Systems thinking: How is it used in project management?

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Acknowledgements

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Abstract

Systems thinking is not a new technique for project management, but neither its application, nor understanding of its benefits, is widespread. Interviews and two surveys have been conducted to explore the use of systems thinking in project management. We find that the majority of respondents believe that project managers use some form of systems thinking at least half of the time, but many recognised systems thinking tools like rich pictures and soft systems methodology are not widely used in projects. Use of systems thinking tools is slightly greater for more experienced project managers, and for those working in sectors that deliver complex technological products such as defence and aerospace. Further research is needed to explore in more detail the sector-level usage of systems thinking.

Keywords: Systems thinking

Contents

1. Introduction

1.1 What is systems thinking?

Systems thinking can be described as 'a discipline for seeing wholes rather than parts, for seeing patterns of change rather than static snapshots, and for understanding the subtle interconnectedness that gives (living) systems their unique character' (Senge, 1990). Systems thinking recognises that the world is made up of interconnected, hierarchically organised technical and social entities which often produce behaviour that cannot be predicted by analysing the behaviour of the system's parts in isolation (or by simply aggregating the behaviour of the parts). A system has 'emergent properties' – it is more than the sum of its parts.

Sometimes we may use systems thinking without knowing it. For example, whenever we are interested in looking under the surface of some object or process to understand how it works – to understand how its elements work in concert (or sometimes in conflict) to give behaviour that is different to what could be achieved by the parts working independently – we are applying systems thinking.

"Systems thinking acknowledges the relationship between interacting components"

Systems thinking acknowledges the relationship between interacting components. In doing this, it helps to identify leverage points where interventions will have the greatest impact, not just straight away but over time. Systems thinking also ensures that the big picture (or whole system performance) is designed for, taking into account all relevant factors when implementing change. This enables us to avoid solutions that are an aggregation of optimised subsystems, but are ineffective overall due to the interactions between the subsystems.

Systems thinking has been recognised since the middle of the 20th century with Ludwig von Bertalanffy's *General Systems Theory* (von Bertalanffy, 1968), and arguably a form of systems thinking governs the creation of key project management outputs such as network charts and Gantt charts. Nevertheless, systems thinking has never been an explicit part of mainstream education in project management.

However, the importance of systems thinking is increasingly being recognised in industry, academia and government agencies. In the UK health sector, for example, systems thinking underpins the rationale for Sustainability and Transformation Plans or Partnerships (STPs). To deliver the NHS's 'Five Year Forward View' (NHS England, 2014), 44 STPs across England are each given responsibility for delivering health and care services, integrating services from acute care providers like major hospitals, to county councils, mental health and community providers, to ambulance trusts.

Interest in systems thinking within APM is also growing, with a joint working group set up in 2013 between APM and the International Council on Systems Engineering, and an APM Systems Thinking Specific Interest Group (SIG), launched in December 2016.

1.2 How could projects benefit from systems thinking?

Most project managers take a linear, deterministic view of their projects using tools such as Gantt charts that string activities into a rigid sequence. However, this rather simplistic view takes little or no account of the interaction between activities (Hitchins, 2003). As projects have grown more complex, there has arisen a need to develop techniques to manage that complexity. Major projects could often benefit from the application of systems thinking, for example to:

■ Improve the realism of cost and schedule estimates by understanding that projects are not deterministic. For example, additional tasks are often needed in projects that were not originally expected (such as rework), and this can dramatically slow progress. Systems thinking can help anticipate and manage this effect.

■ Improve the integrity and hence value of the product that is delivered by anticipating possible challenges at the interfaces and by anticipating additional enabling tasks and systems beyond the obvious. A close relationship between (systems) engineers and project managers ensures fewer unexpected surprises.

■ Improve the understanding of stakeholders' needs throughout the (extended) project lifecycle. A systems view encourages broader thinking about how a product or service meets the needs of various stakeholders, and what higher-level goals and constraints exist outside the boundary of the delivered system.

We need systems thinking because traditional linear, top-down or divide and conquer approaches on their own are often unsuccessful for modern projects. Systems thinking does not seek to replace traditional top-down thinking, but to complement it.

"We need systems thinking because traditional linear, top-down or divide and conquer approaches on their own are often unsuccessful for modern projects"

1.3 Exploring the extent of use of systems thinking

Despite the existence of several tools for systems thinking that could be applied in project management, and anecdotal evidence supporting the value of systems thinking, the actual use of systems thinking techniques in projects has not previously been researched.

The aims of this research are to gather qualitative and quantitative data to determine the extent to which different sectors and different types and sizes of projects are currently employing different approaches to systems thinking.

2. Literature review

2.1 Project modelling, optimisation and control

It is natural for humans to think in linear-causal terms, whereby 'A causes B' (Lewis, 1998). This is what traditional operational research (OR) teaches, which is based on a mathematical model involving a few (measurable) variables in a linear relationship (Churchman *et al.*, 1957; Checkland, 1981). This can be thought of as a form of systems thinking called 'hard systems thinking'. Hard systems thinking is incorporated in techniques such as Programme Evaluation and Review Techniques (PERT) and critical path analysis, which help to calculate how tasks can be sequenced in a project to minimise time and cost (Jackson, 2003).

However, to understand systems fully, it must be accepted that A may cause B and that B may at the same time cause A. The idea of linear causality must be replaced by thinking in terms of circular causal effects, because systems involve feedback which introduces circularity (Lewis, 1998). Maani and Cavana (2007) identify several methodologies that fit under the system dynamics approach that can be applied to explore this kind of problem. The aim of systems dynamics in projects is to provide an understanding of the structure of complex systems. This ensures the project behaviour is moving towards achieving its objectives, and where positive feedback is identified, this can be reinforced to boost productivity (Aramo-Immonen & Vanharanta, 2009). Popular techniques to do this include causal loop modelling (which increases understanding of system behaviour), and computer simulation software packages. A project can be considered as a complex, multiple-loop, non-linear, social system with a strong impact of human actors on decision-making. In systems of this type, traditional OR is too simplistic to provide a complete view (Aramo-Immonen & Vanharanta, 2009).

> "To understand systems fully, it must be accepted that A may cause B and that B may at the same time cause A"

2.2 Soft systems thinking – exploring perspectives and requirements

The problem with a conventional project management approach is that projects are treated as 'islands' with closed boundaries, and rely on prescribed formulae to manage them, leaving no room for flexibility and deviations from the project plan (Kapsali, 2011). Traditional approaches such as precise planning are less effective for complex projects due to the way in which unstable systems change (Kopczyński & Brzozowski, 2015).

Kapsali's (2011) study showed that conventional project management methods do not help deployment projects perform well, because they prevent innovativeness and communication through boundaries and restrain managerial action to handle change. This approach cannot accommodate complex projects, as they are characterised by boundaries that change in response to a changing environment (Sheffield *et al.*, 2012). Systems thinking is important in understanding complex projects, and managers are increasingly becoming interested in the subject. Level of understanding of systems thinking varies considerably, however, with many merely having an awareness that it is something that could help them (Jackson, 2003), and although some managers are implementing systems thinking, it is often being practised in an *ad hoc* way due to limited experience (Kapsali, 2011).

Kapsali (2011) argues that project management should be concerned with equipping the team to cope with challenges rather than giving top managers a platform to monitor progress; the system to manage projects needs to be unique to those using it and the environment it is working in. An open or soft approach allows this adjustment and complexity to be accounted for by acknowledging subjectively what the problem is, and encouraging different viewpoints from multiple stakeholders (van Eck & Ponisio, 2008).

"The system to manage projects needs to be unique to those using it and the environment it is working in"

Complex projects that particularly benefit from systems thinking tend to characterise a high number of interactions and a high number of components (Sheffield *et al.*, 2012), as shown in Figure 1. The Agile method can be used to combat project uncertainty, but once projects increase in complexity, project managers may be unable to change their perspective to see the bigger picture. According to Sheffield *et al.* (2012), few project managers employ systems thinking to manage complex projects, even though just a few simple tools could bring unique benefits to problem-solving for these projects.
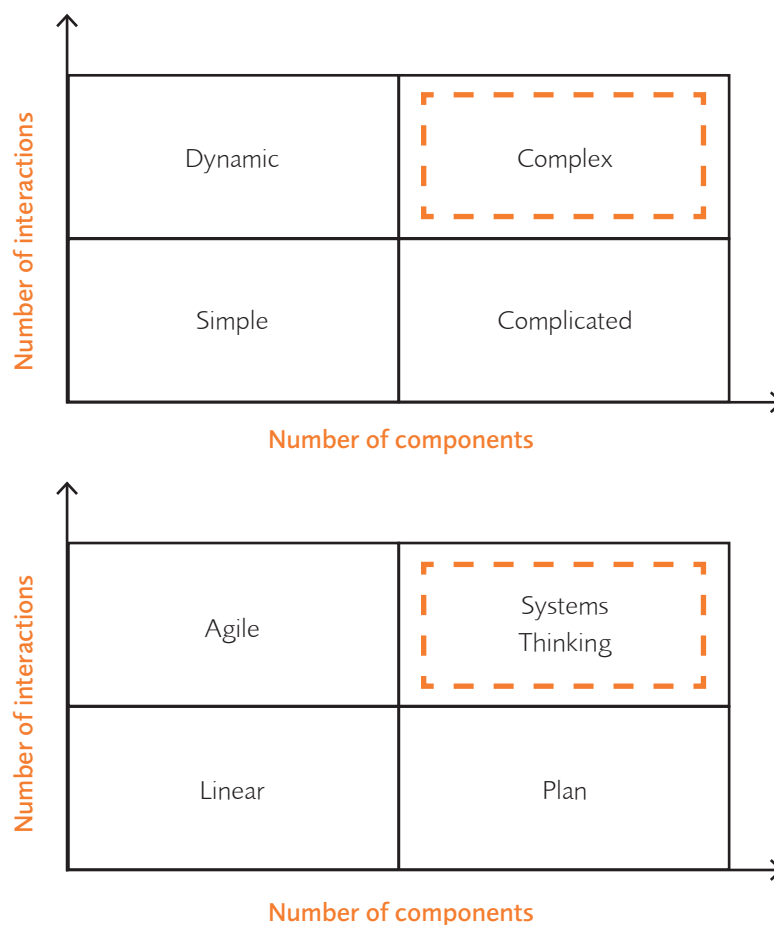

Figure 1: Types of systems and projects and types of project management method (Sheffield, et al., 2012)

Other authors make a different distinction between complicated and complex projects (Snowden and Boone, 2007). Complicated projects can be characterised as having high intricacy (usually with both a large number of components and a large number of interactions) and require a high level of specialist knowledge to complete. Complex projects, on the other hand, can be seen as having an additional characteristic of a high level of uncertainty in the organisational domain – with unclear or incompatible stakeholder needs (Loch, De Meyer and Pich, 2006). These complex projects are therefore likely to include a large number of unknown unknowns (Snowden and Boone, 2007).

