Towards the definition and use of a core set of archetypal structures in system dynamics

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Abstract

There has been considerable research in the field of system dynamics over the last decade concerned with defining generic structures and templates by which to classify structures and behavioural insights in dynamic systems. These have appeared both in stock/flow and causal loop terms. This article focuses on generic causal loop structures more commonly known as system archetypes, a profusion of which have now been defined. The purpose of the article is to improve the usefulness of system archetypes both as free standing devices to aid model conceptualisation and as a means of disseminating insights arising from models. In order to achieve this three postulates are made: First, that system archetypes can be usefully condensed down to a more understandable core set of four totally generic archetypes, consisting of the four ways of ordering a pair of reinforcing and balancing feedback loops. These are described, named and current archetypes mapped onto them with specific examples. Second, that for every "problem" archetype there exists a closed loop "solution" archetype. It is suggested that some misunderstandings with current archetypes arise from the fact that they often combine problem and solution links in the same diagram. Third, that each archetype has important characteristics, which are vital to understanding the role of archetypes in assisting systemic thinking. The particular characteristic introduced and highlighted is the concept of organisational boundaries. The article concludes by discussing the importance of the reduced set of archetypes, and organisational boundaries in particular, in explaining some barriers to implementing systemic thinking, using a range of examples encountered by the author in recent consulting practice. Copyright © 2003 John Wiley & Sons, Ltd.

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Introduction

The origins of system archetypes

The demonstration of systemic insights has been the province of system dynamics from its early days (Forrester 1990; Meadows 1982) and generic structures have often been used to describe insights in terms of system structure and its associated behaviour over time.

More recent research in the field of system dynamics has focused on refining the classification of generic structures. For example, generic "infrastructures" based on stocks and flows (Richmond 2002; Paich 1985), generic "system archetypes" based on causal loop maps (Senge 1990; Wolstenholme and Coyle 1983; Wolstenholme 1990; Kim 1992) and other classifications (Lane and Smart 1996) have been proposed.

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This article focuses on the system archetype group of generic structures.

System archetypes (Senge 1990; Wolstenholme 1990) were introduced as a formal and free-standing way of classifying structures responsible for generic patterns of behaviour over time, particularly counter-intuitive behaviour. Such ''structures'' consist of intended actions and unintended reactions and recognise delays in reaction times. The system archetypes currently classified can be seen as a synthesis of much qualitative and quantitative modelling effort cumulated over many years by many analysts, which can be used to help to generate understanding in new application domains. This isomorphic quality makes them a very powerful mechanism for accelerating learning in an increasingly turbulent world.

The role of system archetypes

There has, however, been some criticism of the validity of system archetypes when used in a free-standing way. Specifically, they have been challenged as to whether they are really capable of displaying the behaviour claimed for them (Homer 1996; Forrester 1994). This stance has been countered with the argument that, although they may be theoretically weak, they do provide a compelling summary of system insights, which is effective in practice (Lane 1996).

The stance taken in this paper is that system archetypes have an important and multiple role to play in systemic thinking. They can provide a free-standing means by which to apply systems thinking by conveying to people that their plans for change will have side effects, and encouraging them to explore these. However, they also have a much wider role within the system dynamics modelling process. Current experience of using and teaching archetypes to a wide range of audiences by the author has lead to the view that archetypes have a role both at the front and back of the modelling process: up front, as a means of using their isomorphic properties as a way of starting the model conceptualisation activity by transferring insights from other models, and at the back, in ''collapsing'' down insights from models (Wolstenholme 1999).

It is important to recognise that system archetypes are first and foremost a communications device to share dynamic insights. The insistence that they must always be capable of direct simulation does not hold up. Any abstraction of a model in either stock–flow or causal loop terms must always be a compromise between simplicity for communication and completeness for validity.

The Purpose of the Paper

In order to assist people with using archetypes more widely and constructively, it is felt important not only to clarify the role of archetypes, but also to improve understanding of what system archetypes really are. This article is aimed at

simplifying the classification of system archetypes and improving the definition of their characteristics.

A major objective of the paper is to raise awareness of the existence and importance of boundaries within organisations as a determinant of organisational evolution over time. System dynamics has always distinguished between exogenous and endogenous factors. However, the concept of distinguishing between different sectors of organisational ownership and responsibility on causal maps was not present in the original concept of system dynamics and does not appear until 1990 (Wolstenholme 1990). Whilst most visual system dynamics software now provides a means of drawing, and even simulating, models within sectors, the concept of drawing boundaries is still missing in the current representation of system archetypes.

It is suggested that there is potentially much merit in further developing understanding of boundaries as a component of systems thinking. Organisations are by definition very bounded entities in terms of disciplines, functions, accounting, power and culture. Boundaries are the one facet of organisations that are perhaps changed more often than any other. Further, they are often changed in isolation from strategy and process on the whim of a new top team or political party, usually to impose their own power and instate their own people.

It is also important to realise that boundaries may be of different types. They may be between the organisation and its environment; they may be very physical accounting boundaries between different functional parts of the same organisation; they may be between management teams or indeed mental barriers within individuals.

Although the aim of systems thinking is to cut across the boundary perspective of organisations, this view should not ignore the existence of boundaries as basic elements of organisational structure. An important step in implementing systems thinking should be to understand how a systems concept can exist comfortably within a sectored organisation. The key would seem to be to recognise the boundaries, but to make them as transparent as possible. To see them as necessary ''net curtains'', not ''heavy drapes''. Systems thinking has a major role to play in helping people to communicate better at the boundaries and to develop cross-boundary working.

Importantly, the superimposition of organisational boundaries on system archetypes helps explain why systemic management is so difficult. First, organisational boundaries highlight dramatically that action and reaction are often instigated from separate sources within organisations. Second, organisational boundaries imply that reactions are often ''hidden'' from the ''view'' of the source responsible for the actions. Third, organisational boundaries force system actors to actively confront the need to share information and collaborate to achieve whole system objectives.

