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Bridging from Phenomenological Research Methods to Systems Interventions: A Case Study of SSM

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Abstract — *The development of systems practitioners at the doctoral level in Engineering has revealed the need to address the integration, or bridging, between the basic research methods of engineering management and systems problem structuring methods (PSMs). The metaphor of bridging is appropriate since this emergent need is not entirely addressed by the use of multimethodology. Whilst action research might be viewed implicitly as the research strategy* of *systems practice, sitting within the overall paradigm of phenomenology, we argue that basic research methods, in the broadest sense, require practical integration with PSMs in order to meet the needs of socio-technical systems research projects that span the boundary between engineered hard systems and social systems. Our observations arise from the experience of delivery of an Engineering Doctorate (EngD) in Systems Programme of research that now includes more than 65 individual projects with a wide range of engineering companies spanning the water industry, defence aerospace, energy production, rail transport and construction. In this paper we explore this need for integration with respect to the case of Checkland's Soft Systems Methodology (SSM), although the approach could have been applied to other PSMs. We conclude that integration in this case needs to focus on a number of key aspects across all stages of the SSM methodology. Prominent among these are widening the range of techniques for initial exploration of the problem situation, early consideration of potential ethical issues involved in system intervention, improved modelling approaches to describe purposeful activity holons, advanced hard systems modelling and longitudinal studies to capture learning from a series of sequential interventions, and active definition of additional detailed data gathering and research to support the stakeholder debate on initial intervention options.*

Keywords — *Research Strategy, Research Paradigm, Phenomenology, Action Research, Systems Practice, Problem Structuring Methods, Soft Systems Methodology, Multimethodology, Engineering Doctorate.*

1. Introduction

1.1. The EngD in Systems Programme

The Industrial Doctorate Centre (IDC) in Systems, a collaboration between the University of Bristol and the University of Bath, offers an Engineering Doctorate (EngD) in Systems Programme which is aimed at high-calibre engineers from graduate level to early/mid-career stage with the purpose of developing the systems-thinking capabilities of future leaders in industry. The portfolio of projects is diverse: >65 projects, and growing at ~12-15 per year, and involving >30 companies representing both Small and Medium-sized Enterprises (SMEs) and multinational companies; it spans industrial sectors including defence and aerospace, rail, transport, energy production, construction and the water industry. It comprises applications to product development, improvement of processes, methods and tools, and decision support; and the projects themselves seek to apply systems thinking to enhance performance and deliver better outcomes in areas such as safety, quality, sustainability, and innovation. Current teaching is based on methods drawn from disciplines spanning systems engineering, management, problem structuring and systems thinking, and seeks to integrate across them in order to meet both the specific needs of the projects and the necessity for appropriate academic rigour in doctoral level research. Pedagogic development itself is needs driven, based on feedback from Research Engineers and industrial partner organisations. In the early stages of teaching research methods, we introduce Research Engineers to the philosophical assumptions, paradigms and strategies associated with different research traditions from physical, applied and social sciences. All are potentially relevant when researching and intervening in complex socio-technical problems, and Research Engineers are challenged to develop ongoing reflective logs and action plans relating the application of these principles to the planning of their own research.

Research methods teaching is structured into two blocks taught at the beginning of the first and second years of the 4-year programme. The first component of research methods teaching provides a basis for Research Engineers to formulate their first draft research plan for their system and problem situation. The second component of research methods follows later in the programme and feeds into a unit on advanced systems with a view to achieving methodological and rigour. This bridges the step between the basic research methods and more developed approaches needed for systems interventions as exemplified by the use of Problem Structuring Methods (PSMs).

1.2. Purpose of the paper

This paper develops a perspective on, and discussion of, Checkland's Soft Systems Methodology (SSM) (Checkland, 2010, Checkland, 1999, Checkland and Scholes, 1999, Checkland and Poulter, 2006) and its use to plan and implement interventions in complex systems research. This is developed from the practical experience of the delivery of the EngD in Systems Programme. To achieve this, SSM is related and linked to the fundamental research methods teaching delivered on the EngD in Systems Programme and located within the framework we use there for defining an overall systems research philosophy and design strategy in a given problem situation.

2. METHOD

Our method is to use SSM as a case study for analysing how a typical systems PSM (Mingers and Rosenhead, 2001, Mingers and Rosenhead, 2004, Rosenhead, 1996, Mingers, 2011) relates to and can utilise fundamental research methods drawn from the phenomenological paradigm in the general area of business and management and engineering management research. SSM has its main applicability to pluralist/complex organisational situations and sits within the *interpretivist* stance according to Jackson's System Of Systems Methodologies (SoSM) framework (Jackson and Keys, 1984, Jackson, 2003, Jackson, 2000, Jackson, 1993).

Our results and personal reflections in this paper are based on experience of delivering research methods and PSM teaching to four cohorts of Research Engineers over the period 2006-10 and reviewing their reflective logs produced at an early stage in the programme. These logs require researchers to formulate their initial proposals for addressing their individual projects, including integration of basic research methods into any chosen PSM or systems methodology. The logs are formally assessed and are the basis of initial planning discussions with industrial sponsors and academic supervisors.

3. RATIONALE FOR TEACHING RESEARCH METHODS FOR ENGINEERS

The majority of systems engineering research sits within a positivist research tradition and there has been little evidence for explicit use of a *research method* or even an acknowledgement of stance in much of the published research that could be considered as originating from systems engineering (Brown, 2009). The nature of the EngD in Systems Programme is such that it should more correctly be viewed as applying systems approaches to contexts grounded in engineering, which encompasses systems engineering whilst broadening its coverage to projects based on engineering disciplines that would not normally be considered within systems engineering practice, such as civil engineering. However, once the engineering system, or hard system, under study encompasses elements of the social system around it, or in which it is embedded, then its behaviour will almost certainly be defined by human intentionality, and in this paper will be referred to as a socio-technical system.

Therefore, having moved beyond the study of hard systems, the study of any socio-technical system *must make explicit* its prevalent research paradigm, approaches and strategy. The socio-technical system *under study* needs further qualification too. Research may embody any or all of analysis, design and intervention. It is the last of these, intervention, which is the main focus of PSMs (White, 2009, White, 2006, Rosenhead, 1996, Mingers and Rosenhead, 2004, Eden and Ackermann, 2006) although of course intervention requires prior analysis and design. Typically, the literature on PSMs (including SSM) lacks discussion of how fundamental research methods and strategies should be incorporated to achieve the necessary *rigour* in Doctoral level systems research. Checkland (Checkland, 1999) also hints at this when discussing how the results from SSM should be "*recoverable*" by any outsider interested in critically scrutinising the work and following it to see if they agree or disagree with the findings. Therefore, the question of how to *bridge* between research methods and systems PSMs is quite specific to a researcher who is planning to use a PSM, such as SSM, as part of their research. We believe this needs to be done rigorously, and rigour here is meant to convey the practitioner's goal in trying to improve complex socio-technical systems performance and thus has very practical grounding – it is not mere academic baggage or formalism. We see this as underpinning the following requirements that are fundamental to achieving that goal:

1. Giving the best chance of getting the choice and implementation of an intervention *right first time*,
2. Ensuring the intervention is as robust as possible and *resilient* to changes and errors in assumptions,
3. Forming the best platform/data for optimal *learning* to e.g. improve on the processes of developing transitional objects such as purposeful activity models, and
4. Solving real problems in industrially relevant timescales, where investment in the extra time needed for *up-front* rigour should offer payback in terms of less time later e.g. optimal survey sampling and tight holon/model construction.

Checkland's SSM and other PSMs offer this *practical rigour* in a high level *process* sense, and SSM is perhaps the highpoint here, but the whole use of a PSM in an engineering research context is likely to fall down if this practical rigour does not integrate at a *lower* level in the individual steps, i.e. with use of appropriate research approach, strategies and methods.

