Using generic system archetypes to support thinking and modelling

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Abstract

This paper provides some context for my paper which won the 2004 Jay Wright Forrester award. It describes the system dynamics challenges I received from a number of people and my response to them, particularly to explore the issue of mismatch in organisations between process and boundary structure. It also describes how I have been using generic archetypes in practice since publication of the original work. Copyright © 2004 John Wiley & Sons, Ltd.

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It gives me great pleasure to accept the Jay Wright Forrester Award for 2004. I would like to thank my nominators, the Society awards committee and particularly David Andersen for his kind words in the introduction.

I would also like to thank a number of people who have helped me over many years to develop the thinking that led to the award.

I owe a big debt to my wife, Liz. It was Liz who in 1976 saw a small advertisement in a local paper for a Research Fellow in system dynamics at Bradford Management Centre and thought I might be interested. At that time I was working in operational research at British Coal and the idea of developing more strategic models appealed very much. Liz is an instinctive systems thinker and until recently was the lead in the Department of Health in the UK for, amongst other things, older people's services. For many years she has been my mentor and guide through both systems thinking and health/social care in the UK.

I am also grateful to many colleagues in many organisations for their stimulus and patience with my questions and ideas. In particular I would mention my friends in the System Dynamics Society, Cognitus, various academic institutions and OLM for their continued support and encouragement.

In my lecture today I will focus on how I have been using the ideas of generic archetypes in practice since the award winning paper (Wolstenholme, 2003) was published and some conclusions from this work. These conclusions include the idea of describing the problem of implementing systemic thinking itself in archetypal form. To support the application description, I will summarise the paper and explain the importance of organisational boundaries in system archetypes. I will also outline the challenges that led to the research and will, in turn, suggest one or two of my own research challenges for the future.

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the System Dynamics Society. His numerous publications have included two books *System Enquiry—A System Dynamics Approach* and *The Evaluation of Management Information Systems—A Dynamic and Holistic Approach*, both with Wiley.

The important role of system archetypes in system dynamics

In describing my work with systems archetypes I would like to begin by stating what I believe we try to do in system dynamics. This is to:

> demonstrate the disadvantages of non-systemic solutions to complex issues and to formulate, test and demonstrate the advantages of systemic solutions.

To achieve this objective I personally use a mix of qualitative and quantitative ideas and I believe that good practice in any assignment is to oscillate between the two, since each is complementary to the other. System archetypes are fundamental to this process. They can be used as free-standing solutions to complex issues (Wolstenholme 1990, 1993a,b; Wolstenholme and Coyle 1983; Senge 1990) and as an aid to quantitative modelling (Wolstenholme 1990, 1999; Wolstenholme *et al.* 2004). Archetypes can assist model conceptualisation by virtue of their isomorphic properties to transfer thinking from one domain to another. Archetypes are also useful to communicate modelling insights by collapsing a model down to its basic loops.

Archetypes capture the essence of "thinking" in systems thinking and I feel that they are so fundamentally important to system dynamics modelling that I have always designed my teaching of system dynamics around them. By coffee time on the first morning of a workshop participants have seen examples of, and drawn their own, two-loop archetypes. Only then do we start to look at modelling software and the process of system dynamics, which might help us develop the rigour of the thinking and the understanding of behaviour.

Given this role for system archetypes the objectives of my work have been to:

1. Improve the description of system archetypes. I have defined both "problem" and "closed loop solution" archetypes. In many current drawings of archetypes problem and solution links are often confused, making the message of the archetype difficult to interpret.
2. Simplify and reduce the number system archetypes and improve their usability. It has always puzzled me how many archetypes there are or there might be and this thought led me to the conclusion that all existing archetypes are actually only semi-generic. Further, that there exists a core set of four totally generic archetypes, which underpin all other archetypes. These arise from the four ways of ordering a pair of balancing and reinforcing feedback loops and all semi-generic archetypes can be mapped on to them.
3. To enrich their characteristics. The main contribution here has been the idea of superimposing "organisational boundaries" onto archetypes to improve the distinction between intended and unintended consequences of actions contained in archetypes.

Today I wish to focus on this last objective first.

The important role of boundaries in organisations and hence in system dynamics

The original concept of system dynamics consisted of four components of system "structure". These were:

1. processes, created using stock-flow chains;
2. information feedback;
3. policy;
4. time delays.

Although system dynamics has always made an interesting distinction between endogeneous and exogeneous variables in explaining organisational behaviour over time, this thinking was never extended to sub-sets of the organisation. Boundaries between sectors of organisations were not explicitly present in the original concept of system dynamics and yet often provide insights as to why systemic solutions are difficult to create and implement.

Although the concept of sectors is now integrated into system dynamics software, there is still a great underestimation of the link between sectors and process behaviour. Interestingly, boundaries still never appear on causal maps and system archetypes. I believe boundaries are the fifth component of system dynamics structure and rank equally with the first four.

