# Towards a Core Set of Archetypal Structures in System Dynamics

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## ABSTRACT

Recent research in the field of System Dynamics has been concerned with defining archetypal structures by which to classify insights in dynamical systems. For example, Richmond has proposed both infrastructure and activity archetypes, whereas Senge has defined eight relevant generic structures. Additionally, Wolstenholme has defined a number of management situations as being made up of actual outcomes which are opposed to those intended.

This paper attempts to condense archetypal structures to a minimum set. It is suggested that most archetypal structures can be reduced to a composition of two feedback loops. Given that these are sufficient, there are then only four possible archetypes which represent the four ways or ordering a pair of feedback loops. Further, it is suggested that it is possible to classify all these loop combinations as special cases of 'unintended consequences'.

## INTRODUCTION

System archetypes represent an attempt to classify system structures and behaviours and, in particular, counter intuitive behaviours. The demonstration of such behaviour has been the province of System Dynamics from its early days and often the insights of extensive and complex simulation studies could be summed up by describing a simplified structural diagram of the resultant model.

Archetypes can be seen as a synthesis of much qualitative and quantitative modelling effort cumulated over many by many analysts, which can be used to help to generate understanding in new application domains and systems. This isomorphic quality makes them a very powerful mechanism for accelerating learning in an increasingly turbulent world.

System archetypes are playing an increasingly important role in the overall process of systems thinking. Recent research in the field of System Dynamics has focussed on refining and classifying archetypal structures. For example, Richmond (1988) has proposed both infrastructure and activity archetypes, whereas Senge (1990) has defined eight relevant generic structures. Additionally, Wolstenholme (1990, 1993) has defined a number of management situations as being made up of actual outcomes which are opposed to those intended.

This paper is based on the premise that the refining process still has a long way to go and that the archetypes currently published and used are in fact only semi generic.

Current experience of using and teaching archetypes to a wide range of audiences by the authors has lead to the view that there are problems in users being able to see with any clarity where and when some existing archetypes are applicable. These experiences confirm the need for a more basic classification of archetypes.

An attempts has therefore been made to condense archetypal structures to a minimum set. It is postulated here that most archetypal structures can be reduced to a composition of two feedback loops. Given that these are sufficient to describe, there are then only four possible totally generic archetypes which represent the four ways or ordering a pair of feedback loops.

Further, it is suggested that it is:

* possible to classify all achetypes as special cases of 'unintended consequences'
* possible to split generic archetypes into *problem* and *solution* archetypes
* important to recognise the importance of system boundaries in defining archetypes

This paper defines existing archetypes as *semi-generic problem* archetypes. It presents four basic *generic problem* archetypes and suggests that existing archetypes can be considered as special cases of these. Specific examples of each archetype are given and a *generic solution* archetype defined to go with each problem archetype. First, however the underlying concepts and advantages associated with defining two-loop archetypes will be discussed.

## TOTALLY GENERIC PROBLEM ARCHETYPES

System Dynamics in general, and archetypes in particular, describe systems in terms of feedback loops arising from a combination of actions (rates of change) and outcomes (levels). The behaviour of such loops depends on the specific combination of components defined, together with the delays present, the effects of policies and system boundaries. Of particular importance is the often conflicting effects of actions initiated by different system actors in different sectors of an organisation.

Actions by system actors can be basically of two kinds. These are actions which attempt to control an organisation by introducing balancing (negative) feedback effects and those which attempt to initiate growth of an organisation by initiating reinforcing (positive) feedback effects. The way in which organisations respond to such actions is of prime importance in developing understanding of behavioural insights and is a cornerstone of systems thinking and system dynamics.

It should be noted that responses can come from the same system participants who

instigate the original actions (perhaps due to impatience with the time taken for their original actions to have effect). However, it is more often the case that the response comes in the form of action from other sectors of the organisation or externally. These responses might be natural or arising from the actions of other system actors.

In either case the response itself will be either a reinforcing or a balancing force. Hence, four possible two-loop archetypes can be defined to represent these basic action-outcome-response situations. This thinking will be developed further in the next section of the paper.

## FOUR GENERIC PROBLEM ARCHETYPES

The four basic generic archetypes to cover the two-loop situations described in the last section can be specified as follows:

*** growth intended --- stagnation/ decline achieved.**
( composition --- a reinforcing loop with a balancing loop) (Figure 1)

In this case the archetype consists of a reinforcing loop intended to promote growth, but the response from some other sector of the system is the creation of a balancing loop. The result is, at best, an outcome less than the intended growth rate and, at worst, a decline in performance.