4. OVERVIEW OF SOFT SYSTEMS METHODOLOGY

In broad terms, SSM can be characterised as action research with its own features and characteristics, strengths and weaknesses. If one chooses action research as a research *strategy* based on the model adapted from (Saunders, Lewis and Thornhill, 2006) shown in Figure 1, then SSM offers a *process* for tackling a problem situation, assuming the problem is of the class that SSM is suitable for.

SSM is thus an approach for implementing one of the basic research *strategies* available to systems researchers, whilst at the same time can be viewed as a PSM in its entirety. (Jackson,

2000) positions SSM clearly as appropriate for problem contexts that are plural/simple and plural/complex in the SoSM. It can be used alone where appropriate, or in conjunction with other PSMs (in whole or part) as a multimethodology strategy (Mingers, 2001). By itself it has the major strength that is offers a logical process for engaging all stakeholders and coming to an agreed initial action or intervention for improvement in any system, which accommodates different interest groups – rather that a blind trial with no rationale behind it.

4.1. The development of SSM

SSM was developed in response to difficulty in applying the systems engineering approaches used in traditional engineering and science problems (in hard physical systems) to business and organisational problems in human activity systems. The programme at Lancaster University was conceived from the very beginning as one of action research (Checkland, 2010). There was an early acknowledgement that the education process of the programme, its pedagogy, was characterised as "*learning by doing*" (Checkland and Jenkins, 1974). (Checkland and Holwell, 1998) discuss the validity of this approach.

The consequence of using an action research strategy from the outset allowed for a reflective critique the results from applying systems engineering techniques to "*(human) management situations*" (Checkland, 2010). They learned from the difficulties and failures and this led eventually to the development of what became SSM. Checkland in his reflections (*ibid*) draws attention to the *accountability* of the researcher in action research and that the

> *"…researchers are not outside observers of the situation being addressed but are accountable participants in it."*

This mirrors exactly the nature of the EngD Programme in Systems. The Research Engineers are *embedded* within the partnering organisation for ~75% of their overall time and accountable for the delivery of the project. The Engineering and Physical Sciences Research Council (EPSRC), as funders of the IDC, insist in the three-way contractual relationship between the organisation, the University, and the Research Engineer that he or she is treated *as if they were an employee of the company*. Each of the individual projects can be viewed as instances of action research, although until recently there was not an explicit acknowledgement that the overall programme itself is action research. This has recently been addressed by the Engineering

Systems Leadership (ESL) programme of research at the University of Bristol and the Systems Practice in Engineering (SPiE) project designed to synthesise across the EngD in Systems Programme and replicate the environment that Jenkins and Checkland achieved at Lancaster University.

(Jackson, 2000) characterises SSM as an approach that

> *"...gives pride of place to people, rather than technology, structure or organisation. Thus, its primary area of concern is perceptions, values, beliefs and interests and it accepts that multiple perceptions of reality exist and come into conflict."*

In this sense SSM can be viewed as a development from the systems movement to the seminal work of (Rittel and Webber, 1973) who gave the first persuasive account of "*wicked*" problems in complex socio-technical systems, although there has apparently never been an explicit acknowledgement from this source in the PSM literature but rather through the "*messes*" described by (Ackoff, 1981). Early papers on SSM started emerging around the time of Rittel and Weber's work but perhaps because the critical link was in the opposite direction, i.e. criticism directed towards OR (Rosenhead and Mingers, 2001), it was missed. Rittel and Webber pointed out strongly the deficiencies of the sequential engineering *hard systems* approach that involve precise objectives, control of variables and reductionist approaches to *wicked* human activity problems – for example urban planning, design and public policy making. In their paper, they go further and provocatively suggest that many/most of the problems and mistakes made in society, government and professional services have been caused by a misguided adherence to the *engineering* approach of hard systems thinking in social contexts where it has been shown not to work, e.g. RAND's Systems Analysis based approaches in New York City in the early 1970s described in (Rosenhead and Mingers, 2001).

For engineers recruited to the EngD in Systems Programme, the work of Rittel and Weber, and others such as (Conklin, 2001, Ackoff, 1981), is their first exposure to critiques that show that their research skills, developed in their first degrees and possibly through experience gained as practicing engineers, will not be enough to deal with the complexities of socio-technical systems. So it is really only since the 1970's that *hard systems* approaches to problem solving in complex systems have been recognised as being deficient, and engineers have been confronted with the need to understand and adopt an entirely different rationale to situations in which people are involved. There has been little written that adequately addresses this need although (Hitchins, 2007) does provide adequate coverage of soft systems methodology written from the systems engineering domain perspective. From the civil engineering domain, and in direct response to the Egan Report in 1998, (Blockley and Godfrey, 2000) provide a very practical approach which is based on a process based view of systems (Blockley, 1999).

Early experience of the SSM methodology was based on addressing high level system problems in a consultancy mode – company market development, reaping the benefit from IT, public policy making etc. It has been applied widely and developed significantly since – which has helped establish a body of knowledge and appreciation of its strengths and weaknesses.

4.2. Basic axioms of SSM

The difficulties encountered by engineers in grappling with SSM concepts following a predominantly hard systems training and education should not be underestimated. Feedback and reflective logs produced by our research engineers indicate the major realignment of their thinking required, the "*shock*" of finding their tried and trusted methods are deficient in complex situations and the time required to fully absorb the radically new thinking involved. With this in mind, we are continually searching for language and concepts to help accelerate learning and provide engineers with tools to discuss the ideas with industrial and other stakeholders. A good example of what we have found, and which we are building upon, is a set of suggested 'axioms' of SSM in a briefing note from Cambridge University Engineering Department (CUED, 2011):

1. Problems do not exist independent of human beings. They are constructs of an individual's mind and defined by their "*world view*" or Weltanschauung. So it is important to look at world-views as a basis for understanding any individual's statement of a problem. World views – different but equally valid interpretations of the real world can exist among individuals
2. The problem field is invariably messy – many potentially related problems and sub-problems can interact in any given system
3. Corollary of the first and second axioms – solutions to problems are also intellectual constructs and no problem exists 'in isolation'

4. Improvements and beneficial interventions in any system problem are most likely to come through sharing of perceptions, persuasion and debate.
5. Analysts/researchers/problem solvers should be "*interactive and therapeutic*", not expert. Furthermore, they cannot be divorced from the problem and they cannot act as objective "*outsiders*" as in engineering hard systems research

4.3. The basic (classical) SSM Method

SSM is not a *research method*, however it does provide a high level, overall thinking and engagement process which provides a process for bringing diverse human interests together and looking for sensible compromises on the way forward – but not necessarily consensus.

Figure 2 illustrates the 7 stage ' journey' in the application of the classical SSM approach in action research – as outlined by (Checkland, 1999).

Like many systems approaches, the heart of SSM is a comparison between the real-world as it is and some mental, conceptual, models of the world as appears in peoples' minds. Those involved are therefore required to move in and out of the real and the conceptual, systems thinking, world as they progress through the approach. Out of this comparison comes a better understanding of the real world system and ideas/options for improvement (interventions).

4.4. Later Developments in SSM

According to Checkland's comments in the retrospective section of (Checkland, 1999) the above seven stage SSM model has proved resilient and has a sequence which unfolds logically. However, as a result of practice and application experience in the years since its introduction in 1981, it was considered (around the early 1990s) to be no longer able to capture the flexible uses of SSM that were emerging.

This led to two later refinements and reformulations:

- **The 'Two Streams' model of SSM**. This placed increased emphasis on the two logical strands of analysis. Firstly, analysis based on the conceptual models of stakeholders to surface ideas for systems interventions. Secondly, a cultural and political strand to enable judgements about accommodating different world-views and agreeing an acceptable intervention on this basis.

