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MAKING SURE YOU TACKLE THE RIGHT PROBLEM: LINKING HARD AND SOFT METHODS IN SIMULATION PRACTICE

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ABSTRACT

As well as knowledge of computing, statistics and modelling, a successful simulation analyst needs to develop ways to understand the important features of an application domain. The last two decades have seen the increasing use of 'soft' approaches to help analysts structure the problems they are asked to tackle. The idea is to help ensure that the right problem is tackled. The complementary use of these problem structuring approaches with the technical side of computer simulation offers the prospect of better simulation practice. This advanced tutorial introduces some of these structuring approaches and discusses how they can be used in simulation projects, paying attention to the different ways in which simulation models are used.

1 INTRODUCTION

The programme for this and previous Winter Simulation Conferences covers a very wide range of topics and it is probably impossible for any one person to master everything. Given the 50 year history of research, development and simulation practice, this is hardly surprising. What skill-set is needed for simulation practice? The WSC programmes reveal three technical domains in competence are needed.

- **Modelling**: extracting the relevant parts of a system of interest and representing them, appropriately, within a simulation model. This is a skill that develops though practice and requires the analyst to take a systems viewpoint. Thus this conference includes modelling methodology tracks and appropriate tutorials.
- **Statistical methods**: most discrete event simulations include stochastic behaviour that is represented by sampling from appropriate probability distributions. Thus the modeller needs to know which distributions are appropriate, how they should be represented in the model and how to analyse the resulting behaviour of the simulation. Thus this conference includes analysis methodology tracks and appropriate tutorials.
- **Computing**: though it is possible to build a simple simulation model with little or no computing knowledge or experience, it soon becomes apparent that it helps to know much more than which button to press. Knowing how the simulation program or package works, is a great help in developing simulations that are accurate and run fast enough for proper use. Thus, this conference includes sessions in which simulation software vendors describe their products, at which users can raise particular issues and other sessions in which speakers look under the hood at the inner workings.

It is also clear that successful simulation requires the analyst to understand the application domain within which the work is being conducted, be it manufacturing, health care, aerospace, criminal justice or another domain. That is, the analyst needs to take her understanding of modelling, statistics and computing and bring them to bear in an application domain. Hence, this conference includes multiple application tracks in which authors discuss successes, failures, challenges and technical underpinnings. All of us will have experienced the confusion of working in a new domain in which we were unsure what level of detail was required and what should be included or excluded from the modelling. Obviously, this becomes easier with experience, as the analyst learns which features are important in the domain. However, there is also a danger that an analyst with long experience in an application domain starts to take things for granted that, later, turn out to be important.

1.1 Complementarity

This suggests that there is a need for approaches to help someone new to a problem domain to get to grips with its important features and a similar need for approaches that help prevent the experienced from becoming over-confident. Clearly, there is no silver bullet that will guar-

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antee this, but there are approaches that are intended to help an analyst tease out the important features of a problem situation. The approaches appeared in the OR/MS community in the UK and Europe and are sometimes known as 'soft OR' or as 'problem structuring methods' (Rosenhead and Mingers, 2001). The use of the adjective 'soft' is, perhaps, unfortunate, since it may carry the idea of trivial or simple and this is far from the case. The term 'soft' seems to have become popular following Checkland and his development of soft systems methodology, an approach which will be described later in this paper.

1.2 Problem Structuring

The term 'problem structuring' carries two different meanings. The first is the idea that there are 'wicked problems' (Rittel and Webber, 1973) characterised by clashing objectives, shortage of data, multiple stakeholders who have very different opinions from stakeholders on what is desirable. Though such wicked problems are, in essence, unsolveable, it is still possible to make progress in their resolution by structuring the interrelated issues in such a way that stakeholders can hold an intelligent debate about what might be done. This is the first way in which the term 'problem structuring' is used and can be seen as an attempt to introduce procedural rationality, in the sense that the term was used by Simon (1972, 1976). That is, this form of problem structuring provides a systematic way to collect information, debate options and find some acceptable way forward.