The characteristics of a totally generic two-loop system archetype

It is suggested that the system archetypes currently published are in fact only semi-generic and that there exists a more fundamental reduced set of totally generic system archetypes onto which existing system archetypes can be mapped as special cases. This concept was originally introduced by the author in 1993 (Wolstenholme 1993) and resulted in other attempts to classify systems archetypes (Goodman and Kleiner 1994).

The basic structure of a totally generic two-loop archetype is shown in Figure 1. The characteristics of the archetype are as follows:

- First, it is composed of an *intended consequence (ic) feedback loop* which results from an *action* initiated in *one sector of an organisation* with an intended consequence over time in mind.
- Second, it contains an *unintended consequence (uc) feedback loop*, which results from a *reaction within another sector of the organisation or outside.*
- Third, there is a *delay* before the unintended consequence manifests itself.
- Fourth, there is an *organisational boundary* that ''hides'' the unintended consequence from the ''view'' of those instigating the intended consequences.
- Fifth, that for every *''problem''* archetype, there is a *''solution''* archetype.

Problem archetypes

A *problem archetype* is one whose net behaviour over time is far from that intended by the people creating the ic loop.

It should be noted that reactions can arise from the same system participants who instigate the original actions (perhaps due to impatience with the time

Fig. 1. The structure of a totally generic two loop system archetype
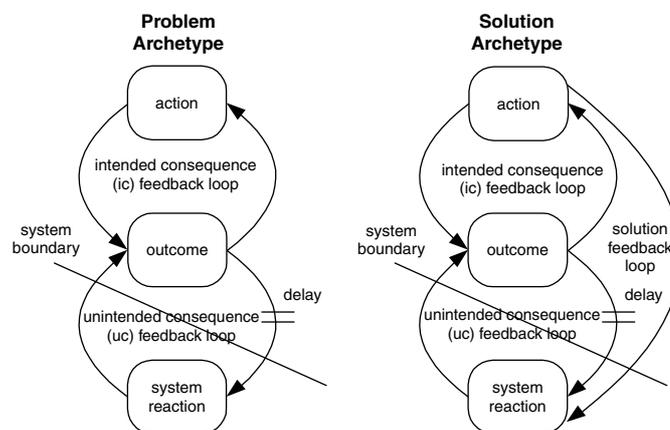
taken for their original actions to have effect). The reaction may also arise from natural causes. However, it is more often the case that the reaction comes from other individuals, groups or sectors of the same organisation or from external sources.

It can be argued that, whilst side effects of well-intended actions are well established and understood in some systems such as heath care, where the treatment can be worse than the disease, side effects are little understood in management and many other social systems. Because such systems are dynamic, self-organising and adaptive, almost every action will be countered by a reaction in some other part of the system and hence no one strategy will ever dominate.

Solution archetypes

The idea of a two-loop system archetype with problem behaviour leads to the idea of a closed-loop *solution archetype* to minimise any side effects and a generic two-loop solution archetype is also shown on Figure 1.

The key to identifying solution archetypes lies in understanding both the magnitude of the delay and the nature of the organisational boundary present. Solutions require that system actors, when instigating a new action, should attempt to remove or make more transparent the organisational boundary masking the side effect. Collaborative effort on both sides of the boundary can then be directed at introducing new ''solution'' feedback loops to counter or unblock the uc loop in parallel with activating the ic loop. The result is that the intended action should be much more robust and capable of achieving its purpose.

A reduced set of four generic problem/solution archetypes

Initiating actions for change can be condensed down to one of two kinds. These are actions that attempt to improve the *achievement* of an organisation by initiating *reinforcing feedback* effects and those that attempt to *control* an organisation by introducing *balancing feedback* effects. Reactions can also be condensed to one of the same two kinds (Wolstenholme 1993).

Hence, there are only four totally generic two-loop archetypes possible, arising from the four ways of ordering the two basic types of feedback loops (balancing and reinforcing). These are named here as:

- *Underachievement*, where intended achievement fails to be realised;
- *Out of control*, where intended control fails to be realised;
- *Relative achievement*, where achievement is only gained at the expense of another;
- *Relative control*, where control is only gained at the expense of others.

Each of these four structures is shown in problem and solution form in Figure 2, and each will be explained in turn.

Underachievement

The composition here is that the ic loop is a reinforcing loop and the uc loop is a balancing loop.

In this case the problem archetype consists of a reinforcing ic loop intended to achieve a successful outcome from an initiative in one sector of an organisation. The reaction from another sector, usually as a result of hitting against a resource constraint, creates a balancing uc loop, which causes a delayed underachievement of the intended outcome over time.

In Figure 2 it is suggested that the closed-loop solution to an underachievement archetype lies in trying to use some element of the achievement action to minimise the reaction in other parts of the organisation, usually by unblocking the resource constraint. That is to introduce a further reinforcing loop in parallel with the ic reinforcing loop to counter the balancing reaction.

Out-of-control

The composition here is that ic loop is a balancing loop and the uc loop is a reinforcing loop.

In this case the archetype consists of a balancing ic loop initiated in one sector of the organisation to control the magnitude of a problem. The reaction from another sector creates a reinforcing loop, resulting in a possible worsening of the problem, which gets more and more out of control. It is useful to note in this archetype that it is usually the control action itself, rather than the outcome, that provokes the reaction.

In Figure 2 it is suggested the closed loop solution to an out-of-control archetype lies in introducing or emphasising a direct link (the ''solution link'') between the problem and the system reaction. The purpose of this link is to introduce or re-emphasise a further balancing loop in parallel with the ic balancing loop to counter the reinforcing reaction.

Relative achievement

The composition here is that both the ic loop and the uc loop are reinforcing loops.

