Systems thinking: taming complexity in project management

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Abstract

Purpose – *This paper seeks to address complexity in project management via an innovative course that focuses on systems thinking.*

Design/methodology/approach – *Intuitions about systems thinking evident in everyday language are developed and applied to phases of the system development life cycle.*

Findings – *Complexity in project management may be tamed by systems thinking. Surprisingly, project managers do not seem to use simple systems thinking tools even though these provide unique benefits in framing and solving problems that arise from multiple perspectives and relationships.*

Research limitations/implications – *The findings are broadly conceptual. They introduce only some elements of a tertiary curriculum developed by the authors and certified by a major project management practitioner group.*

Practical implications – *The findings are of value to educators, practitioners and researchers who seek a practical approach to integrating complexity theory into modern project management practices.*

Social implications – *An individual's educational choices – and institutional policies – are now caught up in a complex dance of cause and effect that is difficult to understand. This research article investigates one educational response, which is to provide practical guidance for coordinated goal-directed activities (including policies, procedures and projects) in an increasingly interconnected and uncertain world.*

Originality/value – *The approach of addressing complexity via a project management course certified by the Project Management Institute (PMI) is innovative, perhaps unique.*

Keywords *Systems thinking, Complexity, Project management, Course content and certification, Complexity theory, Systems theory*

Paper type *Research paper*

> Everything should be made as simple as possible, but no simpler (Albert Einstein).

1. Introduction

Complexity is increasing. Previously, educational choices within the sciences, humanities, technology or business were evaluated within distinct frames of reference. Now, like gas molecules that are heated and pressurized, these separate bodies of knowledge are linked in a dynamic system. Nothing stays the same. Issues of major current importance such as global warming, globalized supply chains and human rights are impacted by many input factors from diverse domains, which combine to produce uncertain outcomes. Globalization may hasten economic growth or the destruction of the planet (McIntyre-Mills, 2010). Digital technologies may enhance social progress or the domination by a privileged few (Zuboff, 1989). Individual's educational choices – and institutional policies – are now caught up in a complex dance of cause and effect that is difficult to understand.

This research article investigates one educational response, which is to provide practical guidance for coordinated goal-directed activities (including policies, procedures and projects) in an increasingly interconnected and uncertain world. For example, in the domain of health, the capacity and scheduling of hospital beds and staffing needs to be managed with an eye to the competing demands of emergency, elective surgery, management of waiting lists, among other factors. In the domain of software development, the problems with today's legacy systems are often a consequence of yesterday's enterprise-wide solution. Health, software development and many other domains need practical guidance in managing cycles of cause and effect. They need systems thinking.

We argue that, as system complexity increases, many previously separate domains of knowledge become interconnected, and systems thinking becomes essential. The argument proceeds by developing concepts about systems thinking, then applying them to project management. The paper concludes by restating the key ''take away'' points.

2. Developing concepts about systems thinking

Concepts about systems thinking are developed in two steps. First, the relevant literature is briefly surveyed to identify types of systems and where systems thinking fits in a typology of project management methods. Second, intuitions about systems thinking evident in everyday language are developed to explore the links between systems thinking and project complexity.

2.1 Systems thinking and project management

Figure 1 groups types of systems and projects by the number of components (social and technical) and the number of interactions. Figure 2 shows corresponding types of project management methods and where systems thinking fits in. A low number of interactions and components characterizes a simple system managed by a linear ''waterfall-style'' project management method. A low number of interactions and a high number of components characterizes a complicated system managed by compliance to an extensive implementation plan (Slack *et al.*, 2010, p. 460). A high number of interactions and a low number of components characterizes a dynamic system managed by an Agile project management method. A high number of interactions and a high number of components characterizes a complex system managed by a systems thinking project management method (Lemétayer, 2010).

Clear evidence of the differences between these approaches is readily available on the Net (Wikipedia, 2011a). The website for an organization named 365 Edu.in features the original waterfall model (365 Edu.in, 2011). Libraries of information on complicated/plan-driven approaches are available from the websites for PMI, Prince2, ITIL®, and its open alternative.