*** control intended --- unwanted growth achieved.**
(composition --- a balancing loop with a reinforcement loop) (Figure 2).

In this case the archetype consists of a balancing loop intended to control a problem, but the response from some other sector of the system is a reinforcing loop, resulting in a possible worsening of the problem. It is useful to note that in this archetype it is usually the control action itself, rather than the problem, which provokes the system response.

*** control intended --- compromise achieved.**
(composition --- two balancing loops) (Figure 3)

In this case the archetype consists of a balancing loop intended to control an outcome *relative to a target or a competitor*, and the response from some other sector of the system is that the target is adjusted or the competitor reacts to compromise the outcome.

*** growth intended --- at expense of others.**
(composition --- two reinforcing loops). (Figure 4).

In this case the archetype consists of a reinforcing loop intended to promote growth *relative to a competitor*, and the response from some other sector of the system is a (degenerate) reinforcing loop, resulting in decline of the competitor. (This represents

a zero some gaming situation and may not be totally unintentional.)

## SEMI-GENERIC PROBLEM ARCHETYPES

Existing, semi-generic problem archetypes can be mapped onto the totally generic problem archetypes defined in the last section of the paper.

Figure 1 suggests that the 'Limits to Growth' and 'Tragedy of the Commons' archetypes are in fact special cases of 'Growth Intended --- Stagnation Achieved'.

In the 'Limits to Growth' case a reinforcing loop is created by which to convert effort (e.g. sales) into improved performance (e.g. lower lead time), but a limiting factor is encountered in some other part of the system (e.g. production investment) which reduces performance.

In the 'Tragedy of the Commons' case a reinforcing loop is created by the actions of one group of system participants (e.g. visits to national parks) to improve an outcome ( e.g. pleasure), but the net effect of many people doing this results in some other effect (e.g. damage) which reduces the magnitude of the outcome.

Figure 2 suggests that the 'Fixes that Fail' and 'Shifting the Burden' archetypes are special cases of 'Control intended --- Unwanted Growth Achieved'.

In the 'Fixes that Fail' case a balancing loop is created by which to apply a fix (e.g. police recruitment) to control a problem or problem symptom (e.g. reported crime), but the response to the action in other parts of the system (e.g. overcrowding of prisons and early release), contributes to an increase in the problem.

In the 'Shifting the Burden' case a balancing loop is again created by which to apply a fix (e.g. police recruitment) to control a problem or problem symptom (e.g. reported crime). However, in this situation it is assumed that a fundamental solution exists and is known (e.g. the need to expand all sectors of the criminal justice system together), but the effect of the fix detracts from implementation of the fundamental solution and contributes to the problem persisting.

It is suggested in Figure 3 that the 'Escalation' and 'Drifting Goals' archetypes are special cases of 'Control Intended --- Compromise Achieved'.

In the 'Escalation' case action is taken (e.g. arms production) by one set of system participants to create a balancing loop for control of an outcome (e.g. superiority) relative to another group. However, the response of another group of participants in another sector of the system is to react by escalating their own action to undermine and compromise the outcome for the first group.

In the 'Drifting Goals' case action is taken (e.g. quality improvement) by a group of system participants to create an outcome (actual quality) relative to a target (planned quality), but achievement of the target perhaps takes too long and the

outcome is compromised by lowering the target.

It is suggested in Figure 4 that the 'Success to be Successful' archetype is a special case of 'Growth Intended --- At the Expense of Others'.

In this case action (e.g. financial allocation) is taken in favour of one group of system participants to promote an outcome (success) for that group and the result is a decline in the outcome for another group of participants in some other sector of the the system.

### Generic Solution Archetypes

Having defined four generic problem archetypes it is possible to indicate possible modifications to them which might alleviate the unintended consequences of each one.

In Figure 1 it is suggested that the solution lies in trying to use the growth action (e.g. sales information) to minimise the system reaction (e.g.under-investment).

In Figure 2 it is suggested that improvement lies in reinforcing fundamental solutions (e.g. a phased expansion of the whole of the criminal justice system) and minimising system reaction (e.g. reduced sentences) to partial solutions (e.g. police recruitment).

In Figure 3 it is suggested that a solution lies in the direction of taking action towards some absolute performance measure (e.g. absolute quality standard) rather than towards some compromised standard.

In Figure 4 it is suggested that equitable allocation policies should be pursued which attempt to balance outcomes.

It should be noted that in each archetype, the solution requires the transfer of information and action across system boundaries. The recognition that solutions rely on individual system participants in separate sectors of organisations developing shared understanding reinforces both the purpose of archetypes and the importance of incorporating system boundaries in the archetypes.