My recognition of the importance of boundaries as a fundamental facet of system behaviour arose from four separate challenges given to me by colleagues over the years. I was encouraged to think about:

- system dynamics and power (Arie de Geus);
- the interaction of organisational structure and process (Peter Checkland);
- how to create a commercial proposition to managers from the difficult content and unpalatable messages of system dynamics (Jorgen Randers);
- how system dynamics relates to Porter's value chain (Richard Stevenson).

The common theme of all these challenges is boundaries. Boundaries are important simply because they:

- exist and cannot be ignored—organisations are by definition bounded entities;
- represent the functions, accountability, power and culture of organisations, teams and individuals;
- are a major key to implementing systemic solutions.

Consider the value chain representation of a financial services company as shown in Figure 1. The value chain is essentially a picture of the organisational sectors of an organisation and, importantly, the **order** in which they **take place**.

Fig. 1. The value chain of a financial services company.

Such an ordered set of activities is explicitly linked to the underlying core processes of the organisation, the states of which can be easily conceived in stock–flow terms from the value chain. For example, the main process underpinning the above financial services value chain is customer acquisition; in the states of "being aware of the services", "enquiring", "buying" and "being serviced".

The value chain representation of organisational structure, together with an appreciation of the process structure across them, forces recognition that boundaries are responsible for:

- The "silo" mentality often observed in organisations, which inhibits the process flow. It is the boundary structure of an organisation that mitigates for local performance measures and against systemic solutions. Boundaries bring to life the system insights that:
  - the best levers for improvement in the behaviour of your own sector often lie on someone else's patch;
  - the benefits of policy change you undertake often accrue to someone else.
- The power and influence in organisations. Different sectors of an organisation have different degrees of influence over their underlying process flows. It is usually the case that sectors at the front of the value chain (early in the process) have more power than those at the back end of the value chain. For example, in financial services resources are frequently allocated to customer generation activities at the expenses of customer service, despite the fact that customer service is vital to customer retention. This is equivalent in system dynamics terms to saying that flows into a stock are often given preference over drains from a stock.
- Boundary management problems. Organisational boundaries are similar to national boundaries. Flows across them require managing and usually the creation of "check point Charlies" where flows must be checked out from one sector *and* checked into the next sector.

It is also important to realise that boundaries change incessantly. They are changed by political and management whim to establish new orders, usually without any thought for the associated process disruption. Further, in large organisations changes are often made so frequently that the previous changes (or even the one before that) have still not been completely implemented. It is not surprising in these circumstances that chaos reigns.

The aim of systemic thinking should be to accept and embrace boundaries as necessary for management and accountability, but encourage thinking across them wherever possible. The concept of acting locally but thinking globally can be restated as a need to look down into the local sector of the value chain but also to look sideways and upwards across and over the value chain. There is a need for boundaries to be more like "net curtains" than "heavy drapes".

Research challenge 1. A major research challenge for system dynamics is to ask what contribution system dynamics might make to the design of organisational boundary structure. For example, is there a "right" set of boundaries for an organisation, which has complete synergy with its processes. If so, should there be one boundary per process or one boundary per feedback loop?

Finally, one of the most important features of boundaries in relation to system dynamics is that they mask the unintended consequences of actions. In the original article I suggested a visual metaphor for the effects of boundaries on actions. The extremes for this were defined as being totally blind to unintended consequences and being totally sighted. Both extremes are rare and there exists a range of conditions in between, each representing different degrees of partial sightedness and hence different degrees of recognition of unintended consequences.

Using generic two-loop archetypes to support the system dynamics modelling process

Introduction

It has already been suggested that generic archetypes can help with the creation of dynamic hypotheses at the front end of the modelling process and with the communication of systemic insights at the back end of the modelling process. In practice, it is often beneficial to use the archetypes in parallel throughout the process to guide high-level thinking whilst detailed modelling is taking place.

Full stock–flow maps of processes and even comprehensive causal maps are often, by necessity, too detailed and can distract from the systemic thinking which provoked their creation. Stock–flow maps can become disjointed as detail increases and this is particularly true when they are created using sophisticated software. Modern system dynamics software brings with it a tremendous learning potential, but can easily mask feedback by:

- the use of ghosting of variables to remove clutter from diagrams;
- the inclusion of the model user within the feedback loop structure of the model, through the use of slider bars;

- the direction of arrows on the flows (this issue will be addressed separately later);

In order to demonstrate the use of generic two-loop archetypes to support a comprehensive modelling initiative, a example will be given in terms of some recent experience in health care modelling (Wolstenholme *et al.* 2004). In support of this example, the appendices to this paper summarise the ideas around archetypes developed in the original article for which the award was given (Wolstenholme 2003). Appendix A presents the concept of problem and solution archetypes and appendix B presents the four totally generic archetypes; "underachievement", "out of control", "relative achievement" and "relative control".