As in the case of *underachievement*, this archetype consists of a reinforcing ic loop intended to achieve a relative advantage from an initiative. Here achievement is gained at the expense of other sectors of the organisation. The net effect is that the unintended consequence works to the benefit of the ic loop and magnifies the relative outcome. The uc loop is reinforcing, but degenerate, and the combination of the two loops forms a zero-sum game.
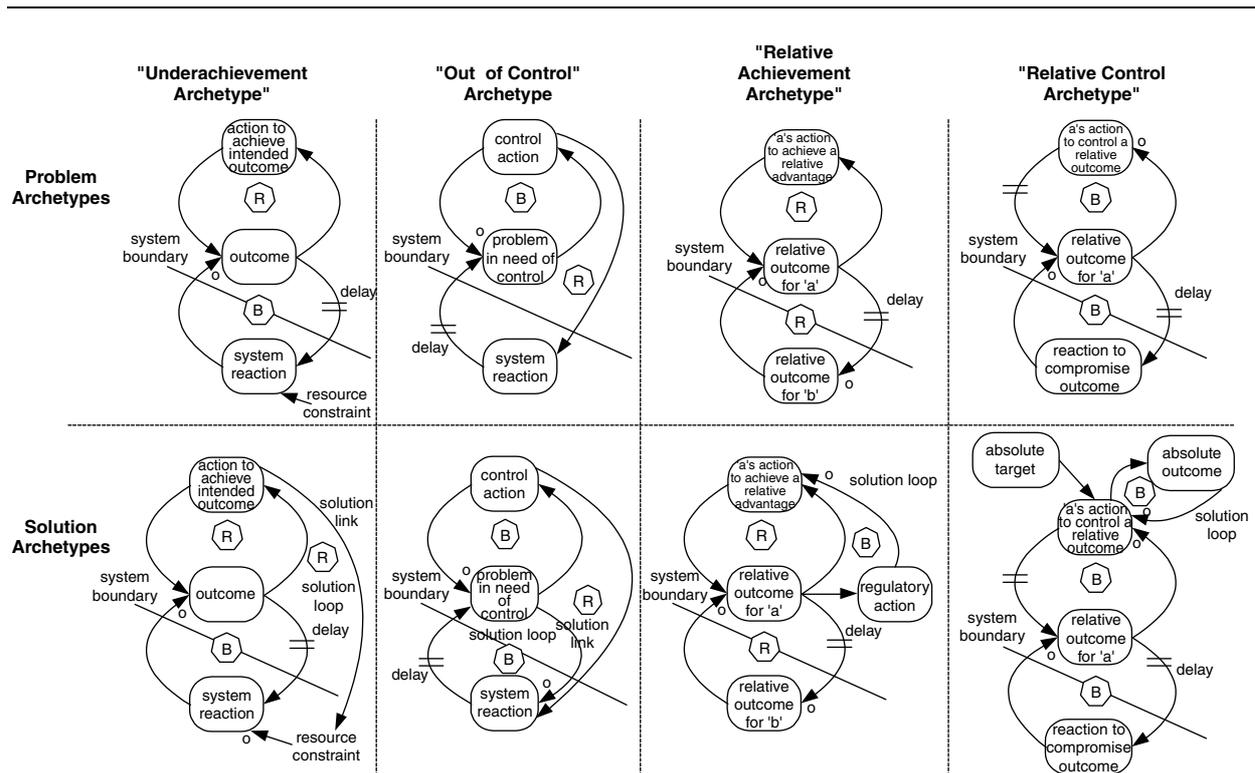
Fig. 2. The reduced set of four generic archetypes; R = reinforcing feedback loop; B = balancing feedback loop; o = opposing action

In Figure 2 it is suggested that a possible closed-loop solution to the relative achievement archetype is to recognise the nature of the victimisation present in the early stages of the reinforcing initiative and then to define a relative target and a new balancing feedback loop by which to control a more equitable transition to a new state, perhaps by external regulation.

Relative control

The composition here is that both the ic loop and the uc loop are balancing loops.

As in the case of *out-of-control*, this archetype consists of a balancing ic loop intended to control a relative outcome. However, the relative outcome triggers a reaction in another sector of the organisation, which then compromises the outcome for the initiator. Delays may be present in both loops, the relative importance of which will depend upon specific applications of the archetype.

In Figure 2 it is suggested that a possible closed loop solution to the relative control archetype is to define an absolute target and balancing feedback loop by which to instigate absolute, rather than relative, control.