Figure 1 Types of systems and projects

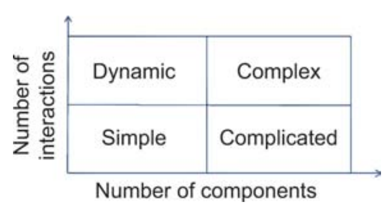
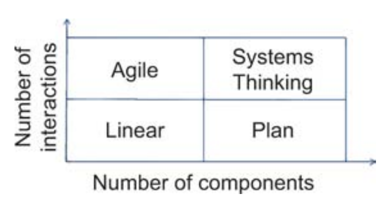


Figure 2 Types of project management methods



While Dybå and Dingsøyr (2008) identify 1,996 studies on the agile method, core concepts are available on Scott Ambler's websites (Ambler, 2011a,b) and You Tube (You Tube, 2010a-f). Current research on managing projects that are complex (Cicmil *et al.*, 2009; Remington and Pollack, 2007; Williams, 2002; Yeo, 1993; Yeo and Lim, 2000) suggests that project managers would benefit from Systems Thinking.

The research cited above establishes the surprisingly fact that project managers do not seem to use simple Systems Thinking tools even though these provide unique benefits in framing and solving problems that arise from multiple perspectives and relationships (Jackson, 2003). To rectify this situation two of the authors have developed an innovative masters course in systems thinking for practicing project managers that is accredited by the PMI Global Accreditation Centre.

2.2 Systems thinking and project complexity

Systems thinking is evident in everyday language. Common expressions include ''what goes around comes around'', ''we're all in this together'', ''the domino effect'', and reference to cycles that may be ''vicious'' (a ''downwards spiral'') or ''virtuous'' (an ''upwards spiral''). Such language expresses the intuition that the properties of the whole system are due to the dynamic interactions between the parts. In this section we will explore these intuitions and explain why systems thinking is important in understanding complex projects. First, however, we must first introduce some concepts about systems. Kim (1999, p. 2) defines a system as ''any group of interacting, interrelated, or interdependent parts that form a complex and unified whole that has a specific purpose''. Based on this definition a project itself can be considered a system. The boundary of a system is the scope of interest or concern and can change as the scope of interest changes. The parts of a system inside the boundary interact with each other but also with the environment that exists outside the boundary. A project may have a boundary based on its initial scope but this boundary could change as the scope changes. The project teams inside the project boundary could have interactions with external stakeholders if they are considered to be part of the environment. A system takes inputs from its environment, and transforms these inputs into desired outputs. In a project the requirements could be considered as inputs that are transformed by the project team into products or services as outputs. A system has structure that defines its parts and their relationships and uses processes or a sequence of activities to perform a function. Project implementation employs structures, processes and activities.

Systems are generally open, i.e. they interact with the environment. They are organized by a hierarchy and exhibit emergence. The notion of hierarchy in systems thinking has more to do with vitality, survivability and purpose rather than the notion of command and control usually depicted through organizations charts (Boardman and Sauser, 2008). The idea of emergence is often described as ''a system is more than a sum of its parts'' and is a result of the dynamic interactions between the parts. Such interactions may lead the system into a chaotic state that settles down to a new state after a while. Project managers working on complex projects (Syed and Sankaran, 2009) often state that they have experienced situations when everything seems to be going out of their control but the project finally settles down into a new state of equilibrium. Systemic knowledge refers to the understanding of dynamic interactions between all of the parts, including both human and technological aspects.

Complex projects are characterized by a boundary that changes in response to a changing environment; frequent interactions with stakeholders to stabilize mutual understanding; inputs, transformations, and outputs that are complicated; a structure that is both robust in the face of competing requirements for a stable, planned hierarchy, and yet responsive to new requirements that continually the emerge from an organizational environment that is both uncertain and dynamic (Lemétayer, 2010). Because individual expertise must be directed at a target that is continually moving, and the movement is both enabled and constrained by multiple values, beliefs and interests (Jackson, 2003, p. 22), systemic knowledge is key to successful project management (Sheffield, 2005).