One point to note in the presentation of archetypes in this article is the explicit representation of organisational boundaries as closed shaded areas. I have tended to use this approach in recent work, rather than showing boundaries as single lines of demarcation as in the original paper.

Background to the example

The example involves the use of a comprehensive programme of modelling of patient pathways for older people at the national level in the UK across primary care, hospitals and post-hospital agencies. The aim was to understand better the interactions of resource allocation on all the performance measures across the pathway. In support of this modelling a number of simple archetype models were created to support thinking and dissemination of insights. One example is shown in Figures 2 & 4 involving the use of a generic "underachievement" archetype and a generic "out-of-control" archetype to demonstrate some of the unintended consequences of one particular non-systemic policy. This was the policy of increasing hospital capacity in response to rising health care demand.

Problem Archetype 1: increasing hospital capacity to cope with a rising demand for health care—an underachievement archetype.

Figure 2 captures a situation between hospitals and the community in which hospitals react to growing demand by increasing capacity. This is a policy link typical of health care management in most developed countries. The intended consequence is to facilitate more hospital admissions and cater for more unmet need in the community. Although only some ex-hospital patients need post-hospital services, an unintended consequence of the policy is to create additional demand for post-hospital services. However, these services also have limited capacity and hence act to limit the effectiveness of the hospital sector expansion. The result is an "underachievement" problem archetype.

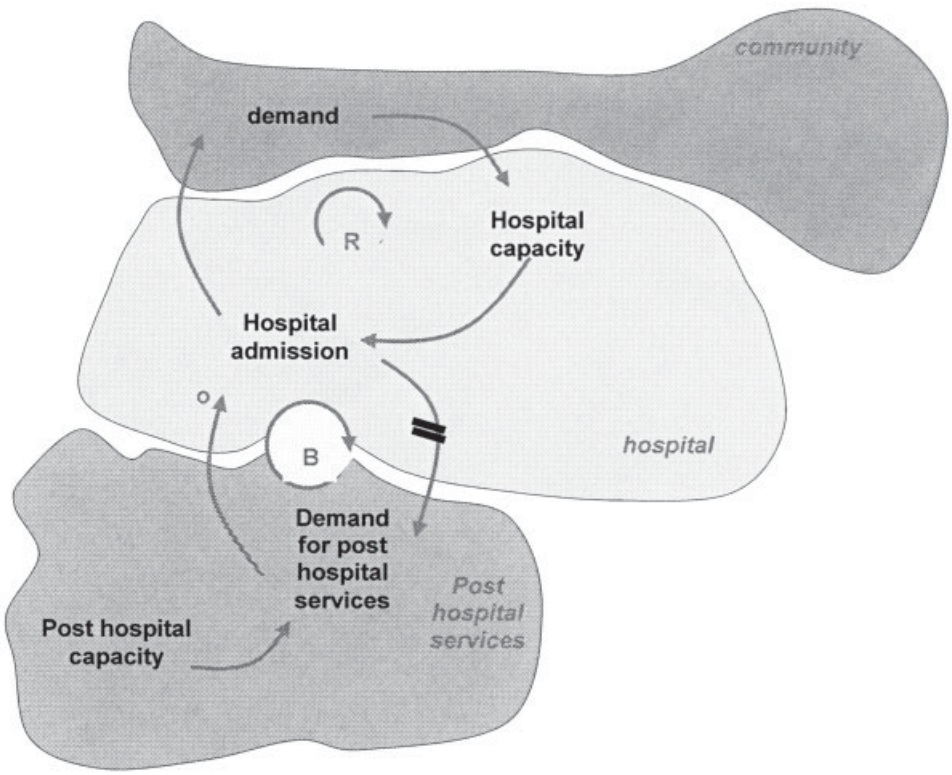

Fig. 2. The "underachievement" problem archetype associated with hospital expansion

Solution Archetype 1: increasing both hospital capacity and post-hospital capacity together

The theory of solution archetypes suggests that the answer to the underachievement should be known from a careful consideration of the structure of the problem archetype. This is to create a solution link between the community demand and the post-hospital capacity. The purpose of the link is to unblock the post-hospital capacity constraint in parallel with the hospital capacity expansion policy as shown in Figure 3. However, such action requires joint understanding and work between hospitals and post-hospital services. Evidence suggests that, at least in the UK, such thinking is at a political level and takes about 15 years to develop and implement.