Mapping existing archetypes on to the reduced set

This section will demonstrate that existing semi-generic problem archetypes can be mapped as special cases onto the reduced set of four totally generic problem archetypes defined. Figures 3 to 6 show such mapping for some commonly used archetypes and these are discussed with specific examples and solutions.
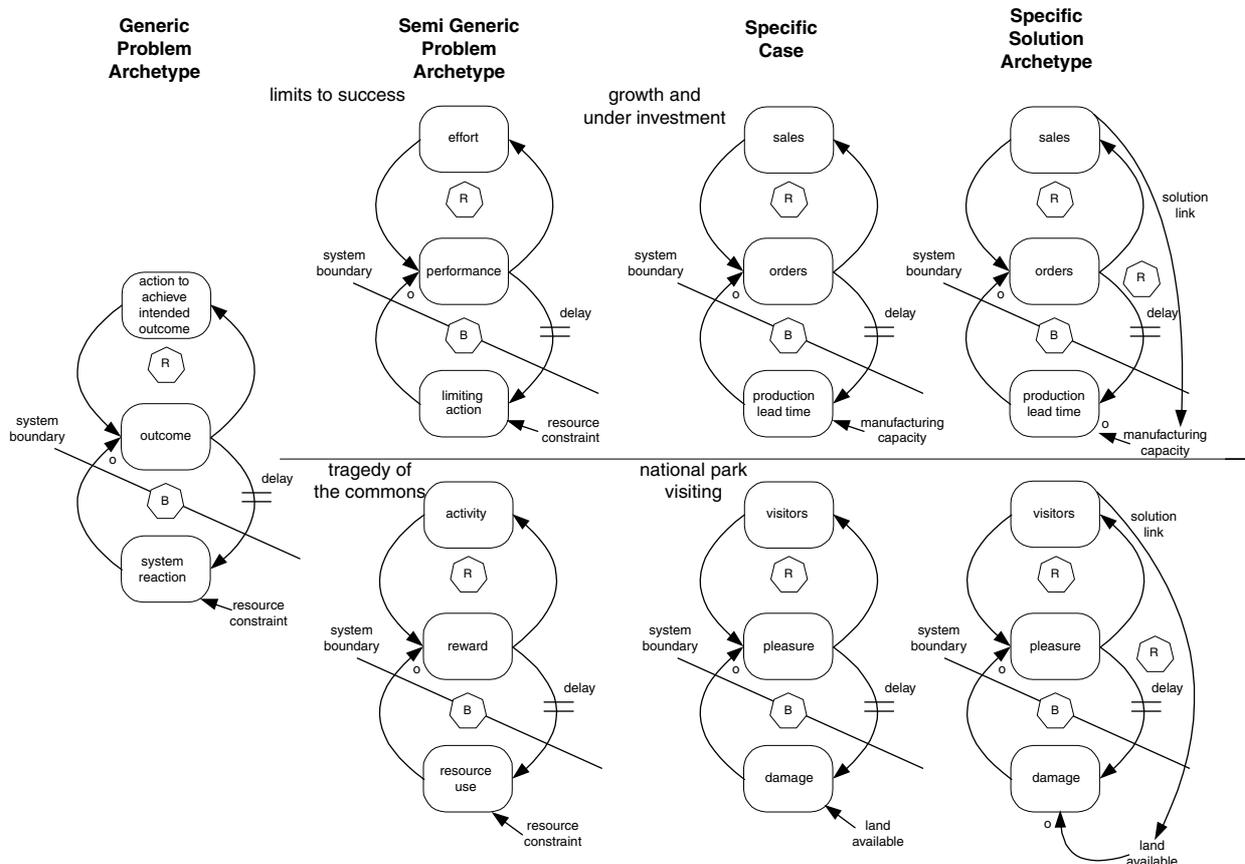

Fig. 3. ''Underachievement Archetype'' (R, B and o as in Figure 2)

Because a number of existing archetypes are usually represented by more than two loops, the resulting condensed versions may look unfamiliar. However, the condensed versions do retain the integrity of their multi-loop counterparts.

It is claimed that introducing the totally generic archetypes first before the existing semi-generic ones, is useful for introducing the concept of archetypes to new users. For existing users who are content with the conventional representation of archetypes in terms of multiple loops, the two-loop representation can be seen simply as a step in developing the story contained in the multiple-loop version. This is particularly true where some conventional multi-loop archetypes contain a mix of problem and solution loops. Eliminating solution loops when describing the problem situation eliminates any confusion.

Further, in describing all the examples of archetypes in this section, readers should note the contribution to understanding afforded by the explicit representation of organisational boundaries.

"Limits to Success", "growth and underinvestment" and "tragedy of the Commons"

Figure 3 suggests that the *limits to success, growth and underinvestment* and *tragedy of the commons* archetypes are special cases of the *underachievement* archetype.

In the *limits to success* case a reinforcing ic loop is created with the intention of converting effort into improved performance within one sector of an organisation. However, an unintended consequence of this effort is that a limiting action is encountered in some other part of the organisation.

In most of the literature, the *growth and underinvestment* archetype is shown as an independent archetype. However, it is shown here as a specific example of a *limits to success* archetype.

In *growth and underinvestment* a reinforcing ic loop is created with the intention of converting sales into orders, within the sales/marketing sector of an organisation. However, an unintended, balancing consequence of this effort is that manufacturing capacity in the production sector of the organisation is exceeded and lead times increase, actually reducing orders. The conventional representation of this archetype also includes a second balancing loop. This takes the form of using the lead time to reactively trigger new capacity additions. However, this second balancing loop can be thought of as a weak solution loop. The stronger closed-loop solution takes the form of sales forecasts being used to control the addition of manufacturing capacity to maintain deliveries in line with sales growth. In other words the balancing uc loop is replaced by a reinforcing one.

In the *tragedy of the commons* case a reinforcing ic loop is created by the activity of system actors with the intention of increasing rewards for themselves. However, an unintended consequence is that the activity results

in overuse of and damage to the environment, which reduces the magnitude of the outcome for all, for example visitors to national parks with the intention of increasing their pleasure. Here the uc loop results in an unsustainable environment to the detriment of everyone's pleasure.

In the usual representation of this archetype, two reinforcing loops are shown representing the separate activities of two groups of people. The side effects of the two groups are then combined in a resource constrained balancing loop. In reality *n* groups are often present in a tragedy of the commons situation and it is argued here that it is equally justifiable to limit the representation to the combined effect of all groups as it is to restrict the representation to two groups.

In the case of the *tragedy of the commons* a closed-loop solution depends on whether the constraint can be unblocked. If more land can be made available, then this should be realised in proportion to the forecast of visitor numbers and hence the balancing uc loop is replaced by reinforcing one, as shown in Figure 3. If this is not possible, demand must be constrained equitably perhaps by rationing visits to a park in line with defining and achieving acceptable damage limitation.

"Fixes that fail", "shifting the burden" and "accidental adversaries"

Figure 4 suggests that the *fixes that fail*, *shifting the burden* and *accidental adversaries* archetypes are special cases of the out-of-control archetype.

In the *fixes that fail* case a balancing ic loop is created by which to apply a short-term solution to control a problem or problem symptom. However, the unintended consequence of this action in other sectors of the system reinforces problem growth. For example, recruitment in the police sector of the criminal justice system to reduce reported crime has an unintended consequence of causing overcrowding of prisons and early prisoner release. This may in turn contribute to an increase in the crime problem by shortening prison sentences and prison time served.