Since the 1970s there has been significant development in the systems approach, and now a much wider range of project complexity can be dealt with than hard systems thinking was able to deal with alone (Jackson, 2003). Jackson and Keys in 1984 developed a framework for classifying systems methodologies called system of systems methodologies (SOSM) (Griffiths, 2017).

Soft systems methodology (SSM) is described as 'systemic', as opposed to the hard 'systematic' approach. SSM developed as creating clear objectives systematically is not always feasible for large projects. In major projects over-estimates and programme slippage are common occurrences, and the most fundamental cause of the problem is change (Yeo, 1993). Change is inevitable in large projects and it's typical for goals to evolve during the life span of mega-projects (Aramo-Immonen & Vanharanta, 2009). Participants should use a systemic methodology to learn what changes are feasible and desirable from the problem context. SSM looks to unfold relationships within projects to enable better decisions to be made (Jackson, 2003). The most accessible component of an SSM study for project management is the 'rich picture', which encourages a deep consideration of the problem situation from the perspective of multiple stakeholders, uncovering sympathies and tensions between the various actors. This can form an excellent foundation for the requirements management process (Niu *et al.*, 2011). From the expression of a problem situation in a rich picture, SSM goes on to develop root definitions of relevant systems, enriched using the mnemonic CATWOE (Customers, Actors, Transformation process, World view, Owners and Environmental constraints), and conceptual models, to reveal different logical ways of interpreting and managing the problem situation.

Both cognitive mapping, and strategic options development and analysis (SODA) are tools that unravel mental models of how individuals think about a certain problem. Employing these two techniques in the deeper levels of systems produces desirable outcomes in both content and process in the product, as it focuses on how individuals view their world and behave (Maani & Cavana, 2007).

"Soft systems methodology (SSM) is described as 'systemic', as opposed to the hard 'systematic' approach"

2.3 Systems thinking across the life cycle

Kopczyński and Brzozowski (2015) identify that the starting point of applying systems thinking in project management is through initially understanding the problem-solving process. Sheffield *et al* (2012) recognise a particular technique that can be used for this initial 'concept' step, as well as systems thinking techniques from project management that apply to two other phases of the development life cycle (implementation and evaluation) as shown in Figure 2.
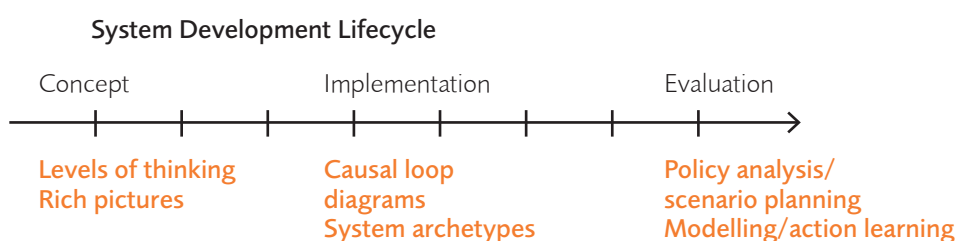
System Development Lifecycle

Concept   Implementation   Evaluation

Levels of thinking Causal loop   Policy analysis/
Rich pictures   diagrams   scenario planning
        System archetypes Modelling/action learning

Figure 2: Application of systems thinking to system development life cycle (Sheffield et al.*, 2012)*

2.4 The five-phase systems thinking and methodology process

Maani and Cavana (2007) outline five phases, along with relevant systems thinking techniques, that can be used to structure problem-solving and can either be used as a process method or individually, depending on the problem.

Phase	Systems thinking technique
1. Problem structuring	- Affinity diagram/hexagon clustering
2. Causal loop diagram	- Causal loop diagram
3. Dynamic modelling	- Rich picture - Stock-flow diagram - Software packages e.g. STELLA, DYNAMO
4. Scenario planning and modelling	- Scenario planning
5. Implementation and organisational learning	- Microworld/management flight simulator

Table 1: Five-phase systems thinking and methodology process (Maani & Cavana, 2007)

2.5 Systems thinking tools

According to Kim (2000), there are 10 distinct types of systems thinking tools. In his reference guide to systems thinking tools he listed these under four broad categories, as shown in Table 2.

Brainstorming tools	Dynamic thinking tools	Structural thinking tools	Computer-based tools
Fishbone diagram	Behaviour over time diagram	Graphical function diagram	Computer model
	Causal loop diagram	Structure-behaviour pair	Management flight simulator
	Systems archetype	Policy structure diagram	Learning laboratory

Table 2: Ten distinct types of systems thinking tools in four broad categories (Kim, 2000)

"Brainstorming tools are designed to help users begin to see the whole system, where all sides of the problem can be explored avoiding a top–down perspective"

Brainstorming tools are designed to help users begin to see the whole system, where all sides of the problem can be explored avoiding a top-down perspective (Kim, 2000). The fishbone diagram is a good prequel to dynamic thinking tools such as causal loop diagrams, which can represent event patterns through feedback loops, and map the structures that are producing those dynamics. The key role of feedback loops in under-pinning systems thinking is emphasised by Arnold and Wade's (2015) review of definitions of systems thinking by influential writers including Richmond, Sweeney and Sterman, Hopper and Stave, and Kopainsky, Alessi and Davidsen.

Structural thinking tools are used as the building blocks for the computer-based tools. They are useful in complex projects as the tools look deeper into the structures of the behaviour and dynamics that are trying to be understood. Graphical function diagrams are used to clarify non-linear relationships between variables, structure-behaviour pairs link a specific structure with its corresponding behaviour, and policy structure diagrams represent the decision-making process that drive policies.

Building models using computer-based tools enables simulations to be used to create interactive decision-making games (management flight simulator) and embed a rich learning environment (learning laboratory) (Kim, 2000). The management flight simulator provides an interactive and user-friendly interface for managers to experiment with the model. This is then used by the learning laboratory to test hypotheses and mental models designed to create individual and group learning (Cavana & Maani, 2000).

Burge Hughes Walsh, a company that provides training and consultancy in systems design and process improvement, put together the following list of 22 systems thinking tools it considered particularly effective (Burge Hughes Walsh, 2017).

18 words	Matrix diagram
Affinity diagram	Morphological box
Conceptual model	Multiple cause diagram
Context diagram	N2 analysis
Decision matrix	Quad of aims
Functional failure mode and effects analysis (FMEA)	Rich picture
Functional means analysis	Root definition
Functional modelling	Sequence diagram
Graphical analysis	Spray diagram
Influence diagram	Systems map
Input-output diagram	Tree diagram

Table 3: Systems thinking tools (Burge Hughes Walsh, 2017)

"There is no broad understanding of what sorts of individuals, organisations and sectors actually use systems thinking practices and to what extent; this research study has sought to explore this question"

Various authors have commented on use of systems thinking techniques across different industries. For example, Sheffield, *et al.*, (2012) said scenario planning is widely used in business and IT strategic planning because it can assist stakeholders to visualise possible futures by expressing individual insights before crucial stages. In the health sector, on the other hand, modelling learning has proved a useful simulation application for capturing new UK NHS policies. Modelling learning requires specialised training in order to be used and this will likely affect the extent of its use, compared to using a rich picture, which requires interpersonal skills rather than technical (Sheffield *et al.*, 2012). Despite these insights, there is no broad understanding of what sorts of individuals, organisations and sectors actually use systems thinking practices and to what extent; this research study has sought to explore this question.

The International Council on Systems Engineering (INCOSE) and the Association for Project Management (APM) came together to form a Systems Engineering and Project Management (SEPM) Joint Working Group. They produced a small paper on systems thinking in which six systems thinking tools were highlighted (APM / INCOSE JWG, 2018):

1. Fishbone diagram (Figure 3). Structures thoughts, and distinguishes hard and soft variables that affect the problem of interest.

2. Rich picture (Figure 4). A part of soft systems methodology which enables a problem situation to be defined by multiple stakeholders and an initial mental model to be created.

3. Actor map (Figure 5). Characterises key organisations and roles that are in, and affected by, the system.

4. Concept map (Figure 6). Shows the knowledge concepts of a topic, where the main concept is broken down to show its sub-topics and their relationships.

5. Trend map (Figure 7). Details trends that influence the system, through collective knowledge of those familiar with the system and its context. Enables activities and events to be visualised to identify potential contextual factors.