Problem Archetype 2: increasing early discharges from hospital—an out-of-control archetype

In the meantime health and social care agencies are faced with a need to find other measures to relieve the problem of operating beyond their design

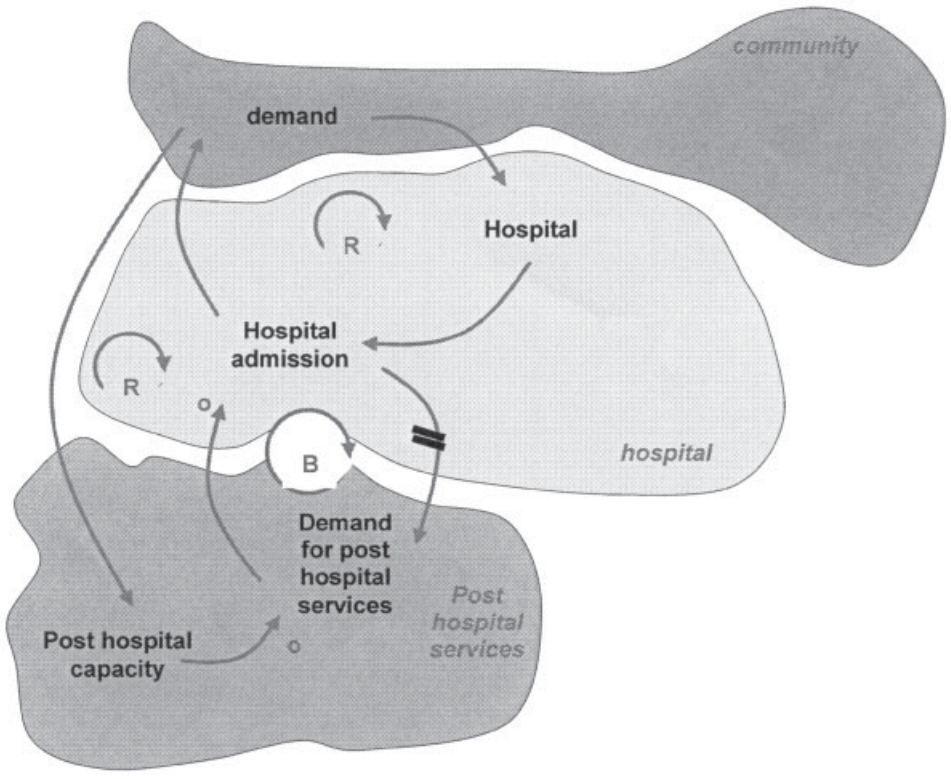

Fig. 3. The "underachievement" solution archetype associated with hospital expansion

capacities. The most expedient action for hospital management is to find a solution (a fix) within their own sphere of control (within their own boundaries) that can reinforce the original intent. One policy that fulfils this purpose is to implement a policy of early discharges from hospital as shown in Figure 4.

This action creates another policy link and another problem archetype, this time an "out-of-control" (or more specifically a fix-that-fails) archetype. The intended consequence of the action is to effectively control hospital capacity and assist the original action of hospital expansion. However, the unintended consequence is to have the opposite effect on hospital capacity across the community boundary as shown. A proportion of people who are discharged early from hospital will need readmission and hence reduce the effectiveness of the hospital capacity for new entrants.

Solution Archetype 2: reducing readmissions to hospital

Again the theory of out-of-control archetypes suggests that a solution should be known. This is to take action to minimise the readmissions in parallel with

