is next customised to produce a first pass model that can then be iteratively developed. The steps of the method are described in Table 3 and an overview of the process is given in Figure 2. An example application of the method is described in the next section.

Table 3 The steps of the conceptualisation method

1	**Specify the Intended Behaviour** Is the aim growth or control. Draw the intended behaviour loop.
2	**Identify the System Reaction** Will the system respond with growth or control. Draw the system reaction loop.
3	**Create a Base Archetype** Link the loops identified in 1 & 2 to create a base archetype.
4	**Specify the Problem as a Generic Model** Take the generic *i*think model corresponding to the base archetype and by renaming the model elements, customise it to represent the problem. It can now be verified that the chosen generic structure is capable of producing appropriate behaviour.
5a	**Qualitative First Pass Model** Flesh out the loops, by adding intermediate variables and the organisational boundaries.
5b	**Quantitative First Pass Model** Add extra detail to the *i*think model to keep it consistent with the qualitative model. Incorporate "order of magnitude" data into the model and experiment with the model.
6	**Iterative Model Development** From here onwards the model(s) can be developed in an iterative fashion.

Issues in Designing a Framework for Conceptualisation

In designing this methodology, careful though has been given to striking an appropriate balance between, providing sufficient structure to help a manager build a model and the danger of enforcing an over prescriptive set of rules that will constrain a manager's thinking. There is a real danger of this, in the specific case of model development and in the more general development of an individual's system thinking skills.

In the case of model development, the availability of generic structures may encourage the forcing of the problem to fit the available model. This is potentially a major problem. Operational Research, for example, has been severely criticised for this very failing. (Ackoff 1979)

The structures used in the conceptualisation framework were chosen to be sufficiently generic to avoid this problem. The selection of a base archetype is merely a starting point for investigation, not a final definitive statement about the problem. The initial identification of a loop pair, can lead to a model than is equivalent to one of the system archetypes or indeed no specific archetype at all. The fact that some of the base archetype can be incrementally developed into more than one of the more complex system archetypes shows the flexibility of this approach.

The framework could have been built around the full set of system archetypes, but it was felt that this would have been too restrictive. In using the system archetypes for conceptualisation, there is a real danger that the selection of an archetype will be both a starting point and an ending point; the modeller will miss out on the challenging but rewarding task of structuring their own view of the system.

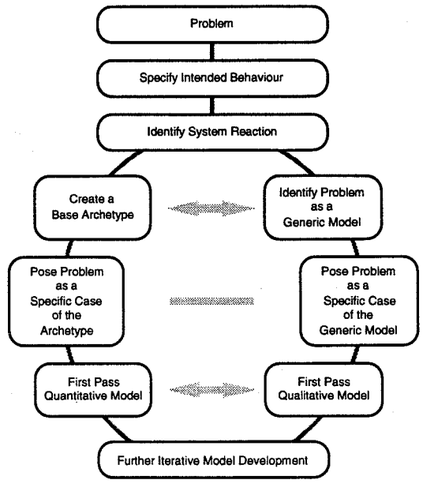


Figure 2 Overview of the conceptualisation method

In the wider context of an individual's modelling skills, system thinking is more than just a simulation technique, it is a distinctly different way of looking at the world. This ability can only be acquired by thinking hard about real problems and therefore there can be no formal proscriptive method for practising systems thinking. This fact has been recognised from the earliest days of system dynamics and has been restated many times over the intervening years. (Forrester 1961; Saeed 1986; Senge 1990; Richmond 1990).

The purpose of the conceptualisation framework is therefore seen by the author as a tool to help the novice system thinker through the difficulties of their early model conceptualisations, so that through this experience they may develop their own system thinking skills. Experienced systems thinkers may not need to use the framework to aid to their own thinking, but it can be used to good effect as a facilitation technique, to aid the thinking of others, when model building with a group of managers for example.

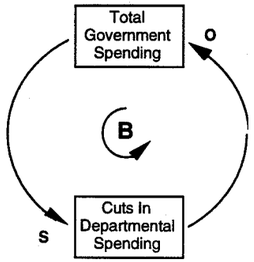
An Example: Conceptualising the Housing Association Model

Problem Description

The government is seeking to control its spending by imposing cash limits on the individual government departments. In this particular case we are focusing on the Department of the Environment and the grant aid that it gives to support social housing. Low cost housing is provided by independent non-profit making bodies called housing associations.