One approach to systemic knowledge is via Systems Thinking (Senge, 1990). Maani and Cavana (2006, pp. 7-8) describe systems thinking as a ''field of knowledge for understanding change and complexity through the study of dynamic cause and effect over time'' that involves four types of thinking:

1. ''forest thinking'' (an ability to see the big picture, to think holistically);
2. dynamic thinking (recognizing that things can change constantly);
3. operational thinking (understanding how things really work and affect each other); and
4. closed-loop thinking (realizing that cause and effect are not often linear and that ends can loop back to influence means).

All four types of thinking are important in understanding cycles of cause and effect, and their attendant time delays.

3. Applying systems thinking to project management

In the following sections selected systems thinking concepts from an innovative project management course are described and applied to three phases (concept, implementation and evaluation) of the system development life-cycle (Figure 3).

3.1 Application to the concept phase

Levels of thinking and rich pictures are applied to the concept phase.

3.1.1 Levels of thinking. In this section we explain why the actual dynamics of the system are usually hidden from view, and introduce the systems thinking methods that are required to surface them. Because each of us has our own perspective, and the system includes the perspectives motivations and emergent behavior of other stakeholders, our own understanding is necessarily provisional and incomplete. By definition, personal motivations, interpersonal agreements, and objective phenomena each have a character that is unique. They cannot be ''levelled'' or homogenized into a body of knowledge that is equally accessible and visible to all. The analogy of an iceberg is commonly used to illustrate a four-level model of systems thinking. The first level is our recognition of events, such as stock market prices and volumes, which we encounter on a daily basis. Most of our knowledge is at this first and superficial level, which may be likened to the visible tip of the iceberg. Hidden from view is a second level, the patterns that link discrete events, such as may be found in a newspaper commentary of the stock market. Even more hidden is a third level, systemic structures, which seek to explain the observed patterns. At the fourth and most hidden level are the mental models, the instinctual or habitual ways of understanding that underpin our individual and collective response to complexity and uncertainty (Figure 4).

For example, a large organization may see all projects through the mental model of a prescriptive plan-driven project management methodology. Such an approach will lead to cost over-runs on simple projects because these do not need all the processes used for complicated projects, and failure on dynamic projects because these need an agile approach to manage uncertainty and rapid change. Success requires insight and learning about organizational routines, and their appropriate and inappropriate application. This insight may be gained by including in the concept or problem structuring phase of systems development life-cycle systems thinking methods and activities that actively examine all four levels of thinking.

Figure 3 Application of systems thinking to system development lifecycle

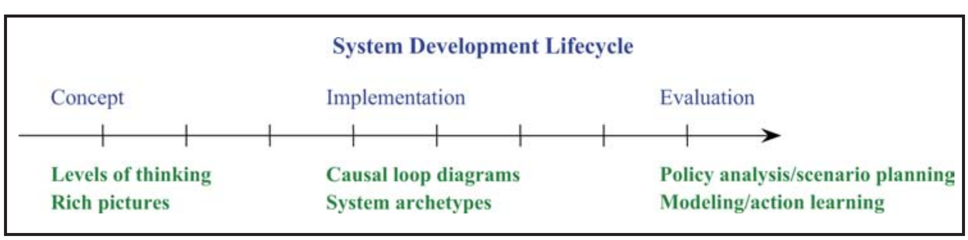
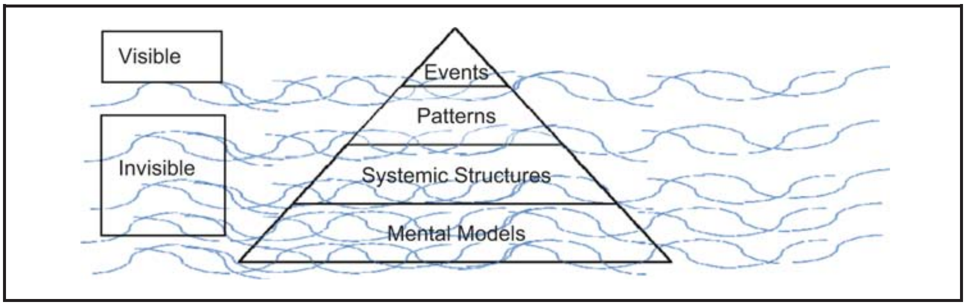