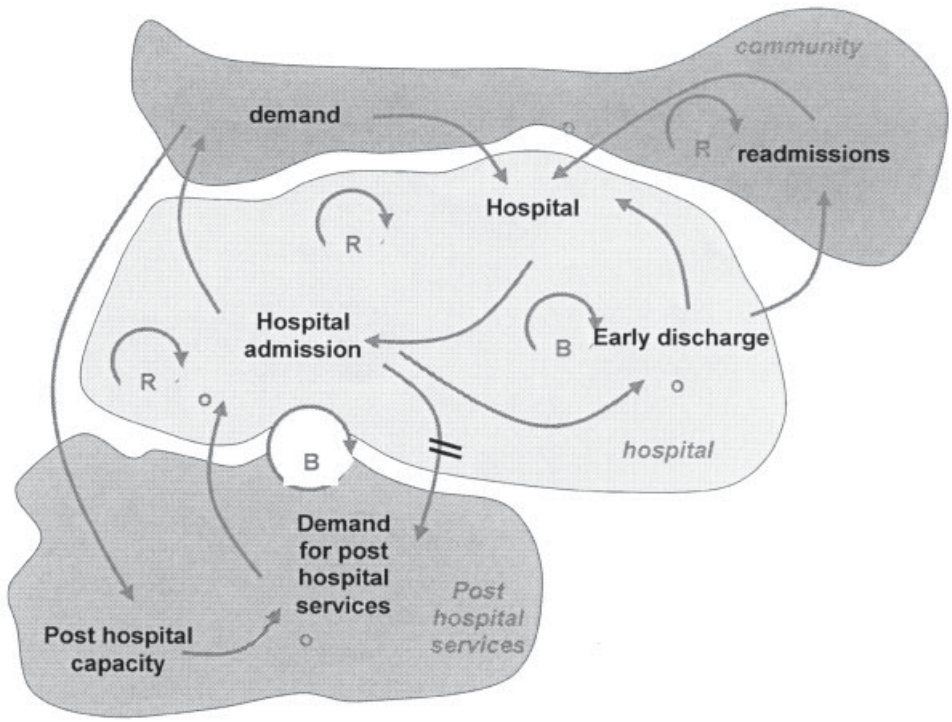

Fig. 4. The "out-of-control" problem archetype associated with early hospital discharges

the early discharge policy. Again the solution is difficult and the challenge is how to work across boundaries. It involves careful choice of people to be discharged early and technical and physical support for them in the community. However, ironically in this case, such support has to come from post-hospital services and countering readmissions further restricts the post-hospital service capacity and hence regular discharges from hospital.

Conclusions of the example

The use of archetypes in the way described assists in the capture and dissemination of policy stories to orientate and support a system dynamics modelling effort.

Causal maps have often been used in this way. However, carefully constructed generic problem and solution archetypes, supported by organisational boundary considerations, provide a more compelling, focused and rigorous approach. Their use, of course, needs to be substantiated as much as possible by evidence-based quantitative models.

A number of interesting issues have been discovered in using system archetypes in this way:

1. Using a *problem* archetype to articulate the difficulty of implementing systems thinking. The issue of implementing systemic solutions can itself be represented as a *problem* archetype. We could say that systemic solutions will always underachieve their potential because of the application of more expedient solutions ("underachievement" archetype, specifically "limits to success"). Alternatively, we could say that fixes will always take preference over systemic solutions ("out-of-control" archetype, specifically "shifting the burden"). Either way there will always be a tendency towards non-systemic solutions, due to the difficulties associated with systemic answers. For example, in asset management there is a tendency to get locked into the fix of maintenance of assets and never achieve replacement of assets.
2. Using a *solution* archetype to articulate how to implement systems thinking. Defining problem archetypes always leads to thinking about solution archetypes. The solution in this case centres on minimising the unintended consequences of systemic solutions. It highlights "what needs to be *undone*" before implementing "what should be *done*". Systemic solutions can only be successful if organisations first dismantle and eliminate costly and chaotic "fire fighting" policies, which have been built up in some sectors to provide expedient safety valves. A general statement of the systemic principle involved here is:

   > to get the best out of systemic policies it is necessary first to remove institutionalised, emergency coping mechanisms (fixes), created because of time delays and difficulties in cross boundary working.

3. Cascaded archetypes. Figure 4 gives a good example of multiple problem and solution archetypes. It is only too easy in such situations (as with causal maps in general) to see every pair of loops as an archetype. This is not the case. A good way to recognise true archetypes is that each must be driven by an intended "policy" (choice) link. So "early discharge" is an alternative policy driver to "hospital capacity expansion" as a means of generating hospital capacity. However, the unintended consequences links of archetypes can be either "behavioural" or "policy" links.

   In Figure 4 all the unintended consequences are behavioural. However, where unintended consequences are policy reactions it is possible to get cascaded, overlapping archetypes. This is a situation where the unintended consequence reaction of one archetype becomes the intended consequence driver for the next. Such sequences of cascaded archetypes might ultimately feedback on one another!

   > **Research challenge 2.** A second major research challenge for system dynamics is to ask what is the merit of perceiving the world as a set of cascaded archetypes and what role cascaded system archetypes might play in support of systemic thinking and model development.

Seeing feedback loops and archetypes on stock–flow diagrams

It is often the case that it can be helpful to identify archetypes within stock–flow maps and the research here has led to developing ways of doing this. It has already been stated earlier that the use of stock–flow maps can mask feedback by the direction of the arrows used for flows and hence some means of unmasking the feedback structure is required.

For many years I have used a simple trick on stock–flow maps to reveal feedback structure. This method does not appear to be widely known and is worth stating here:

> All that is necessary to achieve a one-to one correspondence between causal maps and stock–flow maps is to show the relationship between every outflow rate from a stock and the stock itself as an opposing influence, rather than a flow.

Figure 5 shows a simple "stress" model in stock–flow terms, but with the superimposition of an opposing causal link between the "work completion rate" and "work backlog" stock. This has the effect of instantly converting the stock–flow map to a causal loop map, revealing the model as a two-loop "underachievement" archetype, which emphasises the role of stress as an avoidable unintended consequence of over-time policies.