The second use of the term 'problem structuring' refers to any work done in problem solving to structure the issues before any detailed analysis is conducted. As an example of this, Pidd and Woolley (1980) reports on the problem structuring approaches used by OR practitioners in part of the UK about 30 years ago. When problem structuring approaches are used in combination with analytical approaches such as computer simulation, it is sensible to regard the two approaches as complementary (Pidd, 2004). It is, though, important to realise that such complementary use is based on the mixing of paradigms and methodologies (Mingers and Gill, 1997) and that care is needed when doing so. Detailed discussions of this complementary use can be found in Pidd (2004), which reports on a research network involving both academics and practitioners in the UK established to consider the difficulties and challenges. A more textbook approach is taken in Pidd (2003), which contrasts the problem structuring ideas with more classical management science techniques.

In this paper, the term problem structuring applies in its second form: to the use of systematic approaches to help diagnose a problem and understand the main issues as a prelude to detailed simulation modelling. The aim is to find ways to implement John Dewey's maxim (quoted in Lubart, 1994) that: "A problem well put is half solved." It seems as if he had in mind that a poorly posed problem will be very hard, if not impossible, to solve. As expressed in the title of this paper: making sure that you tackle the right problem. There can, of course, be no guarantee of this, but problem structuring approaches can help reduce the risk of working on the wrong problem. As with simulation modelling itself, users of problem structuring methods grow more expert in their use as their experience develops. There is, though, no silver bullet, no magic formula that will guarantee the correct diagnosis of a problem in such a way that the right simulation model is built and that this is used appropriately.

2 INFORMAL PROBLEM STRUCTURING: CRITICAL EXAMINATION

Since many simulation practitioners are engineers, it makes sense to start by discussing an approach known as critical examination that has been used by engineers for many years. Though engineers are rarely regarded as poets, critical examination is based on 6 questions that are neatly summarised in a verse by Rudyard Kipling from the Just So Stories ("The elephant's child").

I keep six honest working men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who.

These make a very good starting point for considering the main aspects of a problem for which a simulation approach is being considered.

The first question in the verse revolves around *what*. Of course, there are many different questions that could be asked, which begin with *what*. The most obvious and one for which there is rarely a straightforward answer without working through all six questions is, "What's going on?" or, "What's the problem we need to work on here?" It is perhaps better to ask, "What are the main issues that concern people?" In a manufacturing simulation, these might include some or all of cost reduction, uniform high quality, integrating work centres or reducing stocks. In a simulation of a call centre they might include some or all of meeting performance targets for answering calls, establishing equipment needs, designing a call routeing system and determining a shift pattern. Note that these issues are rarely independent and may be in conflict with one another. At the early stage of a simulation project, it is important to simply identify these issues and to keep them in mind as part of the development of a conceptual model.

The second question starts with *why*. Perhaps the most common variants on this are to ask "Why are these issues important?", "Why do particular people think these are important" and "Why is this important now?". Of course, the latter two questions spill over into the *who* and *when* questions. It is not unusual for problems to be known, but not tackled. Sometimes there is good reason for this – there are just more important things to be done; or, people have found workarounds that have been good enough. It is very common for answers to the *why* questions to become more subtle and complex as the work proceeds. Hence it is best to regard problem structuring as something that goes on throughout a project.

Experienced modellers know that they sometimes only have a real appreciation of the problem they are tackling when the work is complete. It was this realisation that led Pidd and Woolley (1980) to conclude that this form of problem structuring is characterised by four features:

- It is **inclusive**: the questioning and deliberation is not just concerned with the technical aspects of the work, but also considers how the model might be put to work and how stakeholders might be persuaded to act on any recommendations.
- It is **continuous**: the questioning and deliberation are iterative or cyclic and continue throughout the project. In the terms introduced by Kolb (1983), it is a learning cycle during which participants learn the aspects that need to figure in the model and its use.
- It has some **hierarchical features**: one problem tends to spawn another and decisions must be made on how detailed or specific the model is intended to be.
- It is **informal**: which explains the title of this section. That is, people get on with it, cutting corners where appropriate and sometimes regretting this later.

With this in mind, the third informal question asks *when* and concerns the time dimension. Typical examples might be: "Is this a once-off problem or one that recurs?" or "Has this been a problem for some time but only recently become important enough for action?" or "When will the model be needed?" or "When will the changes to the systems need to be implemented and properly working?" The first two relate to the earlier *why* questions and the latter two give some idea of the resources that will be needed to do the work and of the level of detail that can be achieved in the model. If the model needs to be built and tested in a couple of weeks, it is unlikely to include much detail.