Figure 4 Iceberg model



3.1.2 Rich pictures. Rich pictures are informal drawings that express how an individual feels about a situation. The aim of the rich pictures technique is richness of personal expression, unrestrained by social conventions and unconstrained by predetermined frameworks. The use of drawing conventions and tools for a more objective representation of a technical problem is expressly discouraged. Rich pictures are often constructed by stakeholders at the concept phase as part of an interview or small group interaction. Monk and Howard (1998, p. 22) state that a ''rich picture is intended to be a broad, high-grained view of the problem situation''. Discussion on completed rich pictures may focus on structures, processes and concerns. Structure may depict the organization or organizations where the problem is occurring, physical facilities, locations, etc. Processes show the transformations that occur within the area of investigation. Concerns are the issues contributing to the problem as identified from the viewpoint of individual stakeholders. Yet a rich picture expresses how people perceive the problem, not their analysis of a pre-defined situation. The goal is to explore stakeholder's key motivations and personal intuitions about the shape of the problem and the way it can be framed for analysis and implementation.

Figure 5 is a rich picture developed by students in the authors' project management course at the University of Technology Sydney (UTS). The students were asked to develop a rich picture for an organization that wished to shift the World Cup cricket from India to another venue immediately after the bomb blasts in Mumbai.

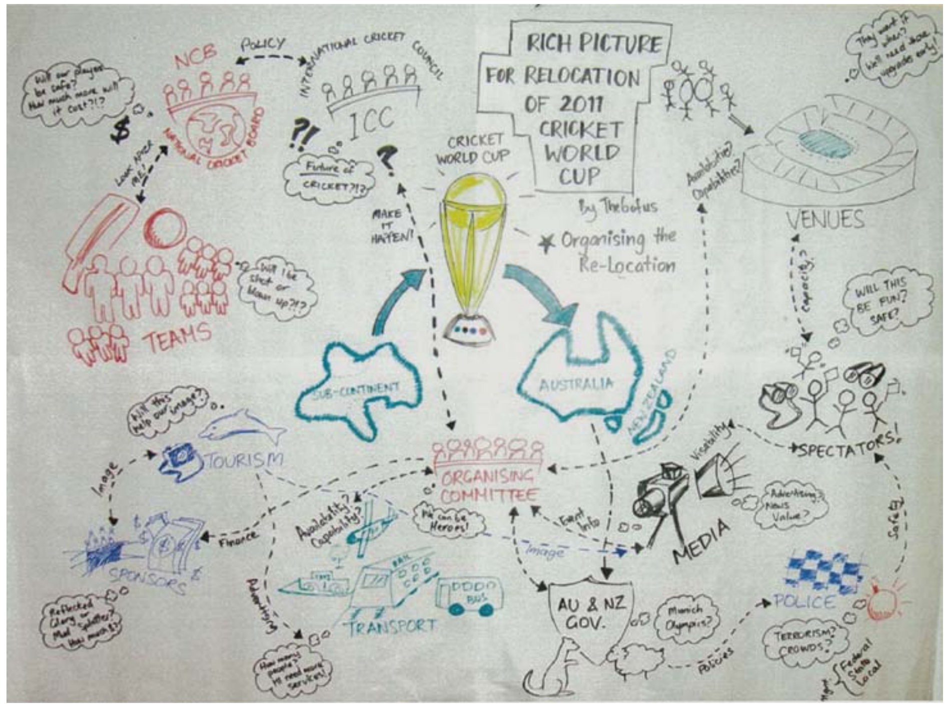
Drawing rich pictures is intended to be a fun experience that encourages playfulness and reduces hierarchy and role specialization. The process surfaces issues and processes, metaphors and mental models, values and attitudes that are unstated but often extremely influential in the governance and management of the project. The diversity of stakeholder goals and motivations that are surfaced makes drawing rich pictures particularly valuable in the earlier conceptual stages of the system development lifecycle (Meadows and Robinson, 2002). The pictures typically retain great personal significance and may spring spontaneously to mind – vivid, still fresh – years later.