6. Causal loop diagram (Figure 8). These diagrams represent the relationships between system elements and identify reinforcing and balancing processes to explore behaviour over time.
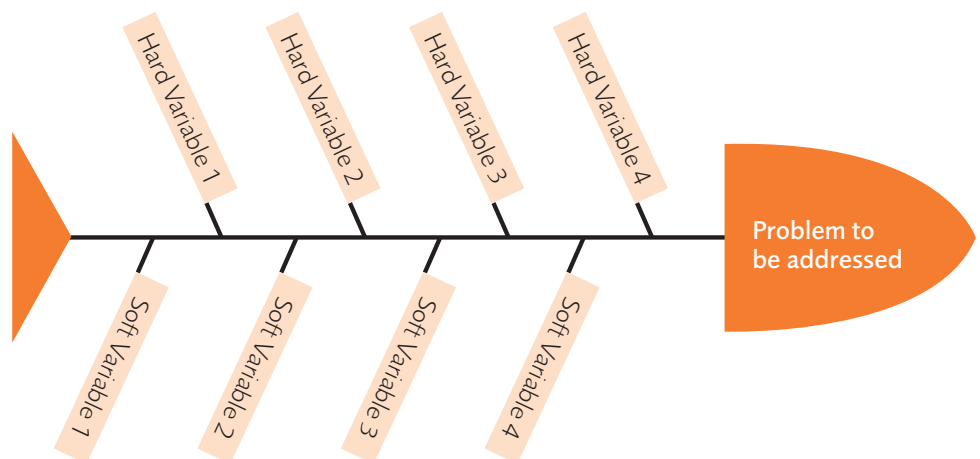

Figure 3: Example systems thinking fishbone diagram (APM / INCOSE JWG, 2018)
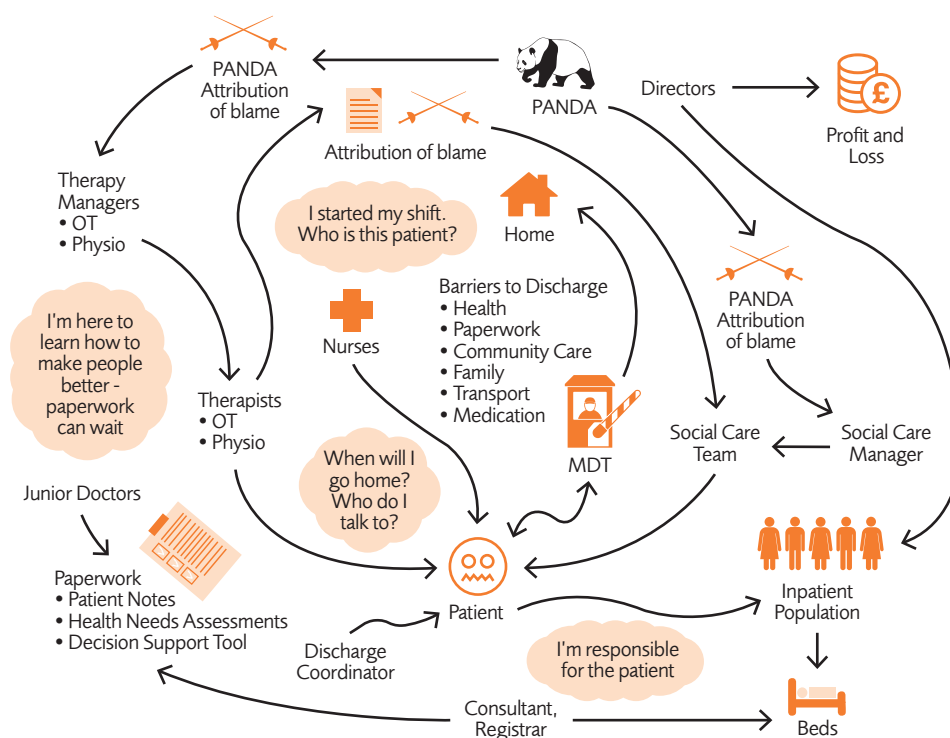
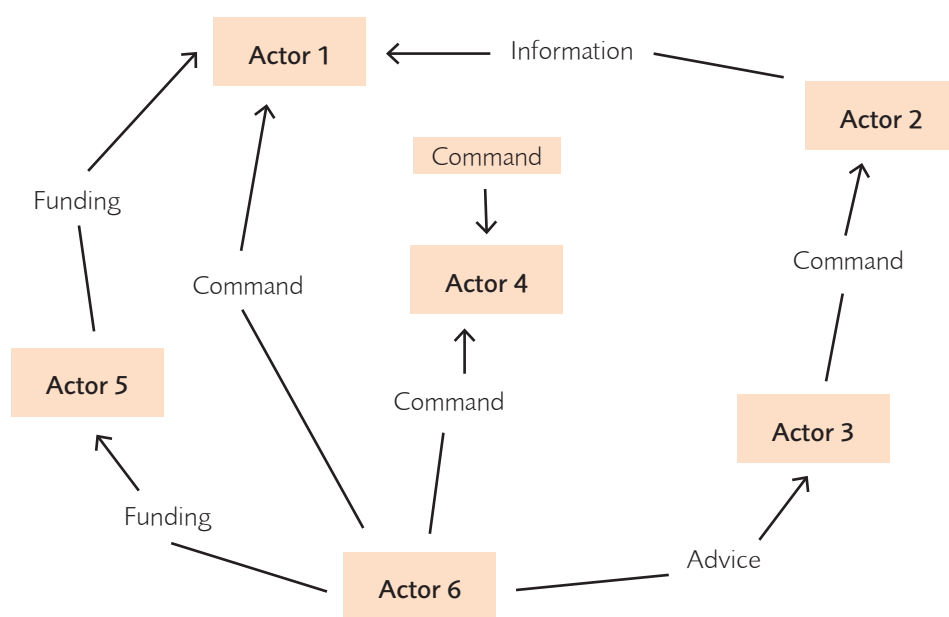*Figure 4: Example rich picture diagram (Emes et al., 2017)*

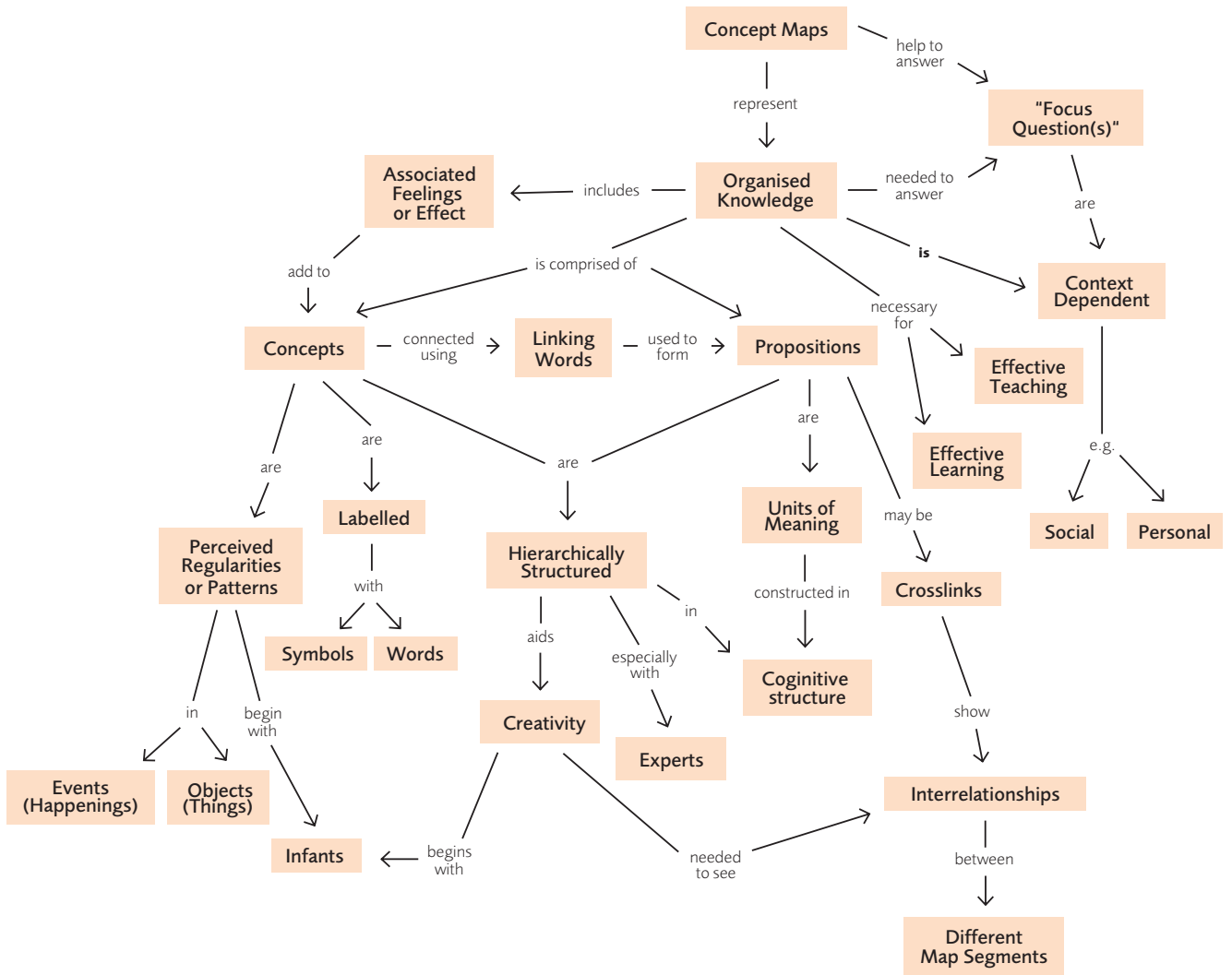*Figure 5: Example actor map, adapted from APM/INCOSE JWG (2018)*

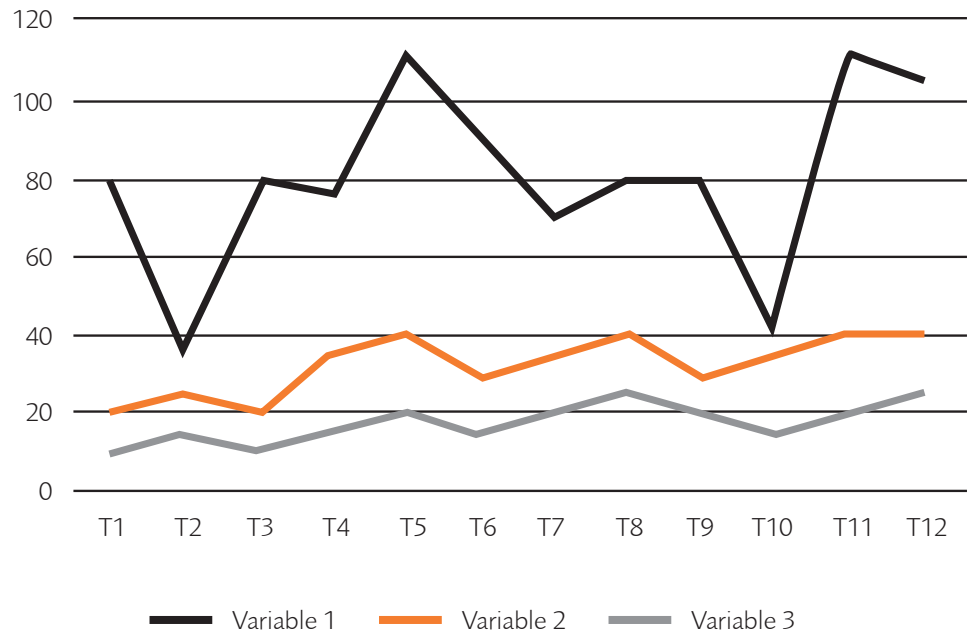Figure 6: Example concept map (Novak & Canas, 2006)