The closed-loop solution here is to introduce or re-emphasise the solution link between reported crime and overcrowding of prisons. That is to introduce a phased capacity expansion of all sectors of the criminal justice system together to maintain the integrity of prison sentences. In other words the reinforcing uc loop is replaced by a balancing loop.

In the *shifting the burden* case a balancing ic loop is again created by which to apply a fix to control a problem or problem symptom, rather than implement a more fundamental solution, which takes longer to apply, for example giving a child treats as a substitute for spending time with the child. In this situation it is assumed that a fundamental solution exists and is known, but the effect of the fix detracts from implementation of the fundamental solution and contributes to the problem persisting. The fact that the fundamental solution
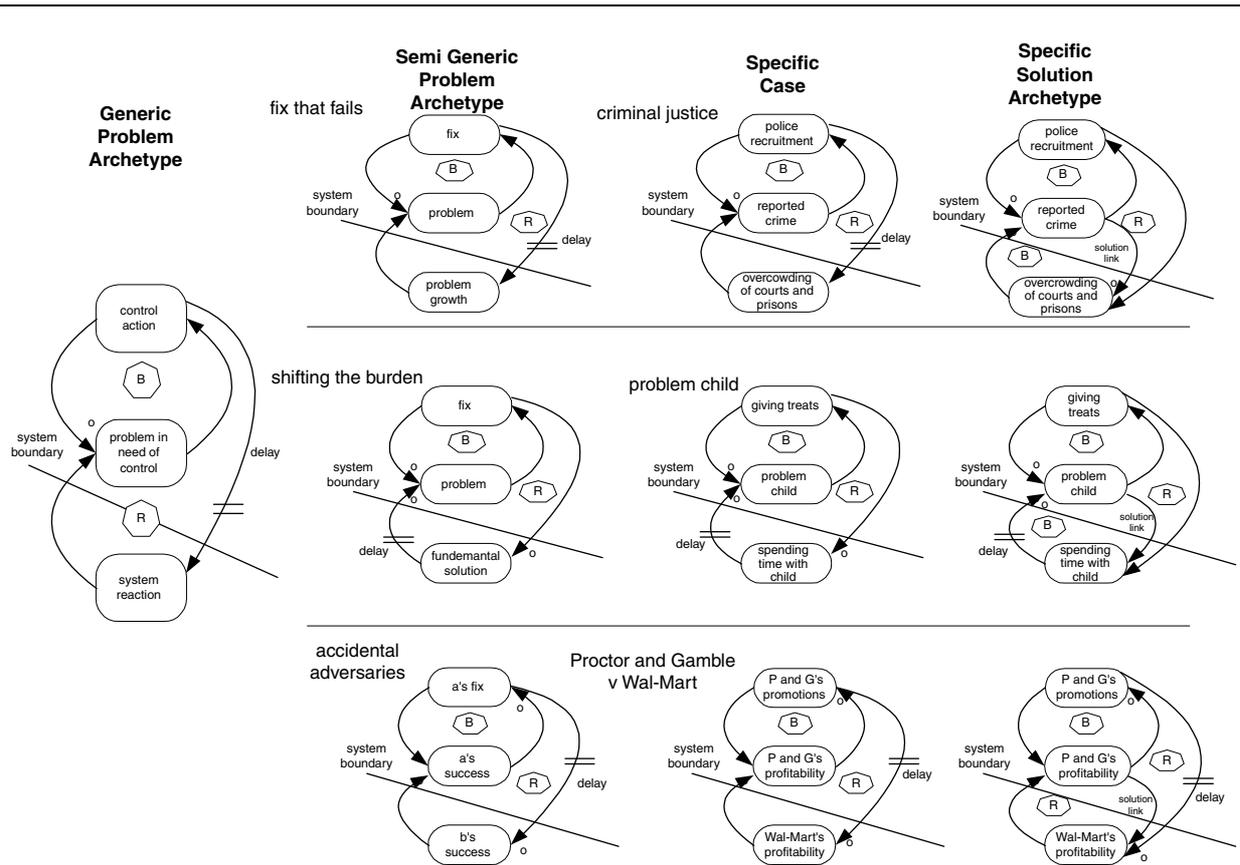
Fig. 4. ''Out of Control'' Archetype; (R, B and o as in Figure 2)

is excluded from consciousness here by some form of ''mental'' boundary is important.

In the case of *shifting the burden* a holistic closed-loop solution might may be to introduce or re-emphasise the need for a direct ''solution link'' between the problem and the fundamental solution, for example spending more time with the child. In other words the reinforcing uc loop is again replaced by a balancing loop.

In the *accidental adversaries* case one group of system actors achieves success by means of a balancing ''fix''. This has the unintended consequence of creating a reinforcing feedback loop that mitigates against the success of a partner on whom the group depends. Hence, they ultimately undermine their own achievements.

The example usually given is that of Proctor and Gamble (P and G) supplying Wal-Mart and this is shown in Figure 4. When P and G's profitability declines, they introduce promotions. However, this results in extra cost and reduced

profitability for Wal-Mart. Wal-Mart's reaction is to overbuy during promotions and stock up these items for future sale at regular prices when the promotion ends. This action in turn causes production scheduling difficulties for P and G, which undermine their own profitability.

The common representation of this archetype has four feedback loops. However, three of these are problem loops and one is a solution loop. The three problem loops comprise one balancing loop for each partner and a single reinforcing loop representing the unintended consequence by which each undermines the profitability of the other. The logic of the situation can again be represented by two loops: a balancing loop, representing the action of the first organisation to introduce an internal profitability control mechanism, and the unintended degenerate reinforcing loop.

In the case of *accidental adversaries* a holistic closed-loop solution is then the same as for the other *out-of-control* archetypes shown in Figure 4. This is to introduce or re-emphasise a link directly between the profitability of each company to mutually support one another's success. The resultant virtuous reinforcing solution loop is actually the fourth loop usually shown in the conventional representation of this archetype.