- **The 'Four Main Activity' Model of SSM**. This is seen as the current contemporary form of SSM and subsumes the seven stage model into an (implied) set of four activities

    a. Finding out about a problem situation, including culturally/politically

    b. Formulating relevant 'purposeful activity' models

    c. Debate, using the above models, to identify a) desirable and culturally feasible action/change which would improve the situation and b) accommodation between conflicting interests which enables action/change to be taken

    d. Taking action in the problem situation to bring about improvement

The following discussion is appropriate to activities within both the original (classical) version of SSM and later, contemporary versions.

5. THE RESEARCH PARADIGM ASSOCIATED WITH SSM

In teaching basic research methods on the EngD in Systems Programme we introduce the paradigms, strategies, concepts and techniques utilised in typical business and management research (Hussey and Hussey, 1997, Saunders, Lewis and Thornhill, 2006). The two pure research paradigms dominating this literature are positivism and phenomenology. These are defined in terms of the five underlying philosophical research assumptions as shown in Table 1.

PHILOSOPHICAL ASSUMPTION	POSITIVISM	PHENOMENOLOGY
Ontological assumption (the nature of reality)	Reality is objective and singular, separate from the researcher	Reality is subjective and multiple, as seen by different stakeholders
Epistemological assumption (what constitutes valid knowledge)	Researcher is independent of that being researched	Researcher interacts with that being researched
Axiological assumption (the role of values)	Research is value free and unbiased	Researcher acknowledges that research is value-laden and biases are always present

Rhetorical assumption (the language of research)	Researcher writes in a formal 'professional' independent style, uses the passive voice, accepted quantitative words and precise definitions	Researcher writes in an informal style, uses the personal voice and conveys the idea that they have 'interacted' with and are part of the research. Accepted qualitative terms are used and limited definitions.
Methodological assumption (the process of research)	Process is deductive Study of cause and effect Static design Categories defined and isolated beforehand Research is context free Generalisations lead to prediction, explanation and understanding	Process in inductive Study of mutual, simultaneous shaping of factors Emergent design Categories identified during the process Research is context bound Patterns and theories are developed for understanding

Table 1. Comparison of philosophical assumptions for positivistic and phenomenological research. Adapted from (Collis and Hussey, 2009).

It is important, in this context, to distinguish between different uses of the word *paradigm*. Here we are concerned with the technical research meaning provided by (Kuhn, 1962) and discussed by (Jackson, 2003). The word paradigm in this context refers to a tradition of research regarded as authoritative by a particular scientific community – for example pure science, applied science or social science. It is the set of ideas, assumptions and beliefs that shape and guide that scientific research activity. In contrast to this, workers involved in the development of systems PSMs are often concerned with wider *sociological paradigms* – in order to assist managers in trying to improve the operations, services or organisations they manage (Burrell and Morgan, 1979, Alvesson and Deetz, 2000). Typical sociological paradigms discussed in this context (Jackson, 1993) include functionalist, interpretive, emancipatory and post-modern. We are not concerned directly with these here although we do note Checkland's view of equating the objective/positivistic philosophical position with the functionalist sociological stance, and equating the phenomenological research methods with the interpretivist (Checkland, 2006). In particular, the ontological, epistemological and axiological assumptions are strongly and classically phenomenological. In SSM:

- Reality is subjective and is accepted to be seen differently by different individuals
- The researcher is part of that being researched and cannot be divorced from the problem situation
- The negotiations and the whole process is value laden, and
- Research structure emerges during the process. However, in terms of the methodological assumptions – the philosophical basis of the approach starts inductively but can easily switch to a more deductive stance later on. This is an example of synthesis and mixing of paradigms in real world research.

Thus, the application of business research methods within an SSM approach will almost certainly rest strongly on a phenomenological research tradition and perspective. With this in mind it is useful to emphasise the typical characteristics of phenomenological research outcomes in terms of the basic measures of research *quality* – reliability, validity and generalisability. Results from an SSM approach cannot be said to be highly reliable– in the sense that another team addressing the same problem would be likely to come up with different models, analyses, proposed changes and actions to improve. On the other hand, an SSM approach is highly valid – in the sense that it provides an opportunity to appreciate the real richness and complexity of the particular situation being examined and actions emerge based on this. The results from an SSM approach in one situation or setting are unlikely to be generalisable to another situation or setting without thought and/or more modelling and debate.

In any systems research project that intends to utilise SSM, it would be crucial to discuss and come to a clear understanding of these matters among all parties. This is particularly the case when Research Engineers on the EngD in Systems Programme may need to engage with managers and other stakeholders who are not fully aware the above concepts. Such individuals may implicitly assume that doctoral level research based on SSM will deliver highly reliable, valid and generalisable outcomes and interventions.

The various stakeholders and involved parties are given particular names in SSM – partly to try and differentiate their possible contributions and partly reflecting the initial *consultancy* focus of the approach. For example, Client, Actors, Problem Owner and Consultant/facilitator.

Some of these roles often overlap. Stakeholder listing and analysis is probably a sensible way of identifying these roles and individuals and agreeing who is playing what. One question facing a Research Engineer is whether he/she has the skills, experience and status to be an SSM facilitator within their organisation.

6. DISCUSSION

Since SSM is essentially a high-level overall thinking and engagement model, embedding of academic rigour within it (for a Doctoral level research project) requires careful selection, justification and application of detailed research methods, tools and concepts in the various stages, and maybe some flexibility/adaptation of the overall methodology.

To illustrate this, we have framed our discussion in terms of the contemporary 4 main activity model of SSM described in §4.4 and selected examples of research concepts and tools which are taught in the EngD in Systems Programme in the following 4 subsections. Further reflections on research methods teaching is given in (Yearworth, Edwards and Rosenberg, 2011) and on the role of systems supervision, an essential component in the delivery of the programme, in (Yearworth, 2011).

6.1. Problem Space Investigation

The first stage activity of SSM involves interactive, relatively unstructured investigation of the problem situation and the rich picture approach (pictures without rules) is promoted as a key tool. However, with the ideas presented in §3, a range of other creative, unstructured or semi-structured approaches are also available – see Table 2. For example, the use of metaphors and analogy can be injected to support/replace rich picture diagramming and improve communication of understanding to all involved. Formal stakeholder mapping and analysis in various dimensions (e.g. power, influence, interest, location) and PESTEL techniques can also be important to develop understanding of the cultural/political environment associated with the problem situation.

PROBLEM SITUATIONS SOME INVESTIGATION TECHNIQUES	
Rational	**Creative**
System/influence diagram	Rich pictures
Preliminary literature review	Metaphors and analogy
Interviews	5WH group questioning
Critical incident analysis	Brainstorming
Morphological analysis	Focus groups
Relevance system diagrams	Lateral thinking (De Bono)
Cognitive mapping	Delphi method
Ishikawa diagrams	Quality circles
Preliminary modelling	Cross professional learning
Preliminary data analysis	Future state visioning
Stakeholder analysis	

Table 2. Comparison of rational and creative investigation techniques. Adapted from (Saunders, Lewis and Thornhill, 2006).

(Checkland and Poulter, 2006) also acknowledges the need for additional frameworks and approaches to support rich picture building in his latest contemporary account of SSM main Activity 1. These can involve examination of proposed interventions and problem owners (as a way of further understanding the problem situation) and a framework for formal social and political analysis.

Examination of the concepts in Figure 1 suggests other possibilities also, particularly the idea of introducing other formal research strategies at this stage, if time allows, to integrate with the overall SSM/Action Research approach. Obvious possibilities include ethnographic strategies - to develop in depth understanding of inner workings of organisational systems and the cultural and political norms involved. Surveys, field experiments and grounded theory may also be considered. The question of available time could be important, however, and could limit the options. Longitudinal research studies to obtain a first understanding of dynamically changing problem situations may also be of importance. Ethnographical approaches have been use in a number of EngD projects so far.

Planned literature review and scoping/planning such reviews to understand what others have found out in similar problem settings is a crucial initial research tool in this stage. Skills in scoping, planning, recording and critical reading are taught on the EngD, as they are central to this.