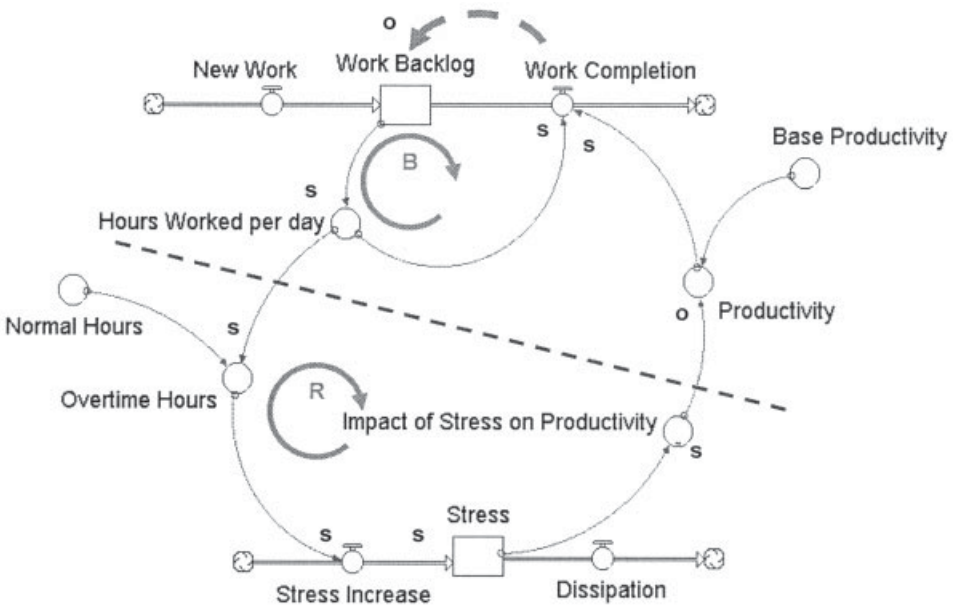

Fig. 5. A "stress" model

Research challenge 3. A third major research challenge for system dynamics is for software developers to find a way to reveal easily causal links and system archetypes within system dynamics software.

Conclusions

This lecture has suggested that system archetypes have much to offer the process of system dynamics and, as a result of the award, I hope that other people might be motivated to increase the overall research effort in archetypes, particularly as a means of accelerating management learning. I believe we need constantly to find better ways of communicating systemic ideas with managers and to keep repeating the same messages if necessary, particularly to those people at the centre of power in long process chains.

The good news is that it is getting easier in my opinion to engage managers in systems thinking. I believe there is a greater receptiveness of the ideas now than ever before.

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Appendix A

Problem and Solution Archetypes

Figure A1 shows a generic problem archetype consisting of an action created within one sector of an organisation to create an intended outcome and an unintended reaction in another sector of the organisation.

Figure A2 shows a generic solution archetype where in parallel with the action there is an attempt to anticipate and lessen the reaction in the second sector. By definition such action is hard to achieve as it requires working across the boundary.