''Success to the successful''

It is suggested in Figure 5 that the *success to the successful* archetype is a special case of the *relative achievement* archetype.

In this case action by one sector of an organisation gains an initial advantage relative to another, possibly by some form of external favouritism, for example
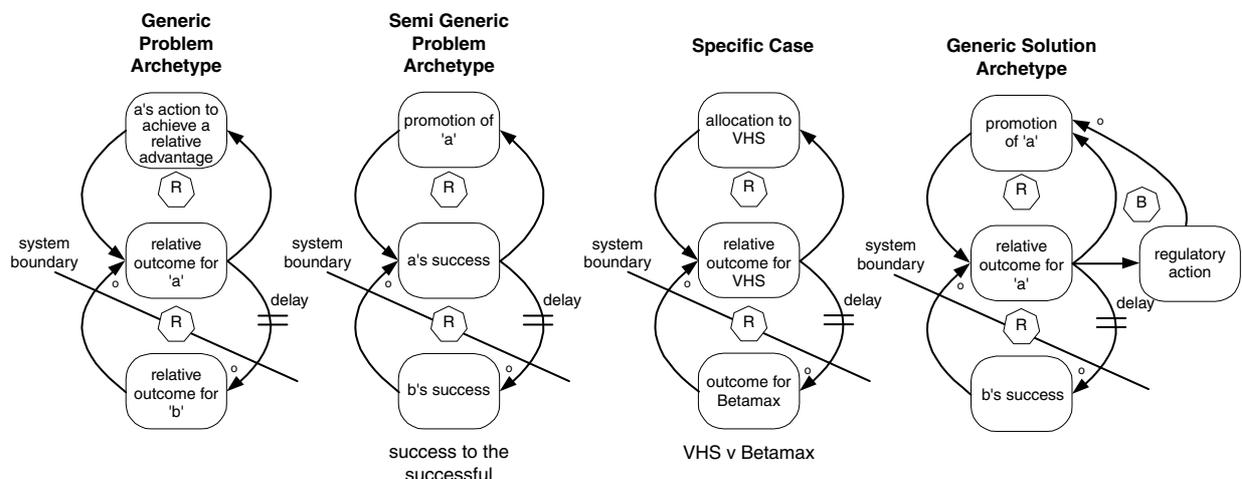

Fig. 5. ''Relative achievement archetype'' (R, B and o as in Figure 2)

the establishment of a standard technology such as happened with VHS in the early days of video recorders. The unintended consequence is a decline in outcome for another organisation. In the case of video recorders the victim was Betamax.

In the case of *success to the successful* the form of an holistic, closed-loop solution might be to introduce a regulatory loop where the balance of business between the organisations is controlled by an outside body.

''Escalation'' and ''drifting goals''

It is suggested in Figure 6 that the *escalation* and *drifting goals* archetypes are special cases of the *relative control* archetype.

In the *escalation* case the ic loop is a balancing loop where action is taken by one sector of an organisation to control an outcome relative to another organisation, for example arms production by one country to achieve weapon
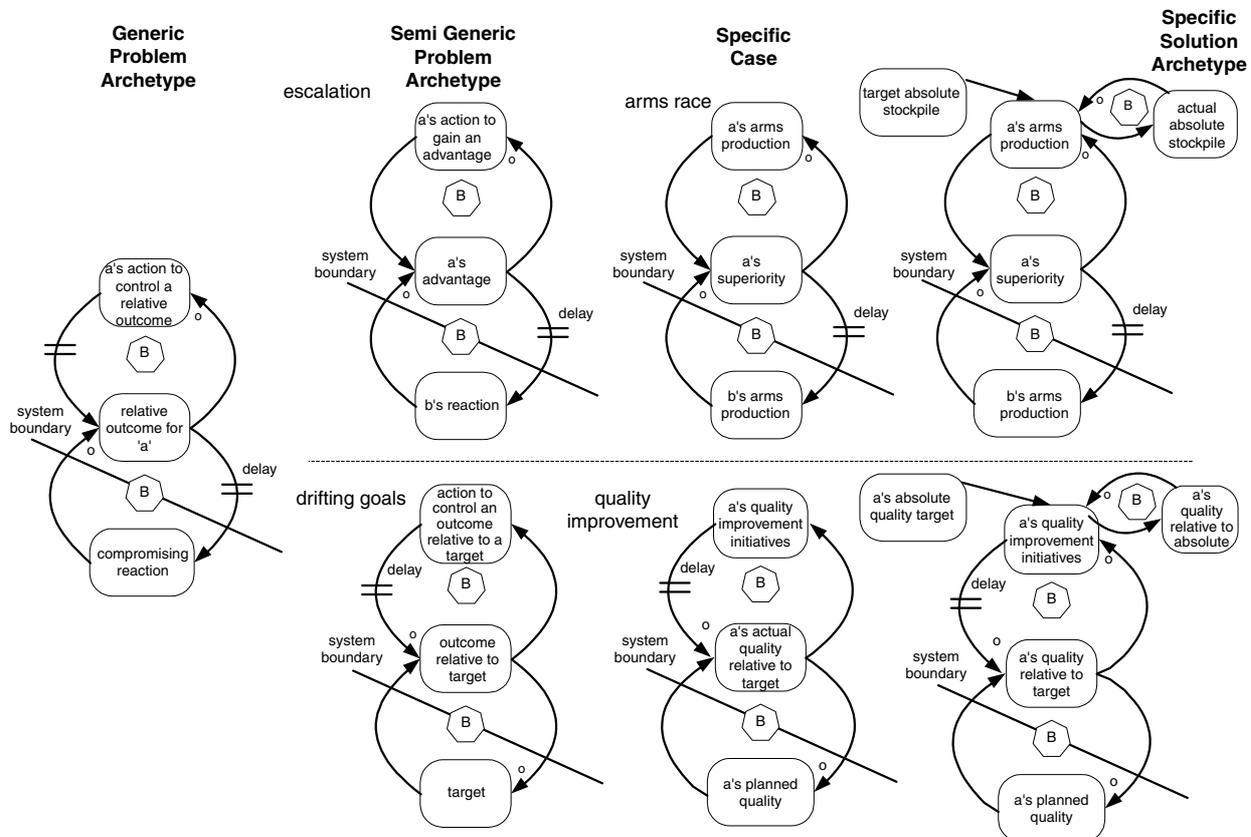

Fig. 6. ''Relative control archetype'' (R, B and o as in Figure 2)

superiority. However, the reaction of another country is to mirror this action by increasing the target for their own arms stockpile. Each attempts to gain relative control, but the net result is escalation in the total stockpile.