It is in these early stages of problem space investigation that ethical questions and issues may arise that need further consideration at later points – see below.

6.2. Formulating relevant purposeful activity models

We cover *modelling* in the taught component of the EngD in Systems Programme to allow Research Engineers to access various modelling concepts in line with the research approach adopted and PSM chosen. The discussion below relates to our views and questions about purposeful activity modelling in the SSM approach and how modelling strategies might be extended.

Building purposeful activity models in SSM is not the same as *conventional* modelling - which engineers have traditionally used for years in hard systems work. We need therefore to take great care in our teaching of modelling as part of the research methods training – to embed ideas of what purposeful activity modelling means in SSM – but also how it may or may not relate to other modelling activities with which engineers are more familiar. Purposeful activity modelling is not an easy concept for engineers to absorb. The following covers some key points as they are emerging in internal debates and teaching of Research Engineers involved in working within socio-technical systems. The key point made by (Checkland, 1999) is that SSM modelling is not like hard scientific or operational research approaches – where a model is an attempted representation of some part of the real world which could conceptually be *validated* and maybe used in some predictive sense. SSM purposeful activity models are *intellectual devices* in the mind of an observer, based on a particular world-view, aimed at triggering/structuring debate about the problem situation. They do not attempt to model any aspect of the real world system. They are more like idealistic (theoretically correct?) representations of how a defined "*purposeful activity"* might be pursued in an ideal system – depending upon the world-view of the observer. They are therefore "*personal accounts*" of how the "*work should work*" to achieve a defined purpose (not how it *actually* works), aimed at stimulating, feeding and structuring debate about potential actions to improve.

Because of the confusion that the original purposeful activity wording/idea has caused – Checkland finishes by preferring the word "*holon*" (Checkland, 1999).

The detailed processes and recommendations for building purposeful activity models/holons are well documented together with a number of pitfalls based on implementation experience. For example, forcing the model's system boundary to coincide with real world organizational boundaries is a well-known mistake since organizations carry out many purposeful activities not mirrored by organizational boundaries.

Generally, from reading the various accounts, our view is that it may be useful for engineers to consider a holon or purposeful activity model to be more or less equivalent to the better-known concept of an idealized organizational or *business process*. Checkland's discussion strongly suggests this, a purposeful activity model must cover a set of purposeful activities (around 7±2) which link together to describe the observer's view of i) how input (I) is obtained for the process ii) how it is transformed (T), and iii) how the output (O) is dispensed with or handed over internally (to another holon?).

The question arises – how to represent such a model or process? The suggested approach (Checkland, 1999) is effectively as a system influence diagram (although Checkland does not refer to it as such), which considers activities as "*system elements*" and shows dependencies and *precedences* between these. Thus, the holon shows those that are independent (can be done first e.g. to generate input) and those that are dependent on others. We find this concept to be a useful and necessary link to bridge to our teaching of general systems concepts. The system influence diagram then indicates the journey through the activities to produce the output and monitor/control it. An example is shown below.

With this understanding of a purposeful activity model (holon), our view is that the system influence diagram suggested by Checkland is only one of a range of possible ways of representing the holon. Other candidate techniques, again perhaps more familiar to engineers, include process mapping tools, process flow charts, activity flow diagrams and project network charts. We also therefore encourage different approaches drawn from these different knowledge areas. The philosophy is that any representation of the holon, using any coherent approach with which the analysts feel comfortable, is useful so long as it stimulates debate on possible improvement actions.

However, we are treading cautiously here - there appears to be an implied reluctance (silence) in the SSM literature to consider other such modelling techniques for representing purposeful activities/holons. Possibly this is because many of are traditionally associated with hard system approaches which try to model the *real world* and are thus firmly rooted in a functionalist paradigm. However, because many such techniques have multiple uses, this seems to be a limit to creativity and we encourage the broadest thinking on options for purposeful activity model building.

Finally, we are engaging with the question of when or if other, even *harder*, more advanced modelling strategies have a place in SSM. By this we mean things like causal loop modelling, systems dynamics modelling (Forrester, 2007, Forrester, 1958, Sterman, 2001, Sterman, 2000), mathematical modelling using MATLAB (Chaturvedi, 2009), Hierarchical Process Modelling grounded in Interval Probability Theory (Marashi and Davis, 2006, Marashi and Davis, 2005, Marashi and Davis, 2004, Hall, Blockley and Davis, 1998, Davis, MacDonald and White, 2010), and black box input/output coherence analysis (Bendat and Piersol, 1986). There are many others. This debate is also not prominent in the SSM literature – possibly because such modelling is based strongly on functionalist, hard systems, real-world thinking which attempts to model the behaviour and response of actual systems. Although (Checkland, 2010) does talk about the "*soft*" approach not throwing away the "*hard*" thinking but *subsuming* it as a special case within the broader approach.

(Jackson, 2003) argues strongly against modelling approaches from the functionalist paradigm straying into soft-systems territory. For example stating that in the case of system dynamics that it risks "*becoming an under-theorised soft systems methodology*". However, (Lane and Oliva, 1998) argue, convincingly we believe, that a "*synthesis*" of system dynamics and SSM brings "*dynamic coherence*" to SSM. However, they do draw attention to the need for theoretical consistency. We could generalise this need for *careful* synthesis to hierarchical process modelling to bring *risk and uncertainty coherence* to a PSM and so on.

The issue is partially tackled by the idea of multimethodology (Mingers, 2001, Taket and White, 1998) although the integration here is of problem structuring methods, or parts of these methods, and not the focus here of integrating *research* methods and PSMs. However (Mingers, 2001) talks of intervention as a process and usefully provides a description of 4-phases that are important at different points in time (Appreciate, Analyse, Assess and Act). This idea is summarised in Figure 3.

It is the Appreciation phase in Mingers schema that most closely overlaps with the process of using research methods we discuss in this paper. However, it is our emphasis on rigour and the necessity for integration across research methods from a very broad perspective that distinguishes the focus of this paper from multimethodology. We also assert that appropriate longitudinal studies need to be integrated too in order to provide the necessary framework for measurement. Thus whilst Figure 3 provides a useful schema with the explicit representation of time it still presents a *one shot* view of intervention. We believe that an iterative approach needs to be made explicit and that the action research spiral of (Kemmis and McTaggart, 2000) shown in Figure 4 provides a better conceptualisation of time.

This has led us to a propose a synthesis of (Kemmis and McTaggart, 2000) and (Mingers, 2001) structured around the use of purposeful activity models as a summarising schema for our work and is shown in .

In this context, we are currently engaging Research Engineers and ourselves with three questions to help in moving this discussion forward as follows:

1. Any purposeful activity model, although not representing the real world, cannot be developed in a vacuum and must presumably draw on the observer's experience of the real world – and maybe *best practices* experienced elsewhere or enshrined in codes, procedures etc. So, to some extent the PA/holon must have elements of real world thinking within it – and represent (possibly) a real world existing in another setting?
2. Any agreed action to improve as a result of an SSM study has the intention of drawing the idealized purposeful activity model and real world system closer together?
3. Bearing in mind that any initial action from an SSM study is likely to be the first in a *roller coaster*, or spiral, journey towards a solution involving several

sequential interventions (particularly in a dynamic system) - some way of *capturing* the learning from the outcomes of these sequential interventions – to inform debate about the next phase would seem important. In other words, do we not need also to emphasise the continual learning and adaptation function of modelling to capture new knowledge as it emerges after interventions? A need similar to this is described by (Mingers, 2001) where he describes approaches to partitioning and decomposing methodologies.

6.3. Debate on the preferred intervention option.

In the third stage of SSM, the decision on which change or intervention option is to implemented and getting "*permission to move*" is presented as being based mainly on "*debate and negotiation*" – hence the frequent emphasis on developing skills such as principled negotiation (Fisher and Ury, 1981).