3.2 Application to the implementation phase

In this section we introduce two systems thinking methods that provide a disciplined approach to ''big picture'' or ''forest'' thinking in the implementation phase. The two methods – causal loops and systems archetypes – facilitate conceptual understanding of cycles of cause and effect and their attendant time delays.

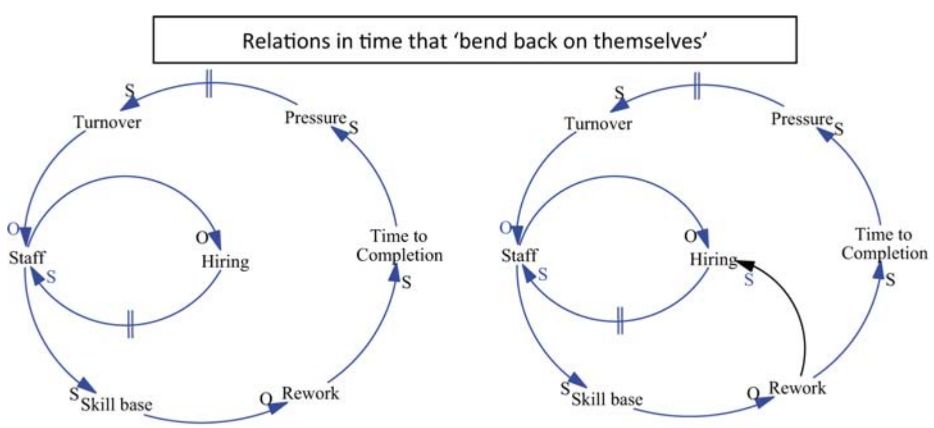
3.2.1 Casual loops. Peter Senge's book entitled *The Fifth Discipline* helped to introduce the idea to managers that cause and effect are often linked (perhaps via intervening events) in a circular arrangement called a ''causal loop''. An appreciation of the working of a causal loop, and its effect on other loops with which it may be entangled, promotes an understanding of the more complex issues that bedevil project management. The aim of developing a causal loop diagram is to understand the fundamental dynamics of the system and to develop policy levers to control variation caused by interaction of components in the system and attendant time delays.

Figure 5 A rich picture of the World Cup cricket organization



The causal loop diagrams or CLDs in Figures 6a and 6b provides a visual representation useful in identifying the cause-and-effect relationship among a set of factors that operate together as a dynamic system. For example, rework in a project is likely to increase completion times. Rework and time to completion are conceived as variables that move in the same direction – more rework results in longer completion times, and less rework results in shorter completion times. This relationship is captured by drawing a directed arrow from ''Rework'' to ''Time to Completion'' and by placing an ''s'' near the head of the arrow to indicate that the variables move in the same direction. A similar diagramming convention is used to capture other important influences, such as the expectation that Time to Completion

Figure 6



(a) An inappropriate policy ('vicious cycle') **(b)** A more appropriate policy ('virtuous cycle') will cause Pressure, and Pressure (after a time delay) will cause staff to leave, or Turnover. A time delay is shown by a double line (''||'') drawn across the directed arrow between the variables.

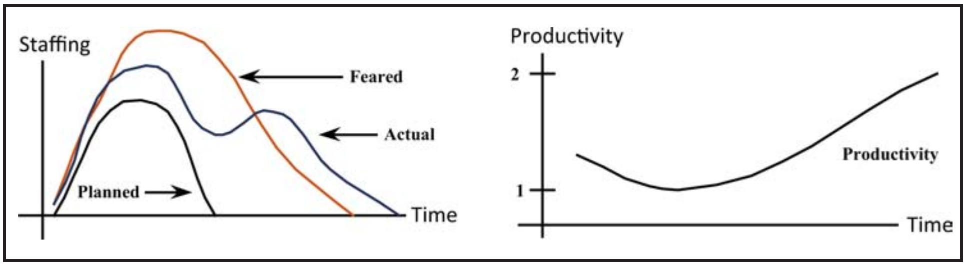
In an investigation of what factors influence what, two issues usually emerge. The first is that cause and effect, like the population of a predator and prey, are often linked in a circular fashion. An increase in predator population causes (after a time delay) a decrease in the population of their prey, and a decrease in the population of the prey causes (after a time delay) a decrease in the population of the predator. That is, we expect to find loops in our diagram of cause and effect, variables and arrows. In this example predator and prey populations move in opposite directions, indicated in the causal loop diagram by placing an ''o'' near the head of the arrow. In Figures 6a and 6b Turnover moves in the opposite direction to (the total number of) Staff. An increase in Turnover causes (an immediate) decrease in Staff, and a decrease in Turnover causes (an immediate) increase in Staff.