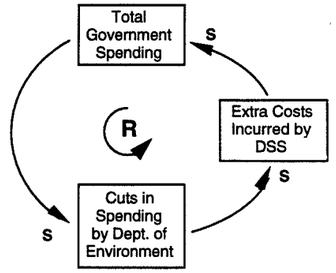
The amount of grant aid given to Housing associations by the Department of the Environment has fallen from 90% five years ago to around 55% today. This reduction in grant aid has required the housing associations to borrow more money in the open market the extra cost of which has caused rent levels to rise. The majority of the people housed by housing associations have low incomes and many cannot afford the higher rent levels. Therefore they claim housing benefit from the Department of Social Security to help pay their rent. (Philips 1993; Page 1993)

Step 1: Intended Behaviour



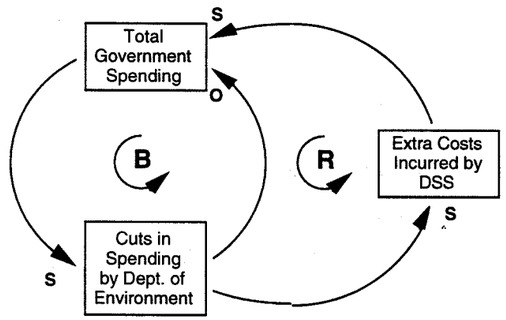
Rising government spending triggers cuts in departmental spending, this causes a reduction in total government spending.

Step 2: System Reaction



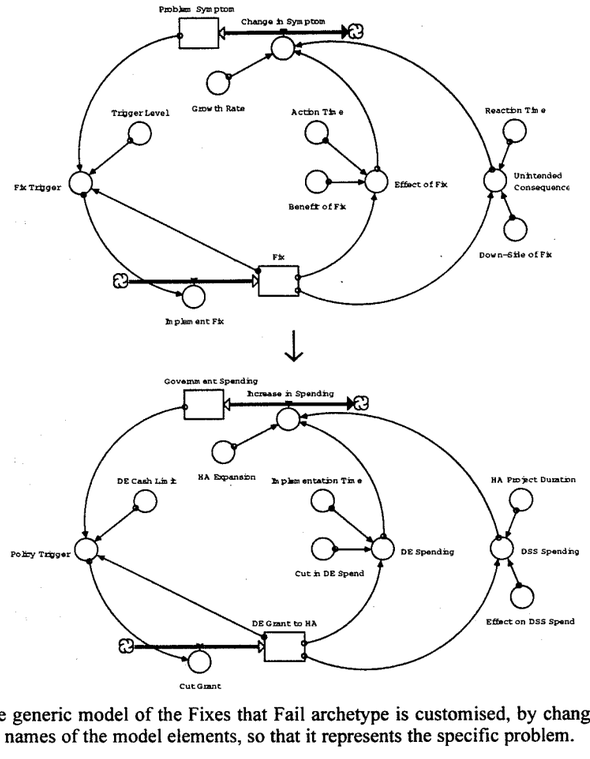
Reduced spending by one government department can and in this case will create extra costs for other departments.

Step 3: Create a Base Archetype



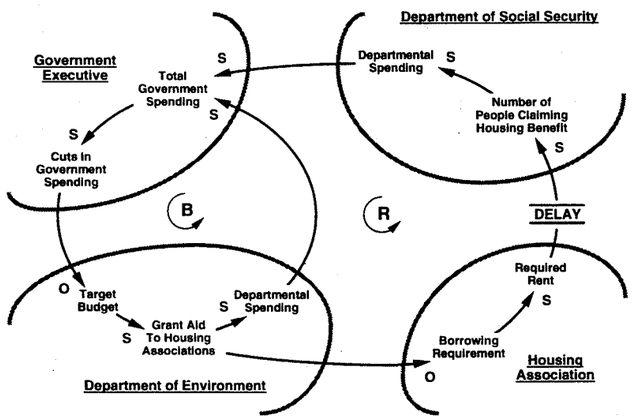
Combining the intended behaviour loop with system reaction loop creates a base archetype; in this case it is the "Fixes that Fail" archetype.

Step 4: Specify the Problem as a Generic Model



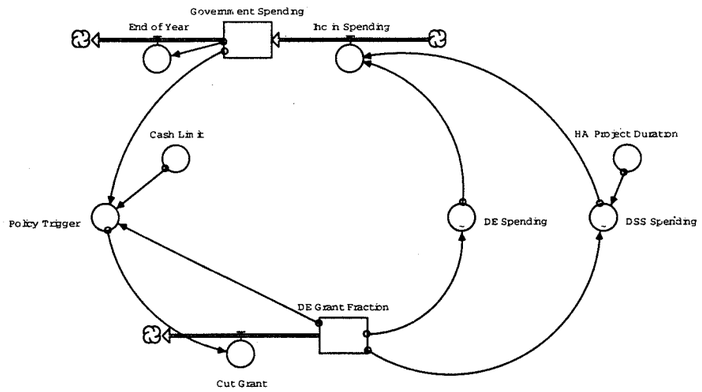
The generic model of the Fixes that Fail archetype is customised, by changing the names of the model elements, so that it represents the specific problem.