In the case of *escalation* the form of a holistic, closed-loop solution might be to oppose the escalation in the total arms stockpile by controlling arms production relative to an agreed absolute target stockpile.

In the *drifting goals* case action is taken by an organisation relative to a target, but it fails to reach the target, perhaps because it takes too long. The unintended consequence is to lower the target, for example attempts to continuously pursue elusive and unattainable performance measures, such as quality of service. Here the boundary is perhaps a mental one, aimed at applying an ''out of sight, out of mind'' philosophy to the erosion of the target.

Again in the case of *drifting goals* the form of a holistic solution might take the form of controlling quality to an absolute target, rather than a relative one.

The generic archetypes in use and the importance of organisational boundaries

Successful systems thinking is about being able to see the whole picture or context of a situation and its interconnections to its environment. Such a perspective enables unintended consequences of well-intended actions to be pre-empted and minimised. However, it is never easy to attain such a perspective and the teaching of systems thinking is a continual search for better ways of developing this view. One major factor inhibiting systemic understanding is the presence of time factors before unintended consequences show themselves. However, an even more fundamental factor is to understand what stops people from anticipating even the most obvious unintended consequences. It is suggested here that the key to this lies in understanding the existence and nature of the boundaries, which conceal unintended consequences.

In order to explore the role and importance of organisational boundaries in the application of systems thinking, research has been carried out based on some examples from recent personal consulting experience of applying the reduced set of archetypes in practice. Selected examples are listed in Tables 1 and 2. Table 1 shows a group of underachievement situations, all of which are examples of *limits to success* archetypes. Table 2 shows a group of out-of-control situations, all of which are by definition *shifting the burden* archetypes, where the fundamental solution is understood.

In each case an issue is defined together with actions that were taken in the organisations involved in response to the achievement or control attempted. In all cases the actions undertaken had clear intended results, but the actual results were far from those intended.

Table 1. Underachievement situations showing a number of issues, actions to achieve improvement, intended results, actual results and holistic solutions

Issue	Action	Intended consequence (ic)	Actual result— unintended consequence (uc)	Holistic solution
New channels to market	Dot-com development	Massive increases in customers and sales	Marginal increases in customers and sales	Gear up customer service and supply chain to match anticipated sales
Poor speed of products to market	Reduce research and development time	More products at market; improved revenue	Poorer quality; shorter product life cycle	Balance product time to market against late life product benefits
Increase in competitive tendering	Spend more time developing a sound business strategy and plan	Business growth	Lack of senior management time on existing core business	Balanced time spent on existing and future business development
Too few people in higher education	Increase places in higher education	Improved job opportunities	High class size; poor staff morale; reduced quality of qualifications	Increase teaching capacity in line with student growth

Table 2. Out-of-control situations showing a number of issues, actions to achieve control, intended results, actual results and holistic solutions

Issue	Action	Intended consequence (ic)	Actual result— unintended consequence (uc)	Holistic solution
Profit warning	Cut expenses; downsize	Reduced costs and increased productivity	Low morale; decreased productivity and reduced profit	Undertake revenue generation initiatives
Falling demand	Centralise; globalise; merge	Wider market reach; reduced costs	High marketing costs of market penetration	Develop better understanding of local market
Excessive demand	Increase productivity and technology	Increased work throughput	Increase in staff stress and leaving	Balanced investment in staff recruitment
High hospital waiting lists	Pay consultants overtime; increase hospital bed stock	Reduced waiting lists	Increased waiting lists	Address factors affecting hospital discharge rates

Discussion of the examples

The research took the form of asking the managers involved to explain their actions. The main interest was in why they chose to allow reductionist thinking to dominate the change agenda and what prevented

them from recognising the unintended consequences of these actions and implementing more holistic solution of the type suggested in Tables 1 and 2.

Discussions on these led to an 11-point classification of reasons in terms of a visual metaphor relating to the degree of transparency of the organisation boundary masking the unintended consequence. The classifications will be discussed in turn.

1. The case of the totally blind

For some people the totality and complexity of the change process would seem to produce a completely opaque boundary and complete blindness to any unintended consequence. This is particularly true when the issue is a make or break activity for the organisation, or the individual leader. In such cases, there is a fear that the longer term will not even exist if short-term objectives are not met. Such thinking has been encountered in start-up companies, particularly dot-com companies creating new routes to market. Here the focus is on immediate customer gain with little thought for the development of the infrastructure necessary to support customer retention and service. However, it has also been encountered in more traditional companies launching new e-commerce initiatives.

2. The partially sighted

There would appear to be many people who are not totally blind to the unintended consequences of their actions, but who only pay lip service to them or insist that they will not be a problem "this time".

This situation is typical of re-organisations where the structure to be employed is essentially one that has been used before and its disadvantages are well documented. For example, organisations decentralise when demand is falling to be in closer touch with the market, but find that they lose economies of scale and incur higher costs. Many organisations repeat this cycle of centralisation and decentralisation every four to five years, saying each time that this time will be different.