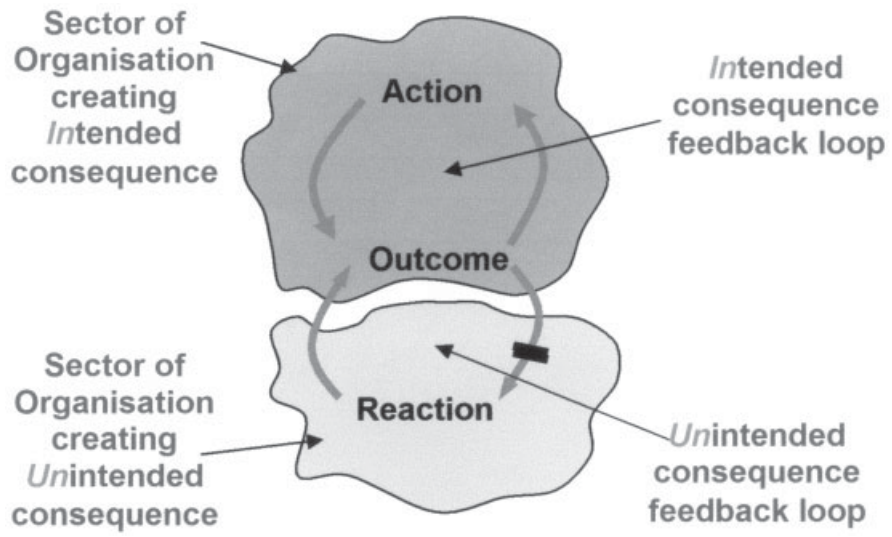


Fig. A1. A totally generic problem archetype

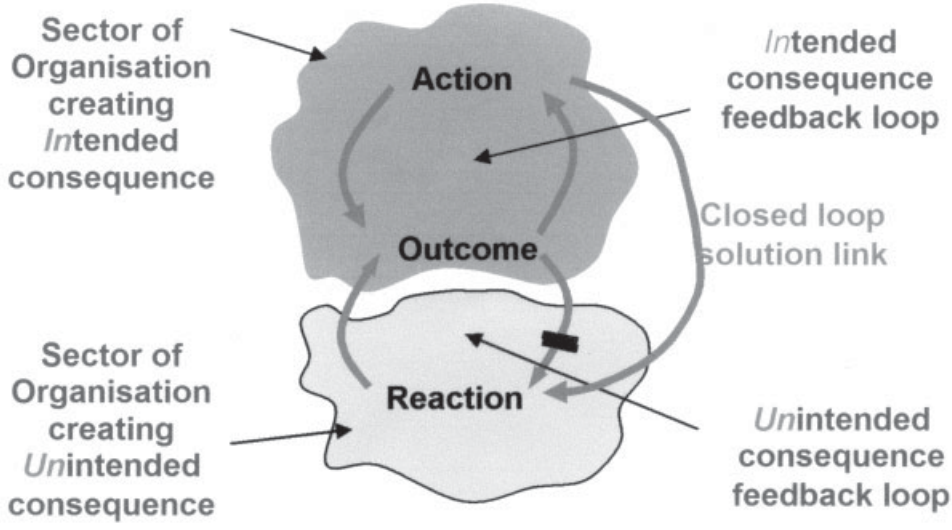


Fig. A2. A totally generic solution archetype

Appendix B

The core set of archetypes summarised:

Figures B1 to B4 show respectively the four archetypes, "underachievement", "out of control", "relative achievement" and "relative control".

Semi-generic archetypes that can be mapped onto the generic "underachievement archetype" (Figure B1) are Limits to success, Tragedy of the commons and Growth and underinvestment.

Semi-generic archetypes that can be mapped onto the "out of control" archetype (Figure B2) are Fixes that fail, Shifting the burden and Accidental adversaries.

The semi-generic archetype which can be mapped onto the "relative achievement" (Figure B3) archetype is Success to the successful.

The semi-generic archetypes which can be mapped onto the "relative control" archetype (Figure B4) are Escalation and Drifting goals.