## THE GENERIC ARCHETYPES IN USE

The objective of defining a reduced set of system archetypes is to assist users in transferring insights between system types and, in practice, it is recommended that this reduced set of archetypes should be used in conjunction with existing archetypes.

The process might be as follows. Suggest that users start with a simple combination of two loops representing an action - outcome - response representation of their own situation. This might be easier for them than trying to remember a broader set

of archetypes and trying to recognise new situations as one of the broader set. Then suggest that they relate this basic structure to an existing archetype. Since there are only two existing archetypes associated with each new basic archetype, it should be much easier for them to focus thinking in this way and to move towards a new, specific case in their own domain.

## CONCLUSIONS

This paper has indicated that further research and development is necessary in the definition and classification of system archetypes. A reduced set of four basic problem archetypes has been suggested, each composed of a combination of two feedback loops. Existing archetypes have been classified as special cases of these four and suggestions made as to how the new generic set might be used in combination with existing archetypes to improve the transfer of ideas between different systems. Additionally, generic solution archetypes have been outlined for each of the problem archetypes and the relevance of marking system boundaries on archetypes emphasised.

## REFERENCES

Richmond, B.M. Peterson, S.and P. Vescuso (1988) An Academic User's Guide to STELLA, High Performance Systems Inc.

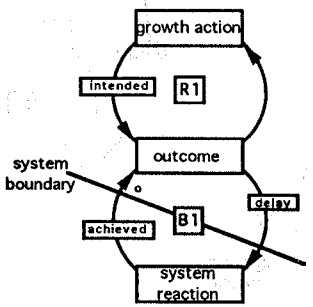
Senge, P. 1990, "The Fifth Discipline", Doubleday.

Wolstenholme, E.F., 1990, "System Enquiry - a System Dynamics Approach", Wiley.

Wolstenholme, E.F., 1993, The Evaluation of Management Information Systems. Wiley, Chichester.

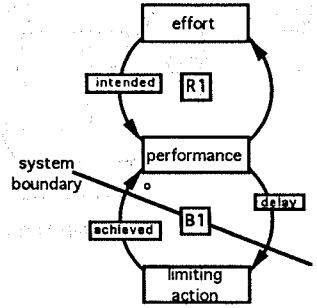
**GENERIC PROBLEM ARCHETYPE**

Intended growth. Unintended consequence is that system reacts to inhibit growth. (reinforcing loop triggers a balancing loop)

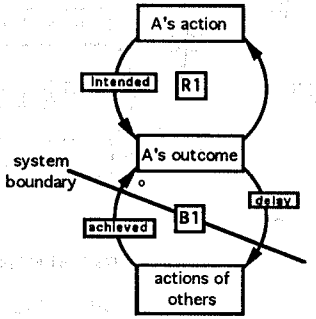



**SEMI GENERIC PROBLEM ARCHETYPE**

Limits to Growth

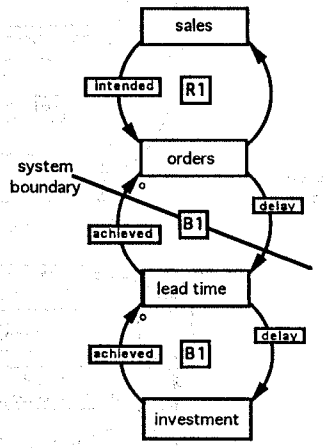



Tragedy Of The Commons

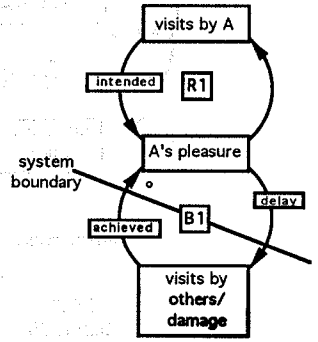



**SPECIFIC CASE**

Growth and Under Investment




National Park Visiting




**GENERIC SOLUTION ARCHETYPE**

use growth action to minimise system reaction

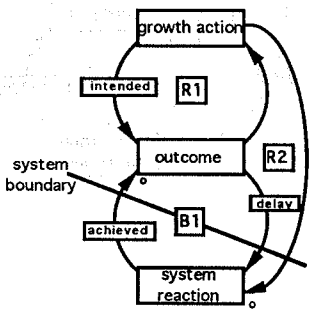
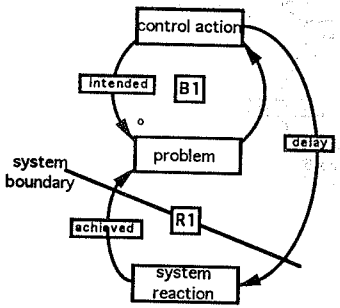