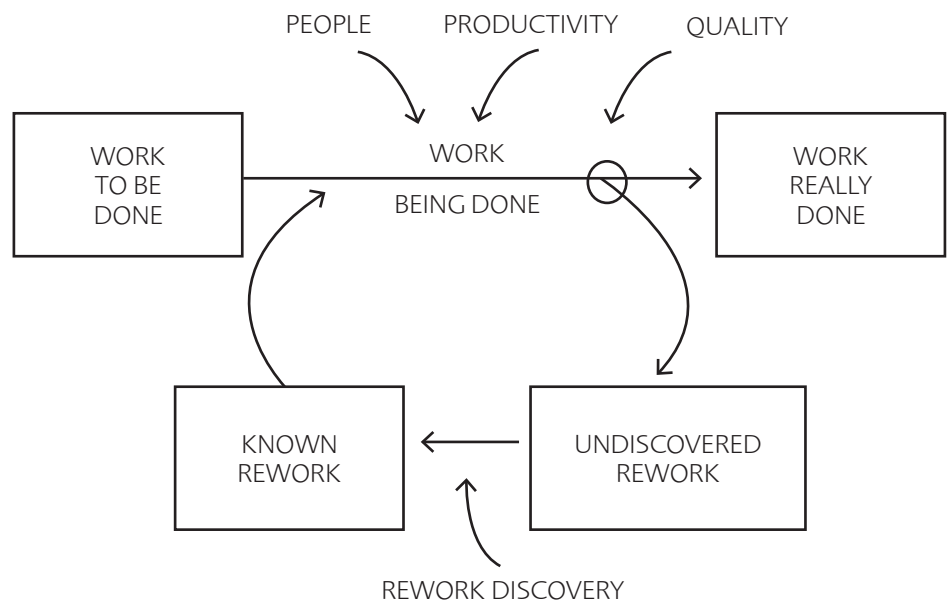*Figure 7: Example trend map, adapted from APM/INCOSE (2018)*

Figure 8: Example causal loop diagram (Cooper, 1993)

3. Research methodology

3.1 Research hypotheses and overall research design

The research had the following hypotheses that the authors were seeking to test:

- Hypothesis 1 (H1) Systems thinking is not widely practised amongst project managers.

- Hypotheses 2 (H2) Systems thinking is more prevalent within larger projects than smaller projects.

- Hypothesis 3 (H3) Systems thinking is more prevalent in domains that develop complex systems, such as in aerospace and defence, than in domains that develop more simple systems such as construction.

- Hypothesis 4 (H4) Systems thinking is more practised by experienced project managers than by inexperienced project managers.

- Hypothesis 5 (H5) Systems thinking is seen to add value by those with the most experience in managing projects.

To explore these hypotheses and to understand how systems thinking is used in project management, a mixed-method research study was performed that blended qualitative insights gathered from semi-structured depth interviews with quantitative data captured through the use of two online surveys (Figure 9).
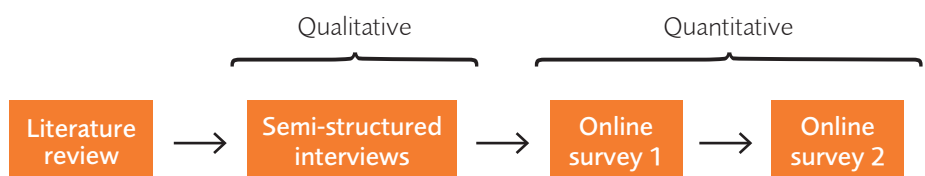
Figure 9: Flow diagram of the research stages

3.2 Secondary research

The literature review described above was used to explore the current tools and methodologies relevant to the subject of systems thinking. It highlighted knowledge and the limits of that knowledge (in particular, confirming the scope of previous research). The literature also formed an important part of the process of designing the questions to be used for the interviews and the surveys to follow.

3.3 Qualitative research

The authors sought to undertake at least 10 interviews with project management experts across a range of sectors with an expressed interest in systems thinking. An email was sent out to members of the APM Systems Thinking Specific Interest Group (SIG) inviting involvement in the study. In the end, 11 interviews were conducted face to face by one or both of the authors, at locations around the UK, and one interview was conducted by telephone by both authors. Each of the 12 interviews had a duration of around an hour and followed the same structured format and style of questions (the interview guide used to structure the interviews is shown in the Appendix). The interviewees were seen as participants, rather than subjects, however, and so were encouraged to be active co-constructers of the narratives that were produced.

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3.4 Quantitative research

Drawing on the findings of the interviews and the literature review, two surveys were developed to reach out to a wider population.

3.4.1 APM member survey
The first survey targeted project managers who were members of APM, with particular interest in reaching out to those involved in major and complex projects, from organisations that were expected to benefit the most from systems thinking.

Closed questions were asked for gathering data on the extent and prevalence of systems thinking techniques that had been gathered during the previous research stages, and also to understand the effectiveness of the techniques at adding value. Closed questions allowed for easy comparison. Open questions were also asked to allow the respondents to supply extra information and expand on any experiences they had with systems thinking. This increased the range and richness of data gathered. The design of this survey can be found in the Appendix. An online survey was held during July and August which received fewer responses than expected – 61 compared to the 100 target.

3.4.2 Annual state of project management survey
Given the relatively low response rate from the first survey, a second survey was undertaken in order to allow cross-sector comparisons to be made. Here, Wellingtone Project Management kindly agreed to include several questions on systems thinking in the annual survey on the state of project management in the UK. This obtained a total of 571 respondents.

Three questions were asked relating to systems thinking, these are outlined in the Appendix.

4. Findings

4.1 Interviews

The 12 interviews were conducted with participants with experience across many sectors, including defence, aerospace, rail, public services (e.g. housing provision), construction, automotive, transport, government, information technology and consumer electronics.

Interviewees generally agreed that there wasn't enough awareness of systems thinking tools. Quoting two project managers from the rail and defence sectors: "we need to increase awareness of systems thinking in organisations, and get people to understand its value" and "all project managers already do it today, but don't know the label of systems thinking … project managers don't think of systems thinking tools as part of their tool box … [they are] unaware of it as a systems thinking tool."

It was also noted that the support given to project managers in systems thinking was very low. Project managers from the rail and public services sectors said when talking about the use of systems thinking in the organisation: "Directors are more interested in the strategic view, and how what we are doing is going to deliver strategy" and, it is "not strategic to the organisation to use it [systems thinking] in projects."

In the public sector, it was discovered that the rich picture was the most useful tool to understand stakeholder feelings (and the 'user journey') and to inform the scope in the early stages of the project.

Systems thinking was generally felt to be under-applied, although it was recognised that a balance had to be struck as in the application of any tool. In the defence sector, for example, one interviewee felt that the use of systems thinking in large projects had a "… danger in investing too heavily in time…" preventing the product getting to market on time.

From the qualitative research, it was clear that the respondents believed many engineers naturally applied systems thinking, but often did not use the label 'systems thinking'. Many project managers seemed to become aware of systems thinking through their engineers. One interviewee said, "systems thinking is fed up through to project managers from engineers. Engineers with experience tend to go on to develop into project managers using their technical background to bring in new methods."

The main aim of the face-to-face interviews was to gather a selection of systems thinking tools that were being used across different industries, in order to create the online survey. Below is a list of tools that were mentioned by one or more interviewees as being used for systems thinking:

- rich picture ■ fishbone diagram ■ actor map ■ concept map
- trend map/graphical analysis ■ causal loop diagram ■ Gantt chart
- flow diagram ■ V diagram ■ viable systems model ■ critical systems heuristics
- soft systems methodology ■ cybernetics ■ cognitive mapping ■ P3M3 ■ PERT chart.

These tools were listed in Q5 of the APM member survey.

> "We need to increase awareness of systems thinking in organisations, and get people to understand its value … project managers already do it today, but don't know the label of systems thinking"

4.2 APM member survey

The vast majority of the 61 respondents to the APM member survey had significant experience, with 52 out of the 59 (88 per cent) of those that answered the question saying they had 10 years or more experience of managing projects (Figure 10). The most common duration of the projects managed (Figure 11) was two years (34 per cent), closely followed by one year (32 per cent) and five years (25 per cent).