Step 5a: Qualitative First Pass Model



Extra model elements have been added to the base archetype, delays and organisational boundaries have been identified.

Step 5b: Quantitative First Pass Model



The direction of the "Fix" flow has been reversed (the fix is a reduction in grant fraction). An outflow has been added to the government spending stock to model annual budgeting. Two graphical functions have been created to quantify departmental spending. This model is capable of producing a convincing reference mode of behaviour.

Conclusions

Observation of a number of systems thinking training courses, has shown that it is a relatively simple task to teach managers how to use the STELLA/iThink software. Model conceptualisation has been identified as most difficult system thinking skill to acquire. In addition the benefit of training mixed groups of analysts and managers has been highlighted.

A conceptualisation framework, that quickly takes managers from a problem to a working model has been developed. The framework has been applied to the conceptualisation of a model of public housing provision.

Currently the framework supports the "Fixes that Fail" and the "Limits to Success" base archetypes. This limits the application of the framework to conceptualisation exercises based around these two base archetypes. Further development work will extend the method to cover the rest of the base archetypes. This will allow the enhanced framework to be applied as a conceptualisation aid to any kind of problem.

Acknowledgements

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References

Ackoff, R.L. 1979. The Future of Operational Research is Past, *Journal of the Operational Research Society*, 30: 93-104.

Forrester, J. W. (1961). *Industrial Dynamics*. Cambridge MA: Productivity Press.

Forrester, J. W. (1968). Market Growth as Influenced by Capital Investment. *Industrial Management Review*. 9(2), 83-105.

Kim, D. H. (1992). Systems Archetypes at a Glance. *The Systems Thinker*, 3(4), 5-6.

Mass, N. J. (1986). Methods of conceptualization (1981). *System Dynamics Review*, 2(1), 76-80.

Morecroft, J. D. W. (1982). A Critical Review of Diagramming Tools for Conceptualizing Feedback System Models. *Dynamica*, 8, part 1, 20-29.

Page, D. (1993). *Building for Communities: A Study of New Housing Association Estates*, Joseph Rowntree Foundation, York.

Paich, M. (1985). Generic Structures. *System Dynamics Review*, 1(1), 126-132.

Phillips, M. (1993). Quick Fix For The Homeless That's Sure To Come Unstuck. *The Guardian* 5/8/93, pp 18.

Randers, J. (1980) Guidelines for Model Conceptualisation. In *Elements of the Systems Dynamics Method*, ed. J. Randers. Cambridge, Mass.: MIT Press.

Richardson, G. & A.L. Pugh III (1981). *Introduction to System Dynamics Modelling with Dynamo*. Cambridge MA: Productivity Press.

Richmond, B., P. Vescuso, & S. Peterson (1987). *An Academic User's Guide to Stella*. Lyme, NH: High Performance Systems.

Richmond, B. (1990). Systems Thinking: A Critical Set of Critical Thinking Skills for the 90's and Beyond. In D. F. Anderson, G. P. Richardson, & J. D. Sterman (Ed.), *Proceedings of the 1990 International System Dynamics Conference* (pp. 934). Chestnut Hill, Mass.

Richmond, B., S. Peterson & C Charyk (1993). *Introduction to Systems Thinking and Ithink*. Lyme, NH: High Performance Systems.

Saeed, K. (1986). Minds over methods. *System Dynamics Review*, 2(2), 150-156.

Senge, P. M. (1985). System Dynamics, Mental Models, the Development of Management Intuition. In *Proceedings of the 1985 International Conference of the System Dynamics Society* (pp. 788). Keystone, Colorado.

Senge, P. M. (1990). *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Doubleday.

Wolstenholme, E. F., & R. G. Coyle (1983). The Development of System Dynamics as a Methodology for System Description and Qualitative Analysis. *Journal of the Operational Research Society* (UK), 34(7), 569-581.

Wolstenholme, E. F. (1985). A Methodology for Qualitative System Dynamics. In *Proceedings of the 1985 International Conference of the Systems Dynamics Society* (pp. 1049). Keystone, Colorado.

Wolstenholme, E.F. (1990). *System Enquiry - A System Dynamics Approach*, Wiley, New York.

Wolstenholme, E.F. (1992) The Definition and Application of a Stepwise Approach to Model Conceptualisation and Analysis. *European Journal of Operational Research*. 59(1992) 123-136 North-Holland.

Wolstenholme, E.F. (1993). A Case Study in Community Care using Systems Thinking, *Journal of the Operational Research Society*. Vol 44, No 9, pp. 925-934.

Wolstenholme, E.F. & D.A. Corben (1993). Towards a Core Set of Archetypal Structures. In *Proceedings of the 1993 International Conference of the System Dynamics Society* (pp. 583-592). Cancun, Mexico.