But more detailed research and data gathering/analysis may be needed at that point also – e.g. using ethnographic, grounded theory or survey strategies to gather and interpret more facts within the problem setting, inform the debate and where necessary help individuals to adjust world views based on facts and new appreciations of reality. Thus, understanding of when to trigger additional research in the later stages and the ability to negotiate and convince others of the benefits of the extra time needed (to better inform the debate) are crucial.

If undertaken, additional research should adopt appropriately sound and rigorous ways of gathering and analysing (mainly) qualitative data. Techniques and skills in e.g. questionnaire development, interview planning and design of focus groups are central to this and covered in our research methods teaching. Following this, the skills in qualitative data analysis such as computer methods, content analysis and discourse analysis of interview transcripts are required in order to objectively inform the debate.

During this stage – a basic model for considering ethics when considering interventions is also required – in order for the chosen one to be fully "*desirable and culturally feasible*". Classical SSM does not give high prominence to ethical considerations although the words in main activity C could be taken to imply this. A full understanding of ethics frameworks and managing decision-making, change and intervention in such situations is important. Ethical matters can involve harm, consent, privacy, confidentiality etc. and decisions may need to align with the ethical framework of a University, Company or sponsoring organisation as well as individual stakeholders.

Since SSM is action research, understanding and managing the potential downside (risk) of any planned intervention in a complex system is a crucial aspect at this stage also - which is often not given sufficient prominence. In broad terms, and using the Cynefin framework of (Kurtz and Snowden, 2003) as a framing device, the risk can be associated with driving the real system/problem situation from the complex into the *chaotic* region of the complex problem space. Risk identification and management techniques, including slowing down, limiting or excluding otherwise acceptable interventions in the final stage are important.

6.4. Taking action in the problem situation to bring about improvement

Here, the idea that a complex wicked problem is never *solved* – but continually *resolved* is important. In other words, the concept that a single intervention will represent the ultimate solution in a complex problem situation does not often accord with reality. In this case need for appropriate performance measurements is apparent together with the necessary longitudinal studies – especially if the project is to be handed on to the next researcher. Given that system boundaries are always open to investigation it is important that some degree of consistency in the definition and measurement of meaningful performance indicators is ensured.

The research journey in addressing complex problems as discussed in §3 and addressed in our research methods teaching is portrayed in Figure 6 using the original Rittel and Webber concept (later taken up by (Conklin, 2001)) that problems are never solved, but continually re-solved in a roller coaster sense by trialling successive solutions and learning at each stage.

SSM – as presented above – does not emphasise this (often required) cycling aspect after the first intervention - and the need for models to be developed which allow learning at each stage based on data gathered after an intervention. In fact, SSM sometimes encourages something of a *one shot* picture. This partly reflects its consultancy background. This cycling aspect of SSM needs careful discussion since it may take the full project beyond the duration of a typical EngD research project - without the problem having been addressed satisfactorily.

6.5. Summary

Based on these 4 strands of discussion we can see that there is a clear need to support the use of SSM with rigorously selected and applied basic research tools for them to meet the needs of the EngD in Systems Programme, given the scope of the projects at the socio-technical boundary and grounding in engineering. We put forward the idea that SSM may well be equally capable of identifying desired interventions/changes in hard systems (engineering artefacts, products etc.) as well as human activity systems (organisational arrangements, work processes etc.) and that this is a message to take back into the *traditional* systems engineering community for further examination. The skills training of engineers also needs to be examined. If SSM is to be applied in an EngD in Systems research project, can the researcher realistically be trained to be and/or act as the *facilitator* as well as a contributor to the process?

The contribution of diverse modelling approaches needs to be examined. Is CATWOE enough as a basis for checking the quality of a conceptual model and root definition of a system? Should a more detailed and *learning-based* check be used – for example inclusion of system inputs/outputs, and system categorisation according to the archetypes from general systems theory? In other words, do we need a better steer nowadays for developing the best conceptual models and root definitions?

Many cycles of SSM may be needed in a real world situation to move to an *acceptable* solution to a wicked problem. Should we emphasise this more in our teaching of the classical SSM method and what sort of implications might this have for a real research project e.g. is identification of the first action or intervention alone and implementation of this enough in a research project? This may not satisfy the industrial sponsor of the project.

We believe that it is crucial to base the identification and selection of the preferred intervention in the later stages of a project on appropriate rigorous research as well as informed debate. More detailed research (under both phenomenological and positivistic paradigms – survey, experiment, ethnography) may be needed in the later stages to inform such a debate. Otherwise this may take the form of a highly biased choice driven by seniority, politics and dominant personalities and hierarchies? The basic SSM approach is lacking in that it can ignore questions of power and hierarchy among actors. And the researcher may well be too junior to handle the process. The question of how emancipatory approaches might be used within the programme is still completely open.

How should a Research Engineer develop an appreciation of and manage the risks involved in any first trial intervention resulting from SSM? How do we cover this in our teaching and give researchers an appropriate toolkit? Should it be part of managing change? The same is also true for ethical considerations.

Implementation of an agreed intervention resulting from SSM can often involve a major project in its own right – based more on hard systems methodologies and agreed objectives/measures etc. and subsequent performance measurement/management. This demands different skills and may take too long beyond the timescale of an EngD in Systems research project? If a researcher takes on a fully blown SSM strategy, should they be encouraged to stop at the point where an intervention is agreed and a performance measurement plan is developed?

To traditional engineering managers, SSM can come across as open ended and difficult to manage – and unlikely to be judged a complete success or complete failure. Also, it is often presented as a process where the human interactions and debate are as, or more, important than the result. How do we portray it to avoid this type of view?

If implementing and managing the introduction of an intervention resulting from SSM, the principles of change management are crucial to engage with – since successful change management is way for the intervention to result in outcomes that then result in the envisaged benefits. So outcomes and benefits modelling are important as a part of change management. But leading and managing change *during* an SSM process is arguably equally important and relates to the skills and background of the facilitator/consultant. For example, helping change world-views of the actors and supporting update and change of mental models. Do we cover this appropriately in our teaching?

Since SSM is a phenomenological research strategy, it aligns with all such strategies in terms of being highly valid, but low on reliability and producing results which are normally difficult to generalise to other settings. How do we ensure this aspect is fully understood by industrialists with a strong engineering focus?

7. Conclusions

Integration of appropriate basic research methods and tools into the SSM Problem Structuring Method is important from the viewpoint of academic requirements in Doctoral level engineering systems research. But equally importantly, integration is valuable from a practitioner viewpoint in a socio-technical engineering context order that a system intervention resulting from SSM can be fully justified and is evidence-based, the logic is recoverable by others and a robust platform is created for any subsequent interventions and sequential action learning.