Size of projects managed varied quite significantly (Figure 12), with 14 respondents (24 per cent) reporting typical cost at completion of £1m, and the same number reporting typical cost at completion of £10m. Slightly fewer respondents (11, or 19 per cent) reported typical cost at completion of £100m.
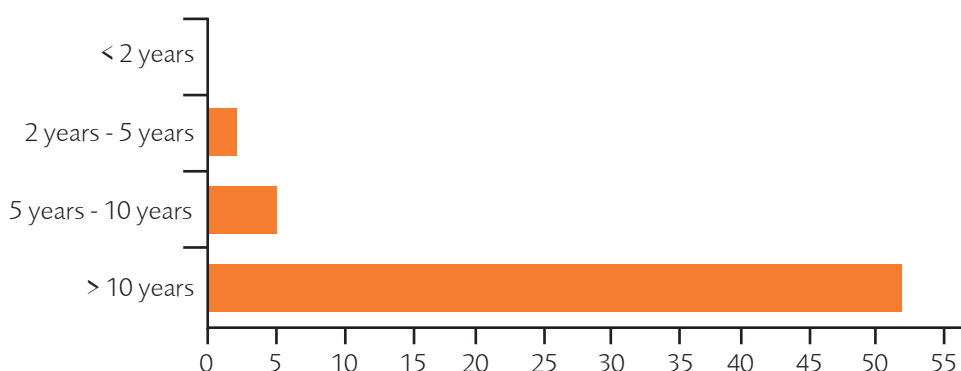

Figure 10: Results of APM survey Q2 – For how many years have you been managing projects?
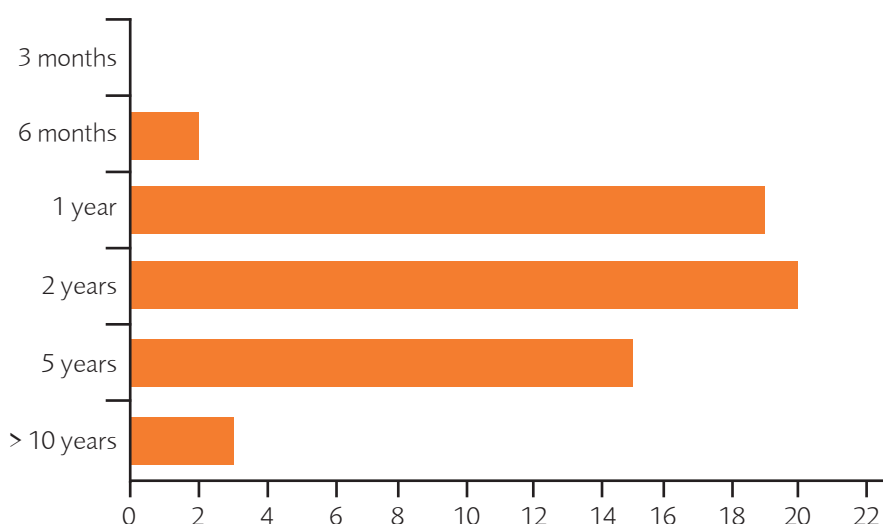
Figure 11: Results of APM survey Q3 – What is the typical duration of the projects that you have managed?
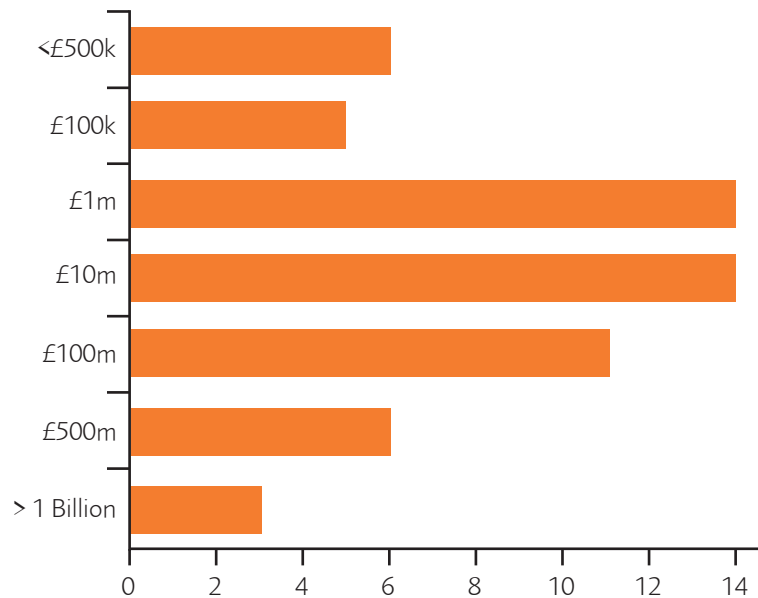
Figure 12: Results of APM survey Q4 – What is the typical cost at completion of the projects that you have managed?

In answer to Q5, part three ("from the tools listed, do you think of them as systems thinking?"), the responses shown in Figure 13 were obtained. The net positive response is shown – the number that answered 'Yes' to the question, minus the number that answered 'No', shown as a proportion of the total that answered the question (varied between 51 and 57). The most popular response was 'causal loop diagram', which 39 of 51 respondents thought of as systems thinking, with only one respondent not seeing it as systems thinking (giving a 75 per cent net positive score). Rich picture, soft systems methodology and concept map were the next most popular with net positive scores of around 50 per cent.
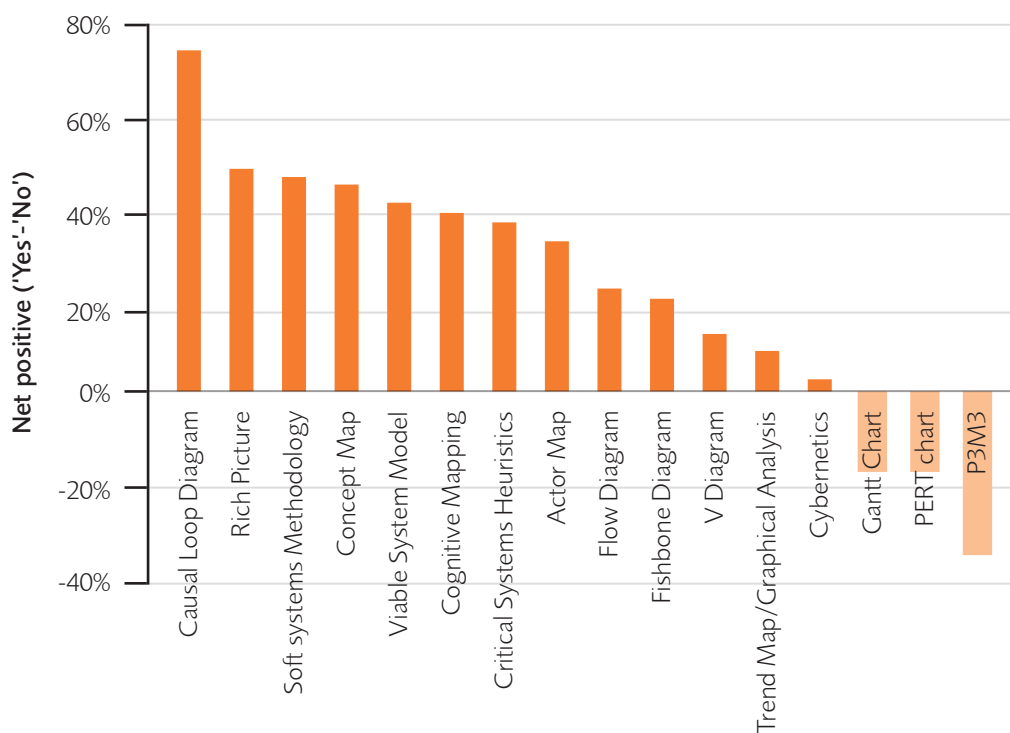
Figure 13: Results of APM survey Q5 (iii) – Is it systems thinking? (N = 57 respondents)

Although most of the 16 tools were recognised as systems thinking, popular project management tools and approaches such as Gantt chart, PERT chart and P3M3 had more people answering 'No' to the question 'is it systems thinking' than answering 'Yes' (i.e. these had a negative net positive score), which is the response we would have expected for these.

Four of the tools were used at least occasionally by over half of respondents – Rich picture (67 per cent), causal loop diagram (61 per cent), concept map (56 per cent), and soft systems methodology (52 per cent). Regular usage (taken here to mean that respondents indicated that they used the technique at least half of the time) was much lower, however, at 35 per cent, 35 per cent, 35 per cent and 25 per cent respectively for the four tools (Figure 14). Some of the other techniques that were not widely considered to be systems thinking scored much higher on 'Use regularly', in particular the Gantt chart (91 per cent) and flow diagram (71 per cent).

Use Ever   **Use Regularly**
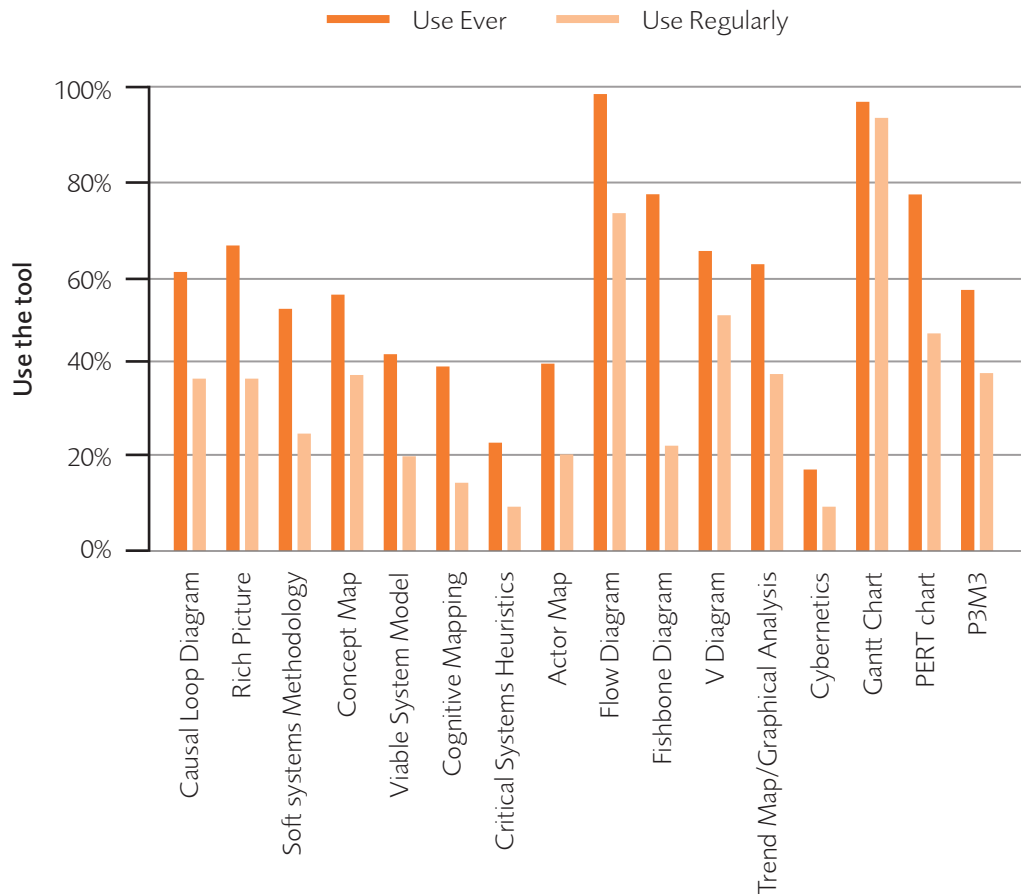
Figure 14: Results of APM survey Q5 (i) – Extent of use of systems thinking tools (N = 57 respondents)

Respondents were generally positive about the effectiveness of the systems thinking tools, with over half of respondents describing rich pictures (65 per cent), concept maps (59 per cent), causal loop diagrams (58 per cent) and soft systems methodology (52 per cent) as very effective or extremely effective. Gantt charts (76 per cent) and flow diagrams (61 per cent) were also felt to be highly effective of the tools not generally considered systems thinking tools.