The mental models and systemic structures underlying dynamic situations are often too subtle to be picked up in sufficient time by those who must coordinate policy across functional areas such as project management and HR. The causal loop diagrams in Figures 6a and 6b may be useful in understanding the variables that drive the observed events, the pattern of interactions via same and opposite effects, and especially the time delay between cause and effect. In Figure 6a, as rework increases and project completion times blow out the pressure on staff, particularly the project manager, increases resulting in an increase in the number of staff leaving, or turnover. The loss of existing staff erodes the skill base of the organization. Staff turnover only produces new staff after a delay associated with the hiring process. New staff erode the skill base which then contributes to increasing rework. The delay between an eroding skill base, rework, pressure and turnover may be lengthy as the increasing pressure is often not immediately obvious as it is absorbed until a crisis develops. This delay, together with the delays associated with hiring may exacerbate a problematic downward or vicious spiral that is damaging and difficult to reverse.

A more appropriate policy is illustrated in Figure 6b, where the effect of the emergence of rework is mitigated by hiring as soon as the rework begins to surface. This more rapid policy intervention may short-circuit the crises routinely generated through stuff turnover. In addition the organization may gain additional stability and a reputation as a good place to work. In this case the policy dynamics illustrated in Figure 6b predict a tighter and more rapid binding of the variables and the emergence of an upward or virtuous circle.

When analyzing causal loops the time delays between cause and effect produce behavior over time that is usually hidden from view. A CLD is usually analyzed using a series of Behaviour over Time (BOT) graphs. The left hand graph in Figure 7 shows three freehand BOTs – the planned staffing for the project, the one that is feared if the project deadlines blow out, and the actual behavior. Lyneis *et al.* (2001) make the point that projects need to have a learning structure built into the project so that predicted and actual behavior can be understood and the learning from the past built into future projects. The authors employed the dynamic relationships represented in CLDs to identify the root causes of the decline in staff productivity during the first part of a project, the so-called ''Rookies and Pros'' effect. In the example in Figure 6a it would be expected that productivity would decline for a

Figure 7 Behavior over Time graphs for staffing levels and productivity



significant time when new staff are taken on, producing a vicious cycle. This understanding enables the project manager to resist the temptation to hire additional staff whose training leads will only lead to a net decrease in the number of trained staff available for productive work.

3.2.2 System archetypes. The study of causal loops reveals recurring patterns called system archetypes that have proven most useful in identifying leverage points and the root causes that underlie difficult problems. Kim (1992) explains that ''system archetypes capture 'common stories' in systems thinking – dynamic phenomenon that occur repeatedly in diverse settings''. One such archetype is briefly explored.