In this context, our view is that integration needs to focus on the following points:

- Active use of the widest range of techniques and tools for initial investigation of a complex socio-technical problem situation, covering both rational and creative approaches
- Early definition and consideration of a suitable ethics framework and ethical questions that may need addressing to effectively manage decision making, change and intervention for it to desirable and culturally feasible
- Careful consideration of the most effective approaches for creating root definitions and representations of purposeful activity models (holons) in order to stimulate debate in an engineering culture on beneficial changes or interventions in the system
- Broadening the concept of modelling to include the progressive synthesis of harder, more advanced predictive modelling approaches, most commonly used under a functionalist paradigm, to capture learning and new knowledge
- The potential need for additional detailed research and data gathering at the point where initial intervention options are being debated, in order to inform the debate and underpin principled negotiation
- Application of appropriate tools and processes for understanding, and managing the potential downside risk of any planned intervention, guarding against system performance deterioration and/or increased chaotic aspects

- The need for modelling approaches to be capable of capturing learning arising from *roller-coaster* type journeys towards a solution involving cycles of sequential interventions, a *spiral*
- The need for appropriate and consistent system performance measurements or metrics to be defined together with longitudinal studies to measure improvement and benefits
- Ensuring all stakeholders are fully aware of the relationship between outcomes from SSM and any later change processes which must be completed in order for outcomes to be translated into improvements and benefits
- Clarifying, particularly in the 'hard' culture of an engineering organisation, the fact that SSM can give highly valid results, but generally these are relatively unreliable and difficult to generalise to other systems or settings

8. Acknowledgements

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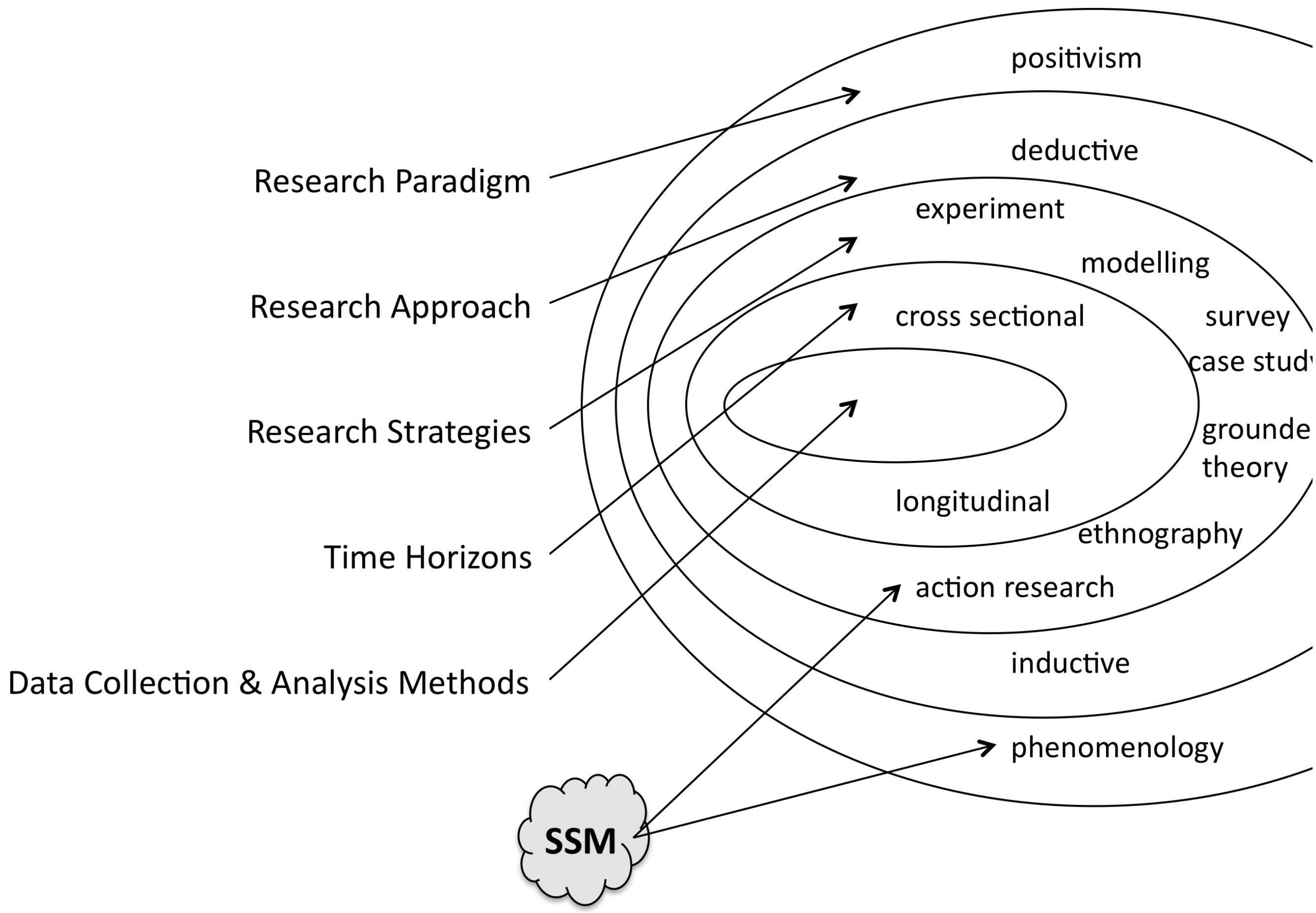
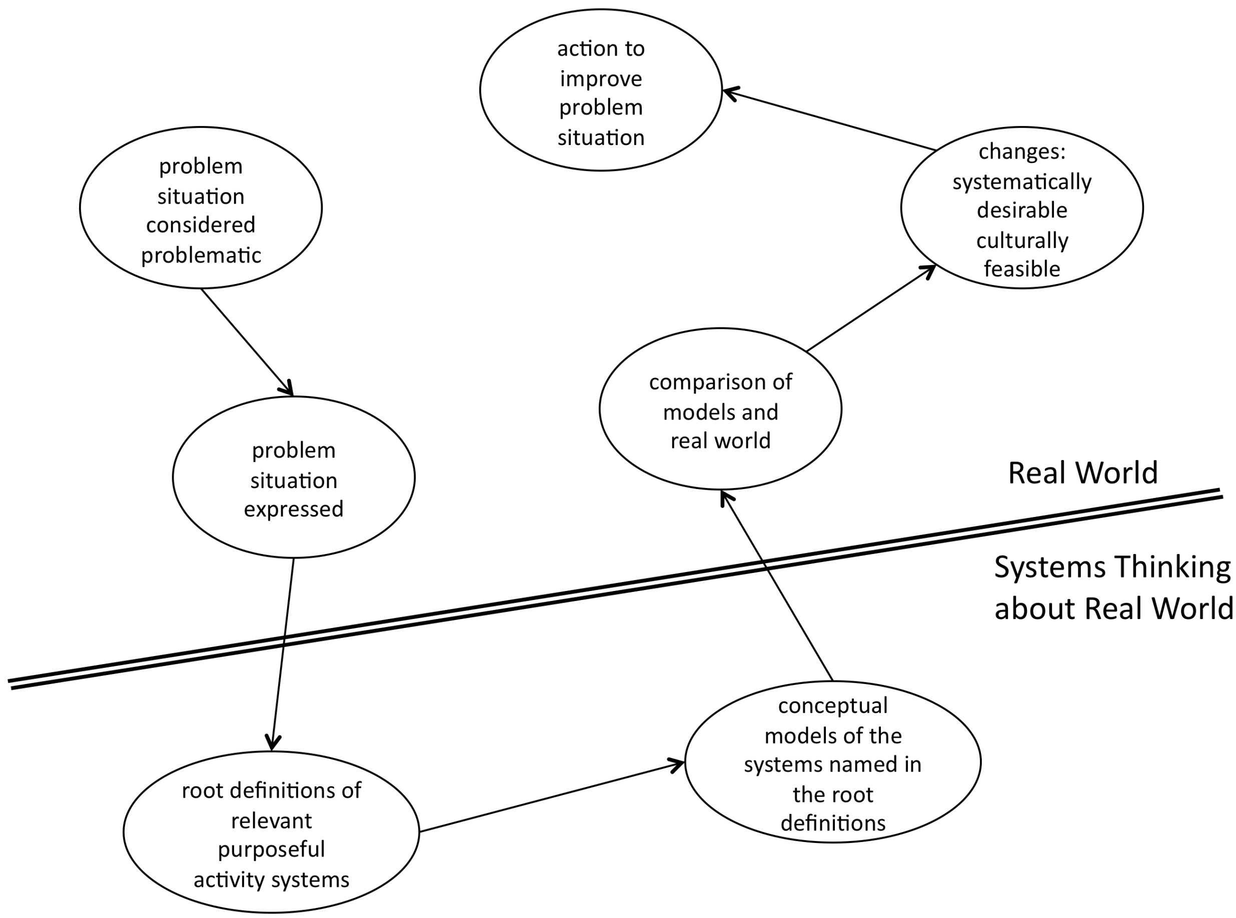


Figure 1. Classification of research methods – the research process "*onion*" – adapted from (Sa Thornhill, 2006).