Reflecting on the research hypotheses outlined in section 3.1, we can say that there is some tentative support for hypothesis H1 – "Systems thinking is not widely practised amongst project managers". Note, though, that although no single systems thinking tool seems to be regularly used, there was no question in the survey that asked about extent of systems thinking use in general (the annual state of project management survey discussed in section 4.3 addresses this general question).

Figure 15: Results of APM survey Q5 (ii) – Is the tool effective? (N = 22 to 51 respondents (varying by tool), effectiveness determined by proportion of respondents answering 'Very effective' or 'Extremely effective')
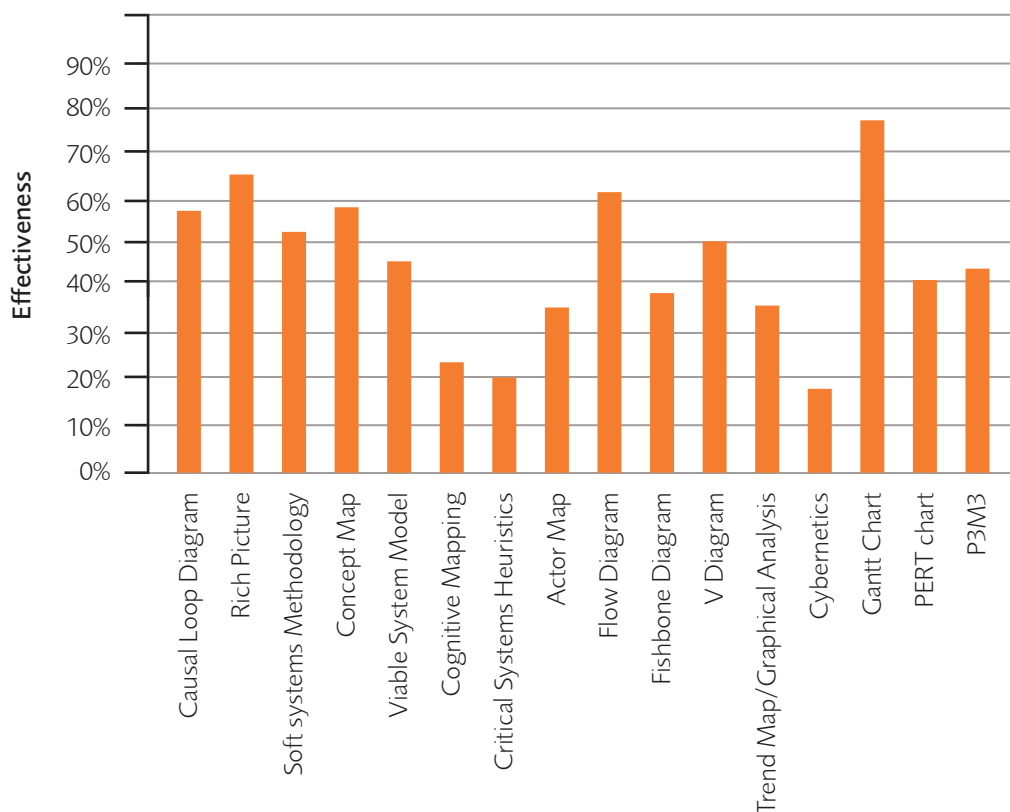
Hypothesis H2 stated that "Systems thinking is more prevalent within larger projects than smaller projects". Respondents were split into two categories – 'Small budget', for those respondents that said they typically worked on projects with budgets of <£50k, £100k, £1m or £10m, and 'Large budget' for those that typically worked on projects of £100m, £500m or £1 billion. For small budget projects, the four tools most recognised as systems thinking (Figure 13): causal loop diagram, rich picture, soft systems methodology and concept map were used regularly (about half of the time or more) on average by 43 per cent of 40 respondents. For large budget projects, they were used regularly by 51 per cent of 21 respondents. Although the number of respondents is too small to be sure that these results reflect the wider population, this finding is in the direction of supporting hypothesis H2.

There were not enough respondents to test hypotheses H3 to H5 using this survey as these required further segmentation of the dataset, and would yield subgroups too small for statistically relevant results.

4.3 Annual state of project management survey

In answer to the first systems thinking question, "How often do project managers apply systems thinking when scoping or delivering their projects?", the vast majority of the 519 respondents that answered the question indicated that systems thinking was at least sometimes used (89 per cent), with very little variation by sector (mean 89 per cent, sd = 6.3 per cent).

When focusing on the proportion that believed that project managers *regularly* used systems thinking (taken here to mean those who answered 3, 4 or 5 on the five-point scale, where 1 = Never, 2 = Sometimes, 3 = About half of the time, 4 = Most of the time and 5 = Always), there was some variation between sectors (Figure 16). Overall, across all sectors, 294 respondents out of 519 (57 per cent) believed that project managers regularly used systems thinking. Given the sample size we can be 95 per cent sure that the wider population would have answered the question within +/- 4.3 per cent of the 57 per cent level.
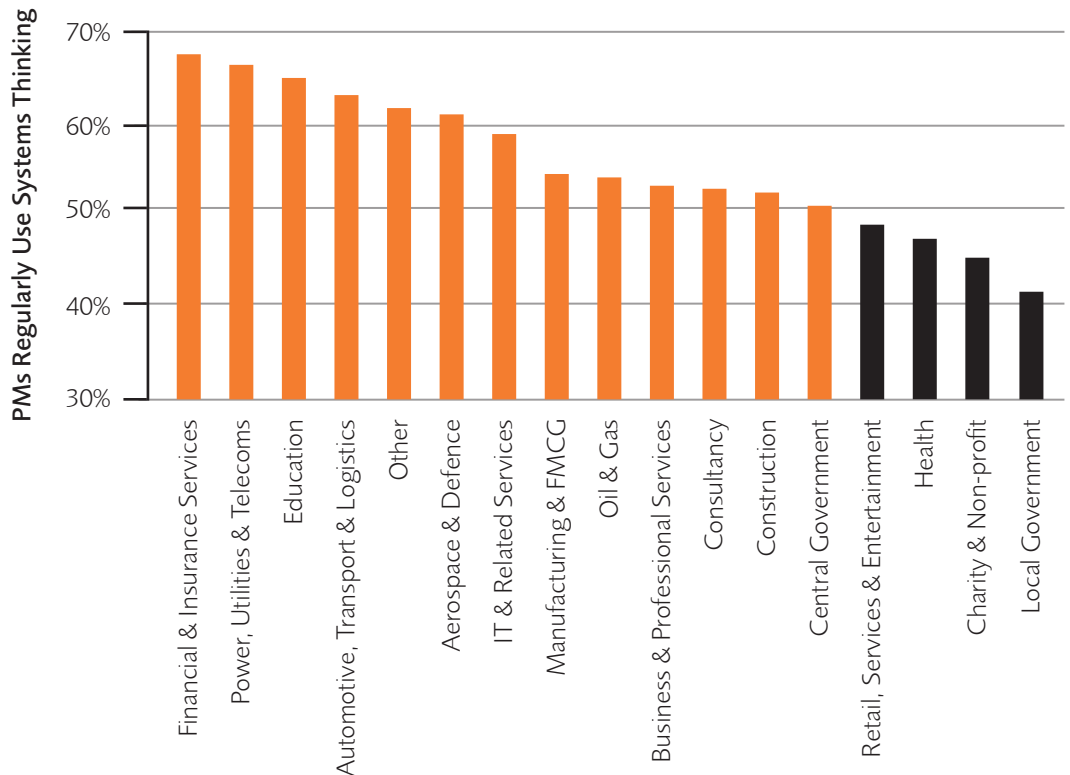

Figure 16: Use of systems thinking by sector (N = 519, % that answered about half the time or more, mean subgroup size = 30.5, sd = 12.5)

Hypothesis H1 "Systems thinking is not widely practised amongst project managers" is quite vague, but we might reasonably consider systems thinking to be widely practised if it were employed at least half of the time by the majority of project managers. With this interpretation, we can express the null hypothesis "Systems thinking is practised at least half of the time by the majority of project managers". On this basis, we can say that the null hypothesis is supported, and that H1 should be rejected for the population in general.

To highlight the ends of the spectrum in terms of responses from individual sectors, in financial and insurance services, 67 per cent of 55 respondents indicated that project managers regularly used systems thinking, whereas the figure in local government was only 41 per cent from 27 respondents. Hypothesis H1 appears to be supported for four sectors as shown in black in Figure 16, but given the relatively low number of respondents (21 respondents from retail, services and entertainment, 28 respondents from health, 20 respondents from charity and non-profit and 27 respondents from local government), the conclusions are not statistically significant on a sector level.

Hypothesis H3 suggested that "Systems thinking is more prevalent in domains that develop complex systems such as in aerospace and defence than in domains that develop more simple systems such as construction". Noting again the limitations of small sector-level sample size, hypothesis H3 seems to be supported with 61 per cent of the 31 aerospace and defence sector respondents indicating that project managers use systems thinking at least half of the time, but only 52 per cent of 25 respondents from the construction sector. Other sectors with high scores on the use of systems thinking are generally those that involve highly engineered systems, where there is a high degree of technical challenge and complexity in the solution space. Other sectors that might benefit from applying systems thinking but are not currently using it widely are those where there is a large amount of complexity in the problem space, such as in government and the health sector.