**Figure 1**
**'Growth intended -- stagnation achieved' Archetype**

R= reinforcing (positive) feedback loop
B= balancing (negative) feedback loop
O=opposing action

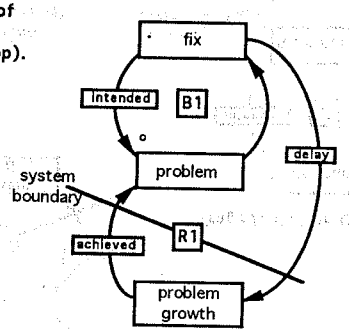
**GENERIC PROBLEM ARCHETYPE**

Intention of action is to introduce control of a problem (balancing loop) .
Unintended consequence is that system reacts to cause growth of problem or to detract from a fundamental solution (positive loop).

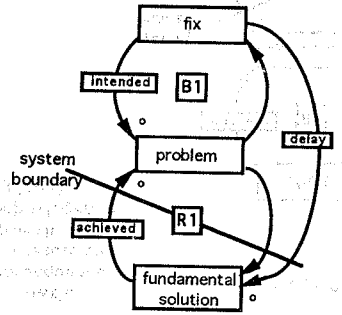



**SEMI GENERIC PROBLEM ARCHETYPE**

Fixes that Fail

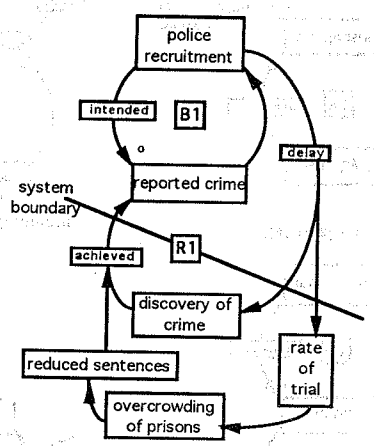



Shifting the Burden

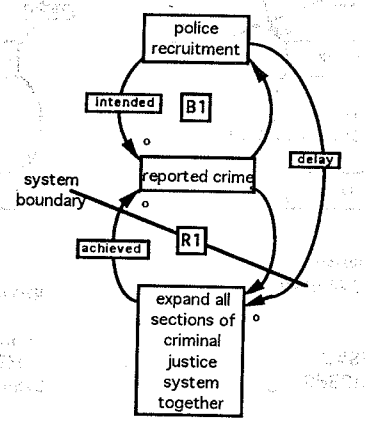



**SPECIFIC CASE**

Criminal Justice




Criminal Justice




**GENERIC SOLUTION ARCHETYPE**

design control actions to minimise system reaction and to reinforce fundamental solutions

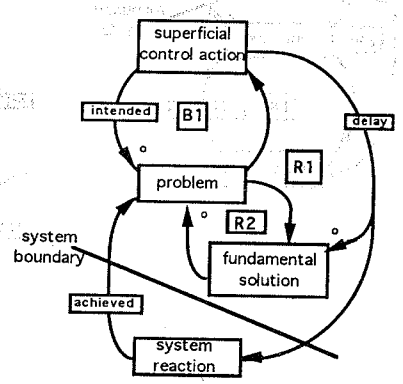



**Figure 2**
**'Control Intended -- unwanted growth achieved' Archetype**

R=reinforcing (positive) feedback loop
B=balancing (negative) feedback loop
O=opposing action