This is also typical of very large organisations where it is difficult to co-ordinate global solutions. An example is the criminal justice system in Figure 4. It may be acknowledged that recruiting more police officers will mean more arrests, but the thinking stops at getting potential offenders off the streets. It is then up to other agencies in the rest of the criminal justice system to make sure they have the capacity to cope with the increased demands on them. There is little understanding or interest that what happens in the police sector will have consequences beyond that boundary, particularly whether or not the actions might lead to more cases of plea bargaining, shorter prison sentences, more bail and more ex-offenders released requiring more police recruitment later.

3. Seeing but choosing not to see (the Nelson syndrome)

In many cases the unintended consequences of actions are well known, but the attitude is that it they have to be accepted and lived with.

This situation has been encountered in numerous situations where demand exceeds supply, caused either by growth initiative situations generating excessive demand or by downsizing generating reduced supply. Here it is expected that fewer and fewer people will be able to cope with more and more business. The assumption is that longer working hours will not be detrimental to the performance of the individual or the organisation. In reality individuals either increase productivity at the expense of quality by scanning, skipping and destroying work or burn themselves out. Whole new industries such as stress management thrive on the results. Sometimes whole organisations legitimise throwing away work to ease backlogs when demands are too great, for example when the demand to scrutinise such items as insurance claims and tax returns vastly outweighs the supply capacity.

4. Seeing, but afraid to act

Particularly in the case of profit warnings or cost escalation, the power of the short-term accounting regime in organisations dominates and it is more important to show good end-of-year returns than to demonstrate long-term sustainability. In these situations to even raise the concept of side effects is tantamount to blasphemy and cynicism and can be career threatening.

5. Seeing, but not believing

In some cases there is evidence that unintended consequences are acknowledged, but perceived to be ''soft'' feedback links of uncertain or low probability. For example, Ministers in the Department of Health in the UK have consistently refused to acknowledge that there is any significance in the relationship between high waiting lists for elective surgery and slow discharges of elderly people from hospital into community and continuing care. Hence, they choose to address high waiting lists by increasing bed capacity in the acute National Health Service (NHS) hospitals rather than by increasing bed capacity in community care. The fact that the NHS and community care are operated by separate, autonomous organisations with separate accounting is very relevant to the boundary debate.

6. Seeing, but unprepared to take risks

Many companies know that there is a good chance that their growth initiatives through new channels to market will generate customers, but are never willing to risk capacity and supply investments to match their expectations. This

reason for reductionist thinking has been encountered in situations as diverse as chocolate bar and pesticide manufacture.

7. Seeing, but the time scale for the side effect is too long to be considered important

The magnitude of the perceived time delay in a side effect is sometimes an important consideration in the attitude to systemic thinking. This situation is encountered often in the area of branded pharmaceutical and agrochemical products. Here, there is a tendency to try to be first to market, rather than to spend more time on research and development. However, in such circumstances the long-term view can be vital. Product sales toward the end of the product life cycle may be 20 years into the future, but are determined by the product quality created in the research and development process. This is particularly true of the viability of patented products when they reach the stage of having to compete with generic products.

8. Seeing but choosing to ignore for political reasons

One important reason why side effects of actions are ignored is that there can be a secondary and perhaps even stronger side effect than the obvious one, but on quite a different agenda. This is often the political rather than economic imperative. For example, to acknowledge that a cut back on roads is necessary to reduce congestion by forcing people away from cars has the bad unintended consequence of being a vote loser. There is an interesting time delay in such situations before it becomes politically acceptable to acknowledge the existence of unintended consequences without losing votes. This is usually well beyond the point at which the side effect is obvious and inevitable to the majority of people. The point at which it was politically respectable to acknowledge the side effects of smoking on cancer and car exhaust pollution on asthma are other examples.

9. Seeing, but ignoring on the assumption that no one will challenge the side effect

It is sometimes in no one's interest to acknowledge a side effect. A deterioration in educational standards as a result of increasing student numbers without increasing staff numbers is a case in point. It is certainly not in the institutions', students' or parents' interest to openly recognise a fall in quality and, if it happens in every institution, it is more difficult to perceive the absolute decline.

10. Seeing, but only seeing too late

One of the characteristics of unintended consequences is that they often tend to build up slowly and incrementally such that the magnitude of the effect is

not perceived until it has reached a dangerous level. This situation is true of the way management time is spent. A classic example is the way in which top teams often focus exclusively on planning when faced with buy-out, merger or franchise opportunities without realising the extent of their neglect of the existing core business.

11. Seeing and acting holistically

It is undoubtedly true that some organisations both embrace and act systemically and this category, although not embraced in the examples used in this article, must be included for completeness. An interesting irony is that those who do act on systems ideas do not like it too widely known for the reason that it could be a significant competitive advantage.

Implications

The above examples suggest that the application of simple generic two-loop systems archetypes linking actions and reactions, with emphasis on the boundaries masking the reaction loop, can be a powerful first step in interpreting situations and improving systemic decision outcomes.

The categories of transparency of unintended consequences described are not claimed to be comprehensive or exclusive. There are undoubtedly many factors involved in decisions of the type discussed. However, the importance of boundaries is an important factor, which should be recognised more explicitly as a major constraint on systems thinking.

Forcing people to confront their boundaries and what lies beyond them and then consciously justifying the degree to which they mix reductionist and systemic thinking is an important step in improving managerial decision making.

Conclusions

This article has suggested that further research 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. Additionally, generic, closed-loop solution archetypes have been outlined for each of the problem archetypes and emphasis placed on the importance of superimposing organisational boundaries on archetypes.

The generic archetypes described have been applied to analyse a number of high-level decisions in a wide variety of settings and the use of boundaries within them has provided a useful first step in encouraging decision makers to justify their mix of reductionist and systemic thinking.

Boundaries are an important facet of management, which has been neglected in systems thinking and system dynamics. Effective systemic thinking is about recognising boundaries, but making them as transparent as possible. Working at or across the boundary must be the watch-word of truly ''joined-up'' management.

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