Hypothesis H4 was that "Systems thinking is more practised by experienced project managers than by inexperienced project managers". Figure 17 shows the variation of response according to the number of years of project management experience.
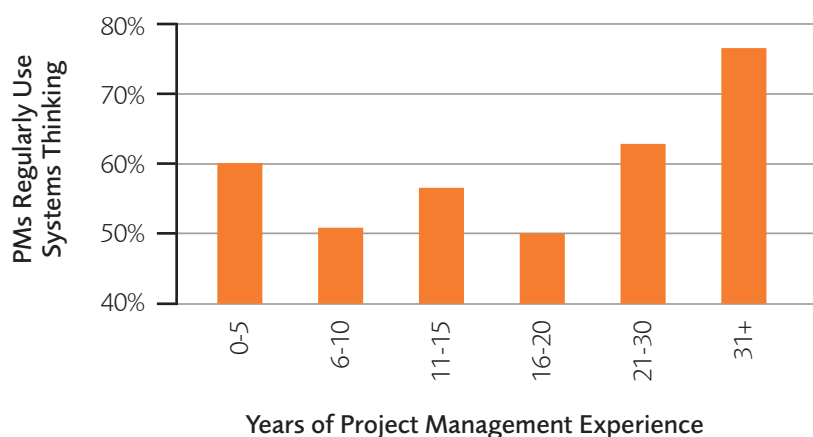

Figure 17: Use of systems thinking according to project manager experience (N = 519, % that answered about half the time or more, mean subgroup size = 86.5, sd = 27.9)

Experienced project managers were defined as being those with 21 or more years of project management experience (133 or 23 per cent of the 571 respondents). Of the 122 that answered the question "How often do project managers apply systems thinking when scoping or delivering their projects?", 66 per cent answered that project managers applied systems thinking about half of the time or more (i.e. they used it 'regularly'). The figure for the 397 respondents that answered with 20 years of project management experience or less was 54 per cent. Of those with the most experience (31+ years), the figure was significantly higher (76 per cent), but there were only 34 respondents in this group. Overall, there seems to be quite strong support for the hypothesis that systems thinking is more practised by experienced project managers.

Hypothesis H5 is that "Systems thinking is seen to add value by those with the most experience in managing projects". Of the 122 respondents with 21 or more years of project management experience, an average of 50 per cent of respondents found the four most recognised systems thinking tools (causal loop modelling, rich pictures, soft systems methodology and concept maps) sometimes, mostly or always useful. Of the 397 respondents with 20 years or less of project management experience, an average of 46 per cent of respondents found these tools sometimes, mostly or always useful. This suggests there is support for the hypothesis that systems thinking is valued more by managers with more experience.
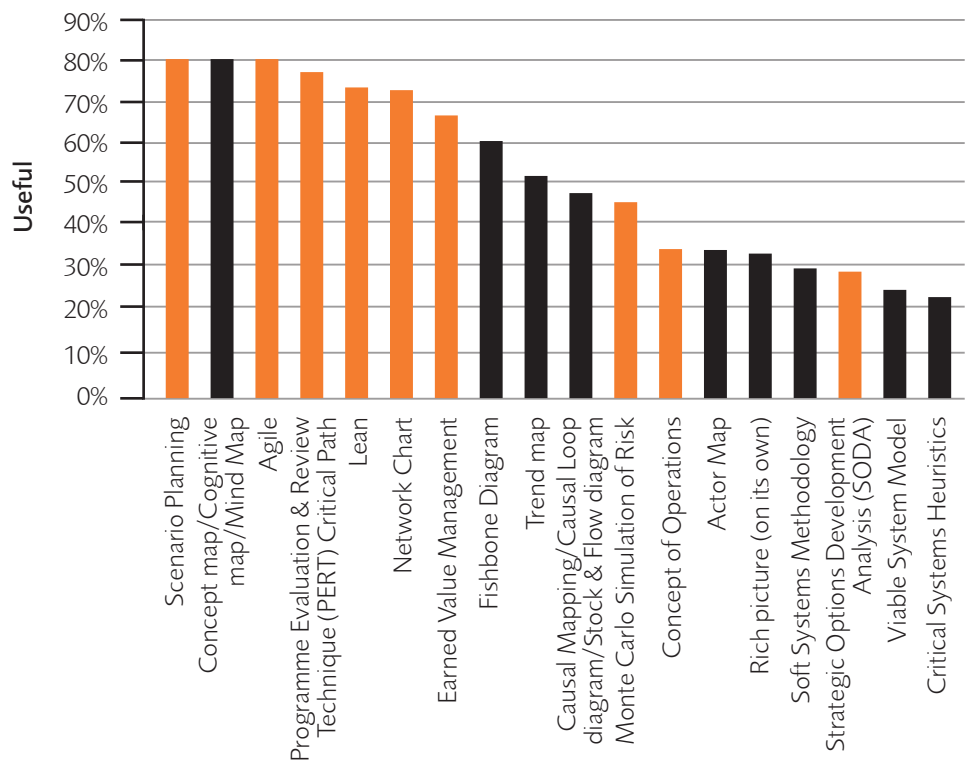

Figure 18: Usefulness of various techniques for project management (N = 519, % that answered technique is sometimes useful, mostly useful or always useful)

Usefulness of systems thinking techniques (shown in black) is compared to various other project management techniques in Figure 18. It is noticeable that the concept map scores particularly highly here – more highly even than highly popular techniques such as lean and agile. Other systems thinking tools are significantly less popular, with rich pictures and soft systems methodology scoring particularly poorly compared to the results of the APM member survey (Figure 15).

5. Conclusions

5.1 Summary of findings

Overall, it was encouraging to discover through the research that some sort of systems thinking is recognised and used at least half of the time by the majority of project managers. There is some support (although weak given the small sample size) for the idea that systems thinking is more prevalent in large projects than small projects, and for the hypothesis that it is used more in sectors that develop complex technological projects such as defence and aerospace than in sectors with simpler products. There is quite strong support for the hypothesis that systems thinking is applied more by experienced project managers than by inexperienced project managers, and quite weak support for the hypothesis that systems thinking is seen to add more value by experienced project managers.

Of the techniques considered, causal mapping or causal loop diagrams are the most recognised form of systems thinking amongst the APM member survey (which was mainly responded to by those with a previous interest in systems thinking). From the wider annual state of project management survey, however, the techniques of concept mapping, fishbone diagrams and trend maps were all thought to be more useful in practice than causal loop diagrams.

"It was encouraging to discover through the research that some sort of systems thinking is recognised and used at least half of the time by the majority of project managers."

5.2 Further research

Since a large proportion of respondents recognise the value of systems thinking, it will give the APM Systems Thinking SIG greater confidence in continuing to investigate how systems thinking can be applied to improve project delivery.

It is suggested that we continue to monitor the usage of systems thinking in project management through an annual survey. This would enable us to see whether the Systems Thinking SIG's efforts at sharing information about systems thinking is being effective.

In future, it would be helpful to design the survey such that stronger sector-level conclusions can be drawn. This could be achieved by increasing the number of respondents, or by reducing the number of different sector options listed. Other useful research could develop case studies demonstrating the use and value of specific systems thinking techniques in project management.

6. Appendices

6.1 Participant information sheet for interviews

'How is systems thinking used in projects?'

You have been invited to take part in a research project. This document should help you to understand why the research is being done and what participation will involve. Please read the following information and ask us if anything is not clear or if you would like more information.

The APM Research Fund is funding a project between March and September 2017 to investigate how systems thinking is used in projects. The project will gather qualitative data from semi-structured in-depth interviews. From these we're looking to discover the extent to which different sectors and different types and sizes of projects are currently employing various types of systems thinking, and examples of how application of systems thinking has added real value to organisations. We will then conduct an online survey to understand the prevalence of these techniques across the wider project management community, and to investigate how much value can be attributed to systems thinking across different sectors and classes of project.

You have indicated that you are willing to participate in the interviews. We are very grateful for your support as the quality of the research depends on the contributions of knowledgeable practitioners. Please note, however, that you may choose to withdraw at any time without needing to provide a justification.

Interviews will take around one hour and will be held at a mutually convenient location. Your contribution to the research will help in the development of several outputs, which will be developed over the next year. We expect these to include an MSc dissertation, a report for the APM, an academic paper and a guide for practitioners. With your permission, we will record (audio only) the interviews to ensure we have an accurate record of what was said. These recordings will be used for the sole purpose of writing up a transcript of the interview. This transcript will be sent to you for review soon after the interview (within two weeks as a maximum), and once the transcript has been reviewed and the content agreed, the audio recording will be deleted. Any information that we collect about you during the interview will be kept strictly confidential. You will not be identified in any ensuing reports or publications without your prior consent.

Contact information:

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Thank you for your interest and taking part in this research.

Participant's Statement - I agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.

Signature

_____

Date

_____

Print Name

_____

6.2 Guide for interviews

'How is systems thinking used in projects?' – interview sheet

Length – *1 hour*

Interviewers: Mr William Griffiths, Dr Michael Emes

(Set context for meeting): *5 minutes*

- Purpose of research
- What we're interested in
- What we want to get out of the interview

(Their work): *5 minutes*

- Can you explain what kind of projects you have managed/are currently managing?

(Into the main bulk of the interview about systems thinking): *25 minutes*

- What does systems thinking mean to you?
- What experiences have you had with systems thinking and any techniques/features that you have used in projects? (look to get examples)
- Why did you use said technique/approach?
- How were/are you applying systems thinking? *10 minutes*

(Benefits) *15 minutes*

- What benefits are you seeing using systems thinking and the value that it is adding to projects you have run (or relevant techniques/approaches they've mentioned)?
- Do you think a practical guide in using systems thinking will be useful for current and future project managers?
- Can there be too much systems thinking (analyses)?

6.3APM member survey

APM Systems Thinking SIG research - 'How is systems thinking used in projects?'