STAGE 1. Examining the real problem situation/system in an unstructured way

STAGE 2. Presenting and analysing the real problem situation

STAGE 3. Developing relevant 'theoretical' or 'ideal' systems and constructing root definitions of these using CATWOE checklist

STAGE 4. Developing conceptual models of the ideal systems

STAGE 5. Comparing ideal system models with reality and the real world situation

STAGE 6. Developing proposals for changes and/or interventions in the real system

STAGE 7. Introducing the agreed changes/interventions in the real system

Figure 2. Schema for *classic* SSM adapted from (Checkland, 1999)

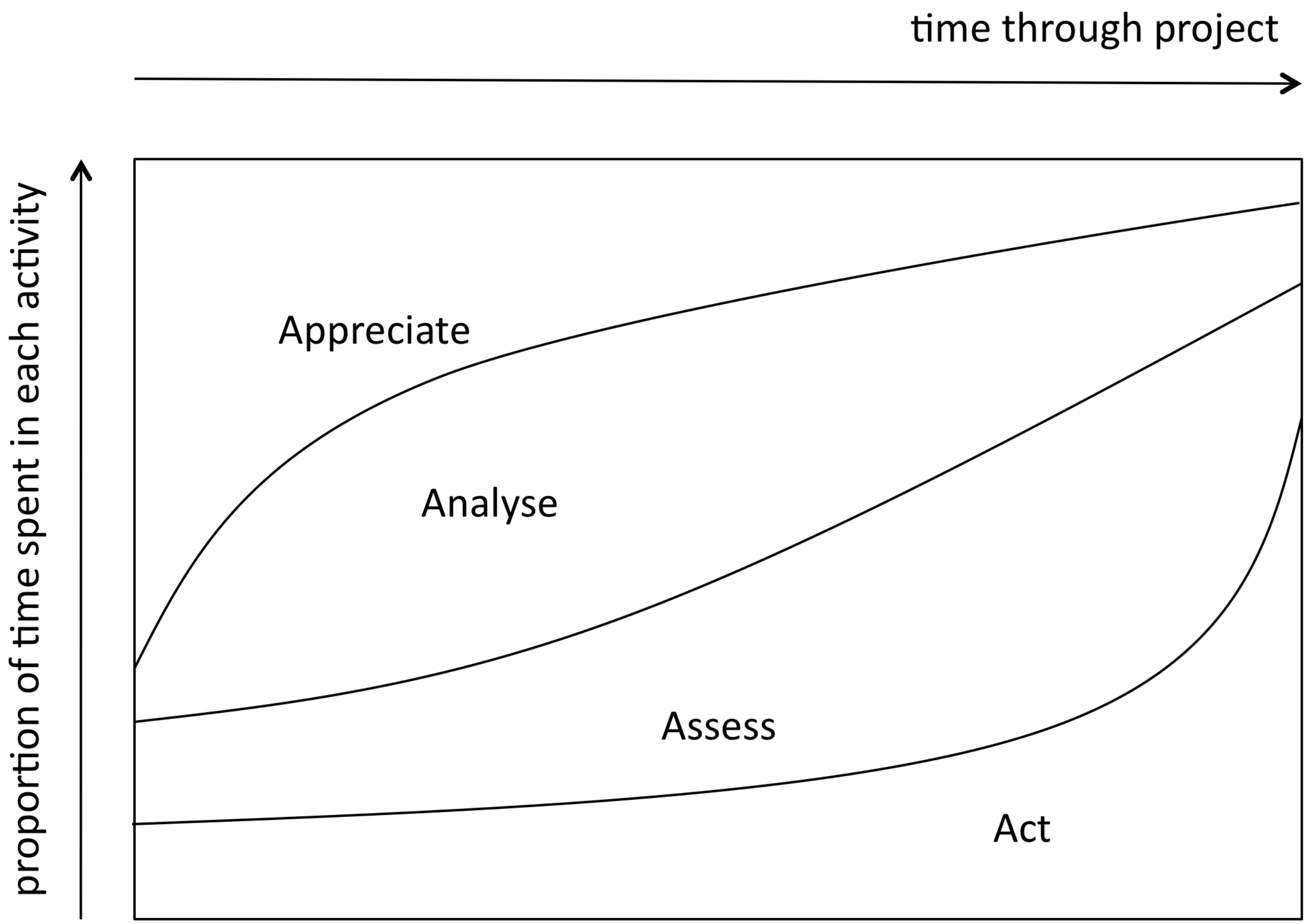


Figure 3. Phases of PSM intervention adapted from (Mingers, 2001).

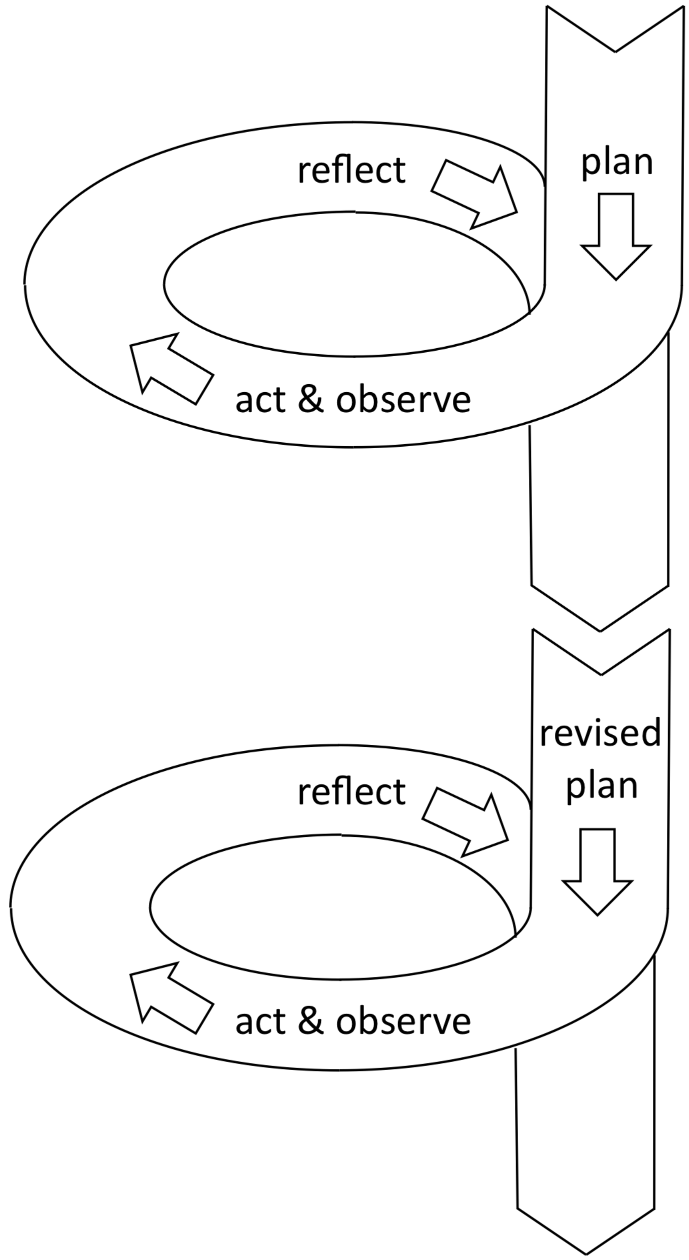


Figure 4. The Action Research Spiral adapted from (Kemmis and McTaggart, 2000).