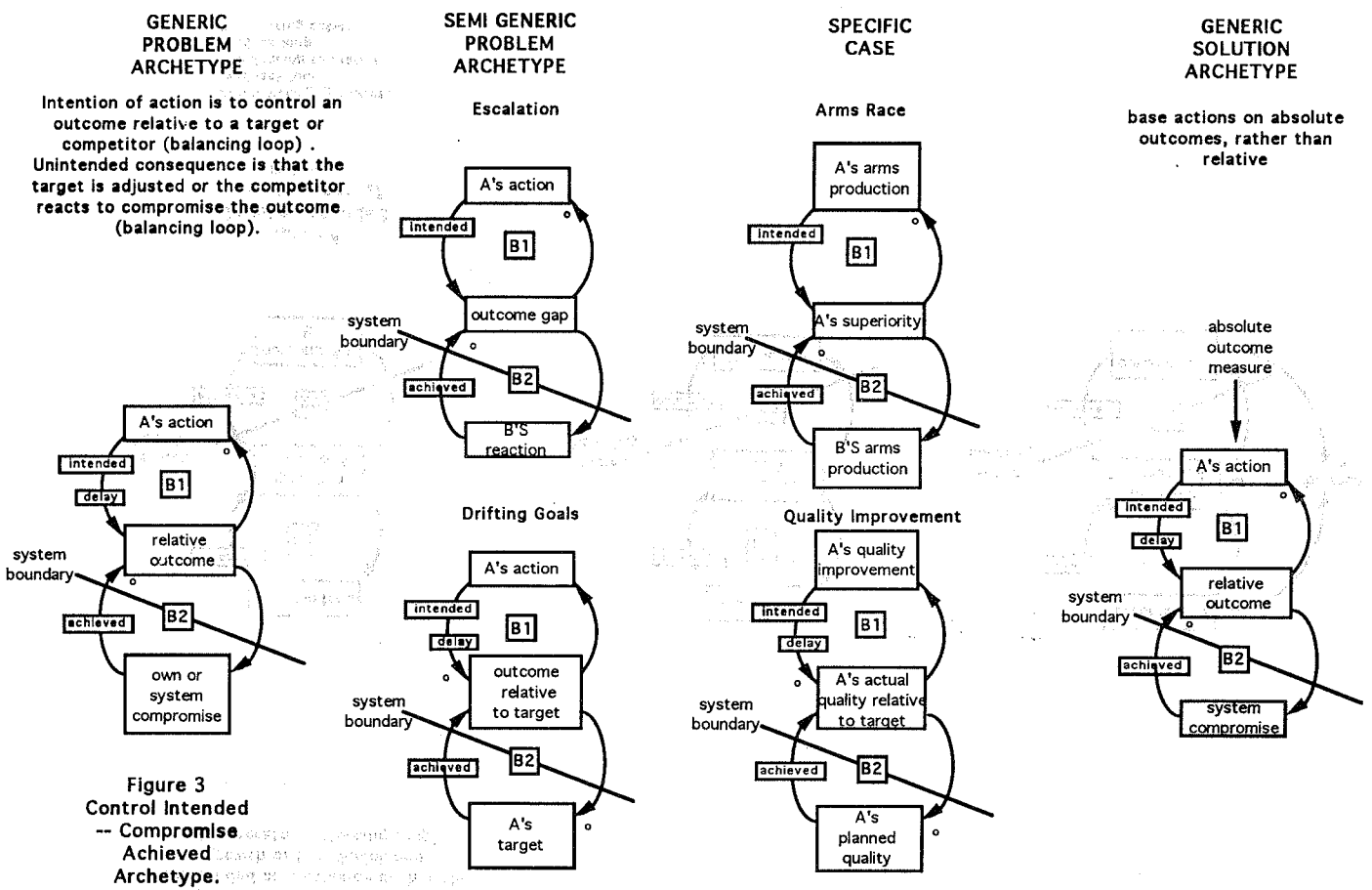
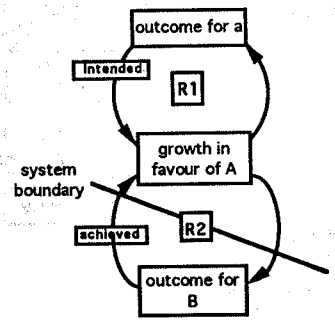



**Figure 3**
**Control Intended -- Compromise Achieved Archetype.**

R=reinforcing (positive) feedback loop
B=balancing (negative) feedback loop
O=opposing action

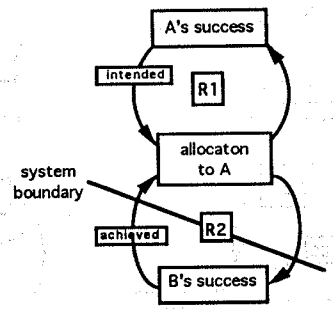
GENERIC PROBLEM ARCHETYPE

1. Intention of action is to support the growth of A (reinforcing loop) . Unintended consequence is that the growth of B is diminished (degenerate reinforcing loop).




SPECIFIC CASE

success to be successful




GENERIC SOLUTON ARCHETYPE

base actions on balance of outcomes

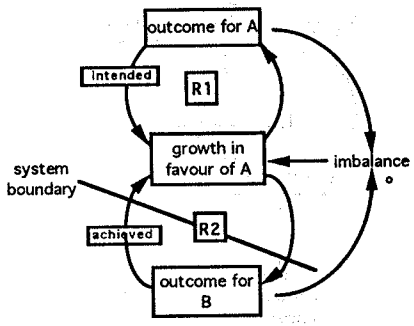



**Figure 4**
**Growth Intended -- at Expense of Others.**

R=reinforcing (positive) feedback loop
B=balancing (negative) feedbck loop
O=opposing action