Q1 - In which sector are you managing projects?

Q2 - For how many years have you been managing projects?

- [ ] < 2 years
- [ ] 2–5 years
- [ ] 5–10 years
- [ ] >10 years

Q3 - What is a typical duration of the projects that you have managed?

- [ ] <= 3 months
- [ ] 6 months
- [ ] 1 year
- [ ] 2 years
- [ ] 5 years
- [ ] >= 10 years

Q4 - What is the typical cost at completion of the projects that you have managed?

- [ ] <= £50k
- [ ] £100k
- [ ] £1m
- [ ] £10m
- [ ] £100m
- [ ] £500m
- [ ] >= £1 billion

Q5 - From the table below, (i) to what extent do you use these tools in projects, (ii) to what extent do they add value to the projects and (iii) do you think of them as systems thinking?

	Extent of use					Effectiveness of adding value					Is it systems thinking?		
	Never	Sometimes	About half the time	Most of the time	Always	Not effective at all	Slightly effective	Moderately effective	Very effective	Extremely effective	Yes	Not sure	No
Rich picture													
Fishbone diagram													
Actor map													
Concept map													
Trend map/ graphical analysis													
Causal loop diagram													
Gantt chart													
Flow diagram													
V diagram													
Viable systems model													
Critical systems heuristics													
Soft systems methodology													
Cybernetics													
Cognitive mapping													
P3M3													
PERT chart													

**Q6 - Are you familiar with any of the following systems thinking tools?
Please tick all that apply**

- affinity diagram
- conceptual model
- context diagram
- decision matrix
- functional failure mode and effects analysis
- function means analysis
- functional modelling
- influence diagram
- input-output diagram
- matrix diagram
- morphological box
- N2 analysis
- quad of aims
- root definition
- sequence diagram
- spray diagram
- systems map
- tree diagram

Q7 - Please comment below on any systems thinking tools you use in projects which are specific to your sector that aren't mentioned above, and that you feel should be made aware of for this study.

Q8 - If you have any real-world examples/case studies of systems thinking adding value in projects, please provide details in the space below, and could you please provide an email address for potential follow up questions.

Q9 - How long have you been a member of APM?

☐ <6 months

☐ 6 months – 1 year

☐ 1–5years

☐ 5–10 years

☐ >10 years

6.4 Systems thinking questions in annual state of project management survey

1. The first question was asked within the context of a series of questions about standard project management approach, which was introduced as:

"Many organisations have defined a standard project management approach, their project management methodology. Please answer these questions about your experience in your current (or most recent) organisation ..."

The question was then:

"How often do project managers apply systems thinking when scoping or delivering their projects?"

[1=Never, 2=Sometimes, 3=About half of the time, 4=Most of the time, 5=Always]

2. In your experience what typical project management processes are the most troublesome to embed? Please choose a maximum of three.

- ☐ risk management
- ☐ change control
- ☐ document management
- ☐ stakeholder engagement
- ☐ benefits realisation
- ☐ cost management
- ☐ lessons learned
- ☐ systems thinking
- ☐ life cycle governance such as gateways
- ☐ project prioritisation
- ☐ resource management
- ☐ project status reporting
- ☐ portfolio reporting
- ☐ planning (scheduling)
- ☐ progress measurement
- ☐ project sponsorship

3. In your experience, what typical techniques or processes, when applied well, have the potential to add the most value in project management? Please choose a maximum of three.

- [ ] risk management
- [ ] change control
- [ ] document management
- [ ] stakeholder engagement
- [ ] benefits realisation
- [ ] cost management
- [ ] lessons learned
- [ ] systems thinking
- [ ] life cycle governance such as gateways
- [ ] project prioritisation
- [ ] resource management
- [ ] project status reporting
- [ ] portfolio reporting
- [ ] planning (scheduling)
- [ ] progress measurement
- [ ] project sponsorship

4. Below is a list of techniques sometimes used in projects. For each technique that you are familiar with, please indicate how useful you think the technique is for project management.

☐ rich picture (on its own)

☐ fishbone diagram

☐ actor map

☐ concept map/cognitive map/mind map

☐ trend map

☐ agile

☐ lean

☐ monte carlo simulation of risk

☐ scenario planning

☐ network chart

☐ causal mapping/causal loop diagram/stock and flow diagram

☐ soft systems methodology

5. Please rank the top five challenges your organisation faces on a regular basis when it comes to project, programme and portfolio management, from 1 to 5 with 1 being the most challenging. Please choose five challenges, rank them 1 to 5

☐ poorly trained project managers

☐ inconsistency in approach

☐ lack of visibility of project status

☐ poor resource management

☐ doing the wrong projects (lack of strategic alignment)

☐ attempting to run too many projects

☐ poor project selection process

☐ lack of senior management support

☐ lack of governance

☐ a lack of project funding

☐ underestimating (at the concept stage) final project cost and schedule

☐ frequent changes to scope

☐ poor risk management

☐ lack of planning skills

☐ lack of systems or strategic thinking (failure to see the big picture)

☐ poorly trained project sponsors

☐ lack of appropriate software

☐ ineffectively implemented EPM / PPM solution

6. Bibliography

APM / INCOSE JWG (2018) Systems Thinking for Project Managers - A White Paper.

ARAMO-IMMONEN, H and VANHARANTA, H (2009) Project Management: The Task of Holistic Systems Thinking. *Human Factors and Ergonomics in Manufacturing*, 19, 582–600.

ARNOLD, R D and WADE, J P (2015) A Definition of Systems Thinking: A Systems Approach. *Procedia Computer Science*, 44, 669–678.

BALA, B K, ARSHAD, F M and NOH, K M (2017) *System Dynamics: Modelling and Simulation*, Singapore, Springer.

BURGE HUGHES WALSH. (2017) *Systems Thinking Tools* [Online]. Available: https://www.burgehugheswalsh.co.uk/Systems-Thinking/Tools.aspx.

BURGE, S. (2011) The Systems Engineering Tool Box - N2 analysis. Available: https://www.burgehugheswalsh.co.uk/Uploaded/1/Documents/N2-Analysis-Tool-Draft.pdf.

CAVANA, R Y and MAANI, K E. A methodological framework for integrating systems thinking and system dynamics. 18th International Conference of the System Dynamics Society: "Sustainability in the Third Millennium", 6–10 August 2000 Bergen, Norway.

CHECKLAND, P B (1981) *Systems Thinking, Systems Practice*, Chichester, Wiley.

CHURCHMAN, C W, ACKOFF, R L and ARNOFF, E F (1957) *Introduction to operations research*, New York, Wiley.

COATES, J F (2016) Scenario planning. *Technological Forecasting and Social Change*, 99–102.

COOPER, K G (1993) The rework cycle: benchmarks for the project manager. *Project Management Journal*, 24, 17–21.

EMES, M R, SMITH, S, WARD, S, SMITH, A and MING, T (2017) Care and Flow: Applying Soft Systems Methodology to understand the patient discharge process. *Health Systems*, 6, 260–278.

GRIFFITHS, A., 2017, How is Systems Thinking Used in Projects, MSc Technology Management dissertation, UCL, August

HITCHINS, D K (2003) *Advanced systems thinking, engineering and management*, Norwood MA, Artech House.

JACKSON, M (2003) *Systems Thinking: Creative Holism for Managers*, Chichester, Wiley.

KAPSALI, M (2011) Systems thinking in innovation project management: A match that works. *International Journal of Project Management*, 29, 396–407.

KIM, D (2000) Systems Thinking Tools: A User's Reference Guide. Waltham MA, USA: Pegasus Communications.

KOPCZYŃSKI, T and BRZOZOWSKI, M. (2015) Systems thinking in project management: theoretical framework and empirical evidence from Polish companies. *Science Articles of the University of Natural Sciences and Humanities in Siedlce. Series: Administration and Management* [Online]. Available: http://www.tstefaniuk.uph.edu.pl/zeszyty/archiwalne/107-2015_7.pdf.

LEWIS, J (1998) *Mastering Project Management*, New York, McGraw-Hill.

LOCH, C. H., DE MEYER, A. AND PICH, M. T. (2006) Managing the Unknown: A New Approach to Managing High Uncertainty and Risk in Projects, Wiley

MAANI, K E and CAVANA, R Y (2007) *Systems Thinking, System Dynamics: Managing Change and Complexity*, North Shore, NZ, Pearson Education New Zealand.

NHS ENGLAND (2014) Five Year Forward View.

NIU, N, LOPEZ, A Y and CHENG, J-R C (2011) Using soft systems methodology to improve requirements practices: An exploratory case study. *IET Software*, 5, 487–495.

NOVAK, J D and CANAS, A J (2006) The Theory Underlying Concept Maps and How to Construct and Use Them. Institute for Human and Machine Cognition.

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

SHAFER, S M, SMITH, H J and LINDER, J C (2005) The power of business models. *Business Horizons*, 48, 199–207.

SHEFFIELD, J, SANKARAN, S and HASLETT, T (2012) Systems thinking: taming complexity in project management. *On the Horizon*, 20, 126–136.

SNOWDON, D. J. and BOONE, M. E. (2007) A Leader's Framework for Decision Making, Harvard Business Review, November

SOSTE, L, WANG, Q J, ROBERTSON, D, CHAFFE, R, HANDLEY, S and WEI, Y (2015) Engendering stakeholder ownership in scenario planning. *Technological Forecasting and Social Change*, 91, 250–263.

VAN DER HEIJDEN, K A (1996) *Scenarios: The Art of Strategic Conversation*, Chichester, Wiley.

VAN ECK, P and PONISIO, L. IT Project Management from a Systems Thinking Perspective: A Position Paper. 3rd International Research Workshop on Information Technology Project Management (IRWITPM), 2008 Atlanta USA. 41–48.

VON BERTALANFFY, L (1968) *General System Theory: Foundations, Development, Applications*, New York, George Braziller.

YEO, K T (1993) Systems thinking and project management – time to reunite. *International Journal of Project Management*, 11, 111–117.

Appendix available online at: https://www.apm.org.uk/about-us/research/research-fund/2017-research-fund-studies/systems-thinking

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