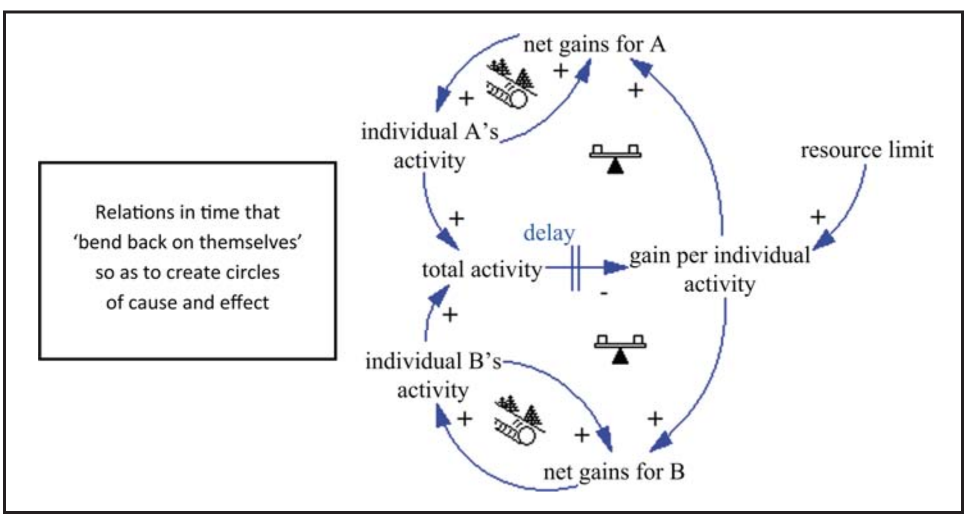
The misuse by individuals of a common resource has dynamics similar to the overgrazing that leads to the destruction of common land (Wikipedia, 2011b). The pattern is observed in many situations and constitutes an archetype known as the ''Tragedy of the Commons'' (Figure 8). In this diagram a '' + '' is employed to indicate that the pair of variables move in the same direction, and ''-'' to indicate a pair of variables that move in opposite directions. The positive or reinforcing logic at the top and bottom of the diagram is balanced by the ''-''sign that occurs in the middle of the diagram. The two loops are interdependent in that an increase in total activity will eventually lead to the reduction in marginal value or gain per individual activity. Once marginal gain is reduced to zero, each additional unit of total activity causes a net system-wide loss. This archetype is frequently employed to study how the dynamics of unregulated competition between individuals may destroy the viability of the common resource or marketplace.

3.3 Application to the evaluation phase

In this section we introduce two systems thinking procedures that provide an integrated approach to the evaluation phase. The two methods – policy analysis/scenario planning and modeling/action learning – have proven most useful in enrolling diverse stakeholders with ''multiple values, beliefs and interests'' (Jackson, 2003, p. 22) in a learning process that provides personal and interpersonal insight into evolving systems representations.

3.3.1 Policy analysis/scenario planning. The aim of this procedure is to develop and test ''policies'', that is, values to be assigned to each variable in a causal loop diagram or related systems dynamics model, such as a ''stock and flow diagram''. Scenario planning is widely used in business and IT strategic planning to assist stakeholders to visualize possible futures. Policy analysis and scenario planning is used prospectively (to evaluate a system concept) and retrospectively (to evaluate an implemented system). As in levels of thinking and rich pictures, the procedure assumes that individuals possess important insights –