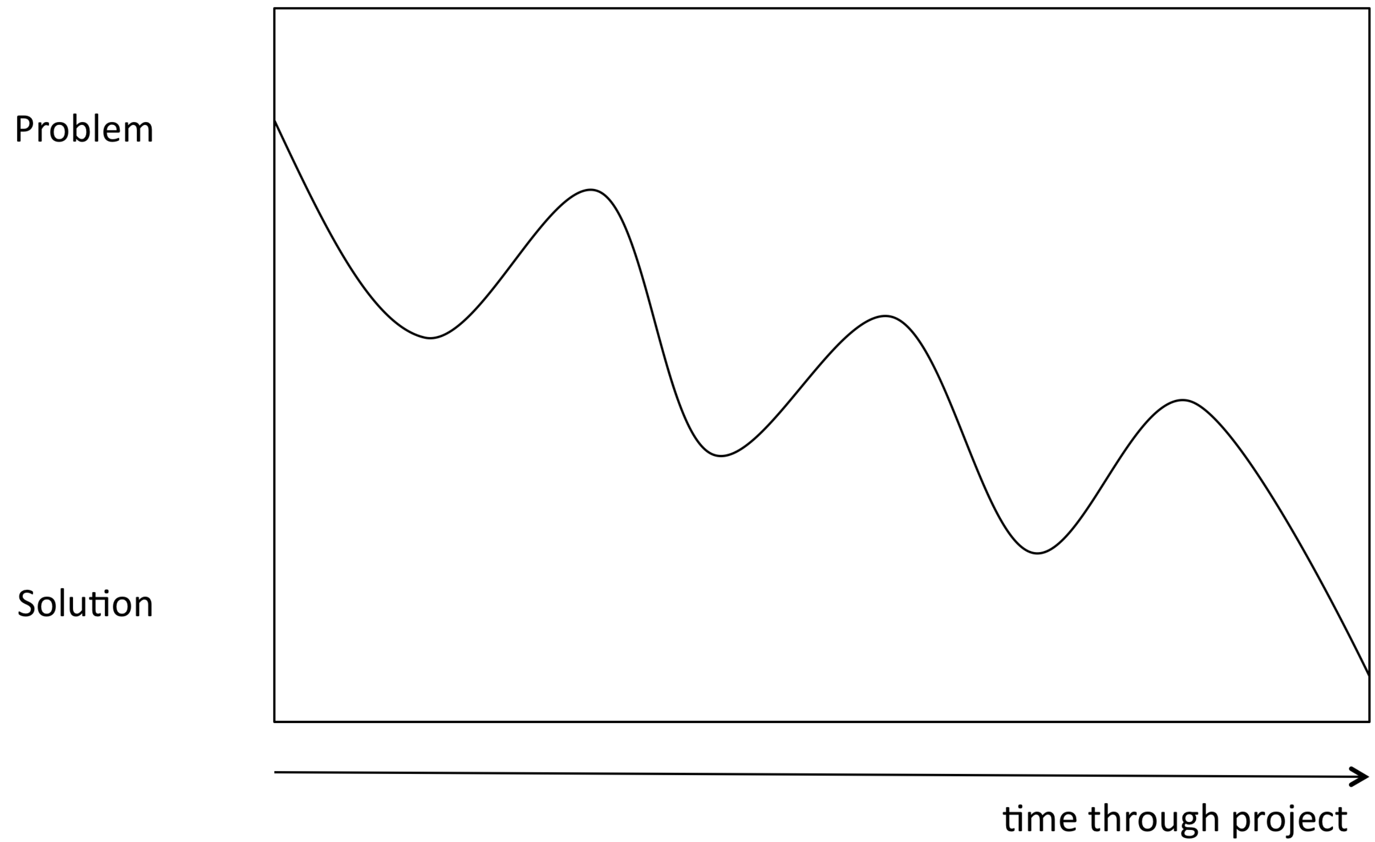


Figure 6. Converging on a solution – the "*roller-coaster*" journey – adapted from (Rittel and Webber, 1973).

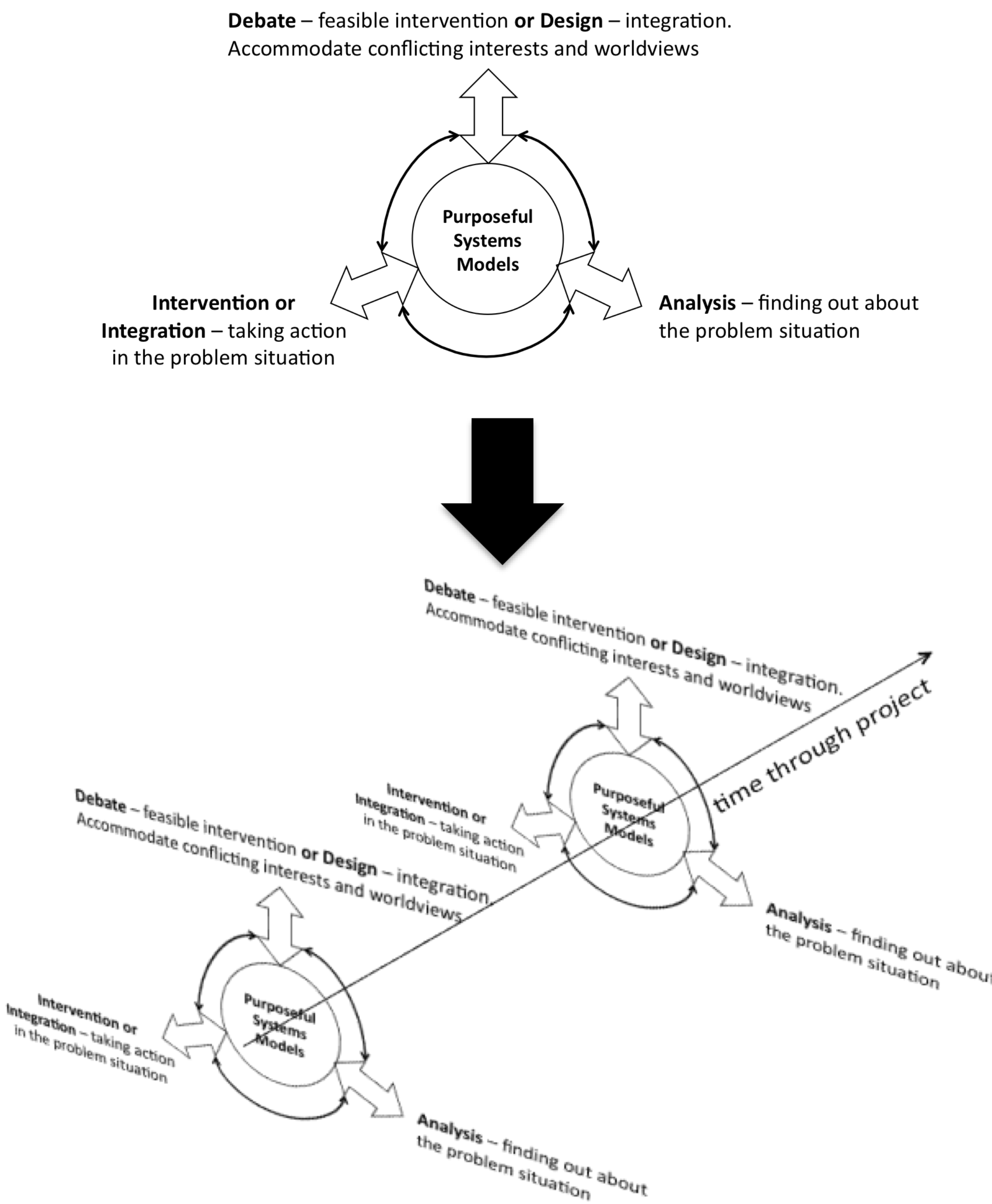


Figure 5. Proposed schema for research method and PSM integration based on an integration of ideas from (Rittel and Webber, 1973, Mingers, 2001, Checkland, 1999, Kemmis and McTaggart, 2000) and needs of the Systems Practice in Engineering (SPiE) project.

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