The fourth informal question asks *how*. The first common example asks: "How am I going to model this?" referring to the technical approach that may be needed. The second common example asks: "How did all of this start to emerge?" Clearly this and the other five 'honest working men' are close relatives or friends and in this form it relates closely to the *who* and *when* questions. But it also relates to the *what* question in facing up to how things are done at the moment or how people might envisage things to operate in the future. This depends both on the analyst's reflection and deliberation and also on the opinions of the people who are interviewed at this stage of the work.

Fifthly, we can ask the *where* questions. Often these are less important when taken at face value, for the location of the system of interest may be obvious. However, even this should not be taken for granted. Location can be very important now that instantaneous electronic communication around the world is available at low cost. Tasks that once had to be located in one particular place may now be located elsewhere in the world. Examples include the transfer of medical images and resulting diagnosis on a different continent from the place that the patient is located, the location of telephone help-desks, the processing of routine documents and the 24/7 development of computer software. The *why* question might also become "Where is this problem occurring?" and this suggests the need for careful understanding of the system of interest.

Finally, and often the most important, are the *who* questions. Since most organisations are inherently political, the people, their motivations and their actions become very important. Put simply, in many situations, some people have much more power to get things done than others. Equally, some people have much more power to stop things being done and this may be just as important. In a privately owned business it may be obvious that the owner calls the shots. In a public body there are often many stakeholders whose views must be considered and their views may conflict. Hence, irritating though it can be to people of a technical bent, considering the main players are can be crucial in getting things done – even for something as basic as data acquisition.

As the preceding argument demonstrates, informal problem structuring is not difficult to understand. This presentation of critical examination should not, though, be used to as a reason wander aimlessly around asking aggressive questions of other people. The idea is that the analyst keeps these questions in her head and, in interacting with other people and using previous experience, teases out answers that will inform the modelling work and its implementation. There are times, however, when something more than this informal approach is needed, when a more formalised methodology is needed to manage a complex situation.

3 FORMAL PROBLEM STRUCTURING APPROACHES

It is impossible, in the space available, to give more than a flavour of common used, formal problem structuring methods. A good survey is found in Rosenhead and Mingers (2001) and detailed accounts can be found in works produced by the developers and advocates of the various approaches. The Journal of the Operational Research Society (Shaw, Franco and Westcombe, 2007) recently produced a special issue devoted to recent developments. Here, the aim is to present a very brief survey and then illustrate the ideas by focusing on one approach, soft systems methodology (SSM), in more detail. Other problem structuring approaches have been used in a complementary fashion with discrete simulation modelling; for example, see Sachdeva, Williams and Quigley (2007). Likewise, problem structuring methods have been used with system dynamics models and Howick (2003) is an example of a paper linking this form of simulation with cognitive mapping, another commonly used problem structuring approach. den Hengst, de Vreede and Maghnouji (2007) discusses the general use of problem structuring methods in simulating airline operations that involved multiple stakeholders.

It is likely that formal problem structuring methods are of most use in situations where strategic issues loom large, rather than in tackling low-level, operational problems. The various formal methods assume that stakeholders may legitimately disagree with one another, that they may behave politically and that there may be disagreement about ends (why and what should we be doing?) as well as about means (how can we increase throughout by 15%?). With this in mind, Rosenhead (1989, p12, Table 2) suggests that the formal methods share six distinctive characteristics:

1. Non-optimizing: seeks alternative solutions which are acceptable on separate dimensions without trade-offs.
2. Reduced data demands: achieved by greater integration of hard and soft data with social judgements.
3. Simplicity and transparency: aimed at clarifying the terms of conflict.
4. Conceptualizes people as active subjects.
5. Facilitates planning from the bottom-up.
6. Accepts uncertainty and aims to keep options open for later resolution.

The idea of problem structuring methods seems to have arisen in the UK OR community in the 1970s and the methods have developed since then and are routinely taught on educational programmes in Europe. Curiously, their penetration has been much lower in the USA and some in the OR/MS community view them with great suspicion. Other communities, for example those involved in software engineering have also developed approaches such as Dialog Mapping (Conklin, 2002) and Design Rationale (Lee and Kai, 1991), with many of the same characteristics. Rosenhead and Mingers (2001) discusses the approaches most commonly used in OR/MS and matches a descriptive chapter on each approach with another discussing an implementation. Their list of methods is as follows:

- SODA (cognitive mapping)
- Soft systems methodology
- The strategic choice approach
- Robustness analysis
- Drama theory and confrontation analysis
- Related methods: viable systems modelling, system dynamics and decision

4 SOFT SYSTEMS METHODOLOGY

Despite its unfortunate title, soft systems methodology (SSM) is widely used in many different ways. An early postal survey (Mingers and Taylor, 1992) investigated the use of SSM. The proportion of users was quite high and, of these, the majority claimed to use SSM with a view to easing a problem situation or to develop understanding. They also claimed that a main benefit of SSM was that it provided a strong structure within which they could achieve these aims. These findings seem to support the view that SSM provides a formalised approach to gaining understanding within an organisation, paying due regard to cultural issues.