Figure 8 Typical structure of the ''tragedy of the commons'' archetype

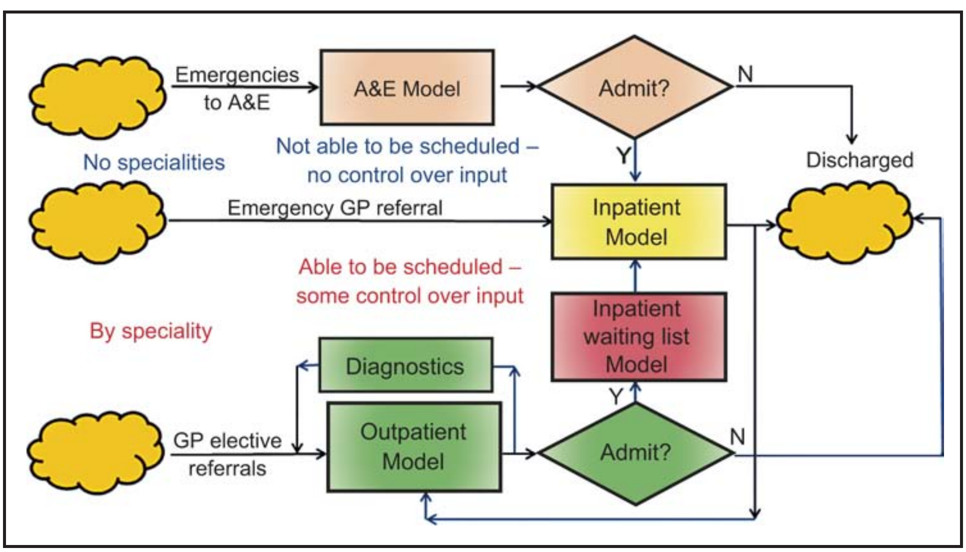


fragments of systemic knowledge – that must be expressed before they can be combined with the insights of others and ''framed'' in formal documents about systems requirements, etc. In policy analysis individuals express their own instinctive or habitual knowledge by ''telling stories'' to others. The stories are collated and common elements that drive change identified. Basic trends and key uncertainties are discussed and underlying rules of interaction surfaced. These cause and effect interactions are explored by constructing multiple scenarios chosen for their strategic importance. A stakeholder group such as a project steering committee may engage in scenario planning at regular intervals so as to maintain a consistent and proactive stance towards generating debate and insight about an uncertain and changing environment (Schoemaker, 1995).

3.3.2 Modeling/action learning. The power of systems thinking is especially evident when dynamic models of aspects of strategically important phenomena are integrated and employed for the purposes of experimentation and action learning by a broad array of stakeholders. Testable versions of causal loop diagrams, such as a ''stock and flow diagram'' are integrated to form systems dynamics micro-worlds. In the following we briefly describe an application of modeling/action learning in health.

Hospital systems are ''complex, dynamic, congested, highly connected systems''. It is difficult to see how all the different people and functions and special interests ''fit'' together to determine the ''quality'' and/or ''performance'' of the whole system. This in turn means that policy initiatives are likely to be clumsy. Pidd (2009) investigated a new UK NHS policy by accurately and succinctly capturing it via a modest number of parameters in four component models – A&E, Inpatient, Outpatient, and Inpatient waiting list – customized to match the observed behavior in the context of particular NHS trusts and hospitals. The new policy imposed a four hour maximum waiting time to admit A&E patients who, of course, cannot schedule their accidents and emergencies. Yet A&E is only one source of inpatient admissions. The new A&E policy may require changes to the policies governing patient flow through the other components. Interestingly the improvement in waiting times observed after the implementation of the new policy could not be simulated by changing parameters in just one of the component models. The simulation of the whole system demonstrated that the observed improvement in A&E processing time required a coordinated set of changes to parameters in the other three models – active waiting list management, more outpatient capacity, better use of beds. The simulation model finds continuing use as a guide for mutual learning among systems thinking researchers and policy makers (Figure 9).

Figure 9 An integrated suite of simulation models



4. Discussion and conclusion

Complexity in project management may be tamed by systems thinking. Surprisingly project managers do not seem to use simple systems thinking tools. Not surprisingly many are trapped into linear thinking patterns and compliance to complicated plans in a situation characterized by a large number of interactions – a situation that cries out for multiple perspectives and a focus on managing uncertainty. Project managers have recently embraced the power of agile methods for managing uncertainty in projects with a small number of components, and a few have discovered how to scale up agile methods for larger projects. Yet very few project managers employ systems thinking methods to manage projects that are complex (Figures 1 and 2).

The language of project managers frequently betrays a lack of understanding of situations involving interconnected cause and effect with attendant time delays. They think they can make things more simple than is possible. They become trapped into promises to deliver against complicated plans when they should instead be embracing uncertainty and delivering on systems thinking techniques.

The systems thinking techniques associated with the concept phase of the system development lifecycle (levels of thinking and rich pictures) require comfort with ambiguity, and interpersonal skills, rather than technical skill. They provide a low-cost way of getting started on systems thinking. The techniques associated with the implementation phase (causal loop diagrams and systems archetypes), and evaluation via policy analysis/scenario planning require a little more practice and represent a logical next step. The remaining technique (modeling/action learning based on quantitative versions of a causal loop diagram) normally require specialized training. The authors observe that Project Managers easily pick up the concepts via the use of visual software such as IThink, Vensim and Powersim.

Expectations about dynamic situations can be managed by the use of the methods introduced here.

Enjoy the voyage.

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