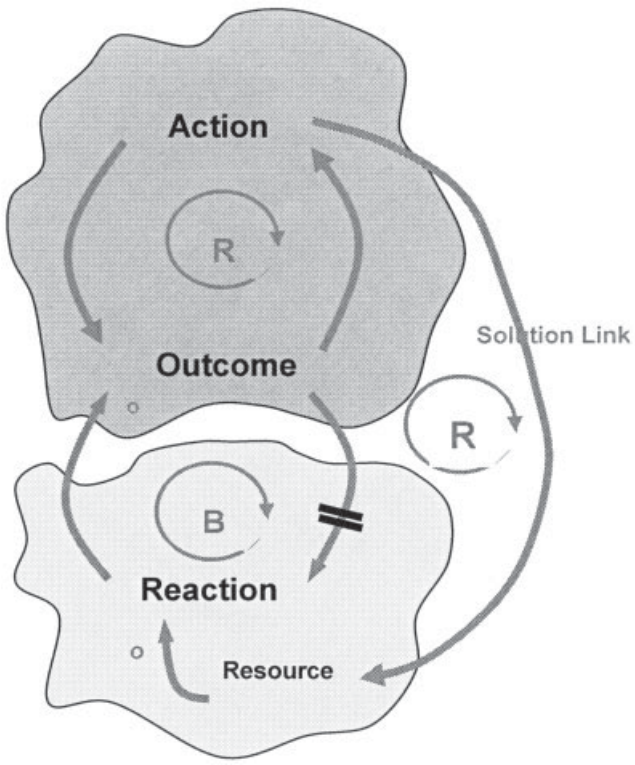


Fig. B1. "Underachievement" archetype

Fig. B2. "Out of control" archetype

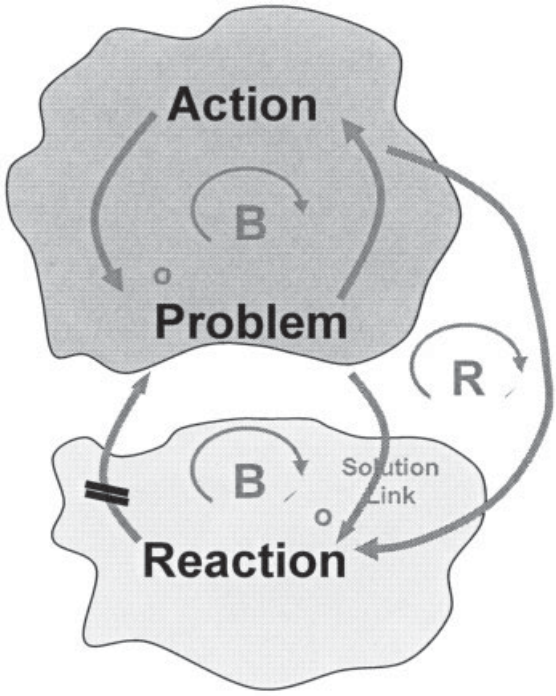
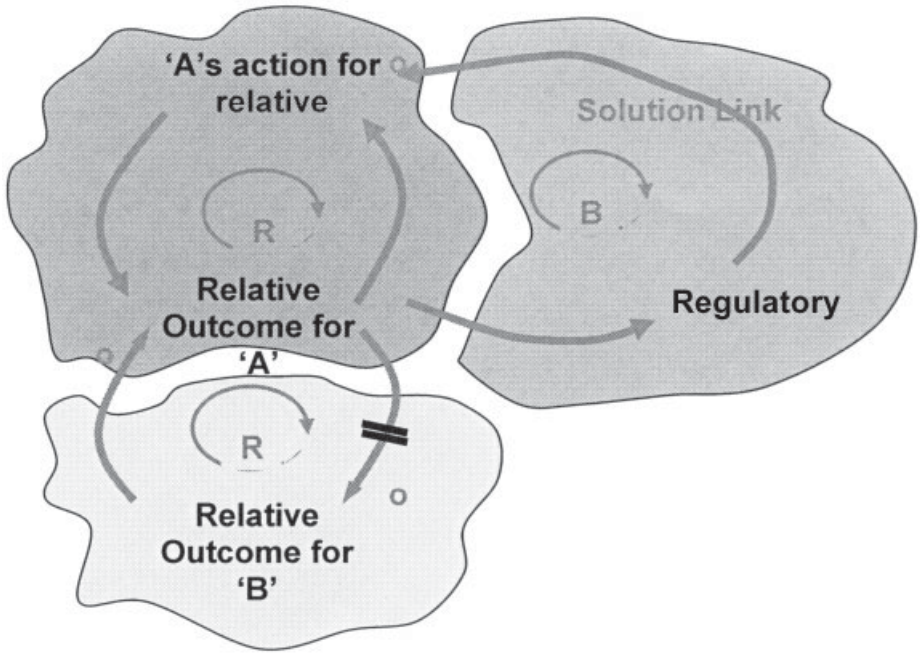


Fig. B3. "Relative achievement" archetype



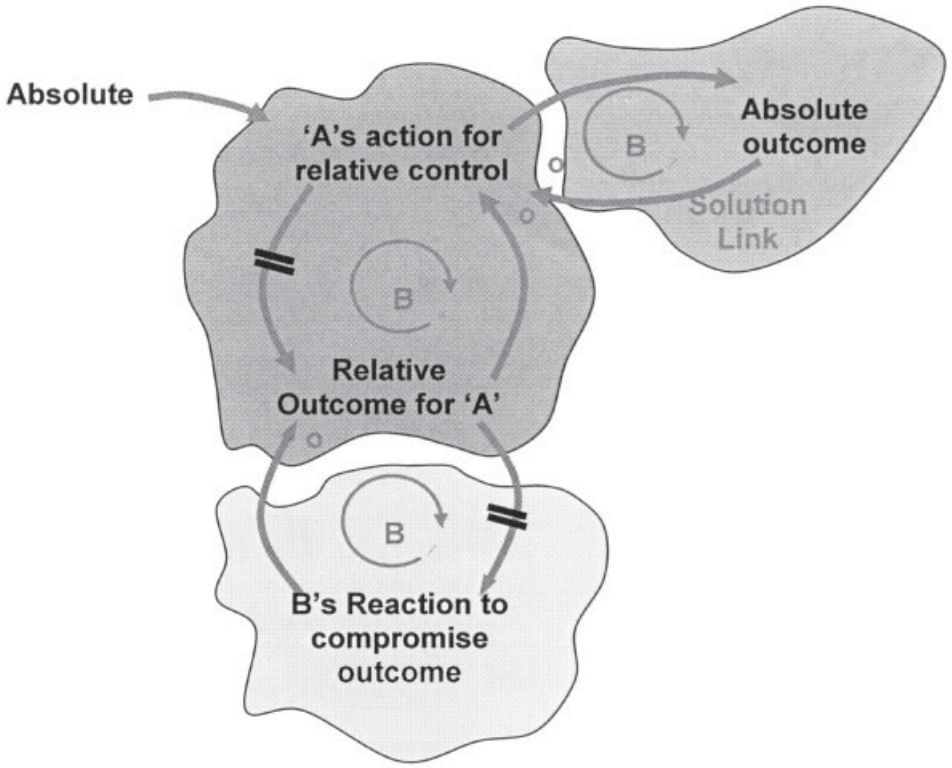


Fig. B4. "Relative control" archetype