Checkland (1981, 1999) describes the development of SSM and its main features. Checkland and Scholes (1999) provides a more practical view of the ideas, Wilson (1990) provides a systematic discussion of how the ideas might be operationalised, which is an issue also faced in Checkland and Poulter (2006). The description of SSM presented here is based on that in Pidd (2003, chapter 5). Paul and Lehany (1996) discusses some general issues in linking SSM to discrete simulation modelling, Baldwin Eldabi and Paul (2004) presents a general methodology based on SSM for understanding stakeholders in healthcare simulations and Lehany and Paul (1996) discusses a specific healthcare application in which SSM and simulation are used in a complementary fashion.

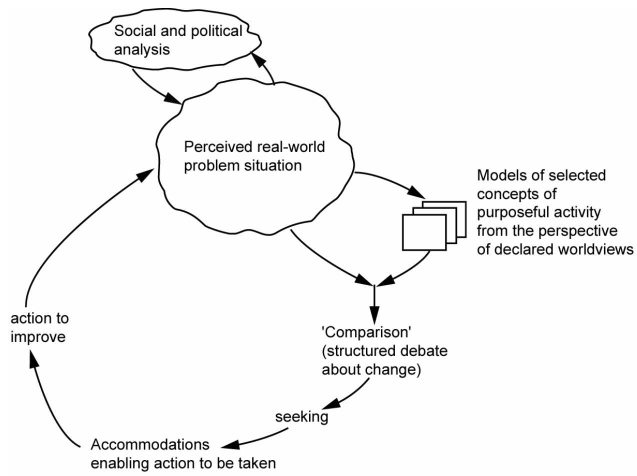

Figure 1: An overview of soft systems methodology

4.1 The Overall Approach of SSM

The original book on SSM (Checkland,1991) presented a 9-step approach to its use. It seems that Checkland rather regretted this mechanistic presentation, for a rather more fluid description is provided in later works. Figure 1, taken from Checkland and Holwell (2004, p 52, Figure 3.1) shows the approach as a learning cycle with a number of features.

The large cloud represents a perceived, real-world, problem situation. Each of those words is carefully chosen and, in many SSM studies, this is the starting point of the work and this is likely to be the case if the SSM is used as a prelude to detailed modelling, possibly using simulation. The word *perceived* is used because a study always begins with a recognition that something needs to be done; that is, some situation is unsatisfactory now or a system needs to be designed or re-configured for the future. Since there are often different stakeholders (including the client and analyst), the perceptions of those people matter and different stakeholders may perceive things rather differently. However, SSM is not primarily intended for philosophical use, but for the world of action and in which something must be done. Hence, this is a *real-world* problem that needs to be tackled.

The word 'problem' is itself somewhat problematic (Pidd, 2003, chapter 3) and so Checkland instead refers to a *problem situation*; that is, the set of interacting policies, people, equipment, actions and intent that may or may not be causing the problematic situation. One of the aims of SSM is to tease out these aspects so as to understand which are most important in seeking improvement. This is the finding out stage of SSM and seems transferable to most application areas and could serve as a useful starting point for many simulation studies to reduce the risk of fruitless endeavour later. In this finding out stage, above the cloud in figure 1 is the need for social and political analysis to inform the developing understanding of this problem situation. In essence this is a formalisation of the six questions involved in the critical examination of informal problem structuring.

The social analysis can be considered in two parts; firstly, a conscious attempt to identify the people occupying various roles in an intervention, as follows. First the 'would-be problem solver': the person who has decided, been told or has requested to investigate the situation. Secondly, the 'client': the person for whom the investigation is being conducted. Finally, the 'problem owners': which would include the various stakeholders with a range of interests. Note that any or all of these roles may overlap – for example, someone may be using SSM to help support their own work. The second part of SSM social analysis is to investigate the problem situation as a social system. The idea is to build on the knowledge of the significant roles that people occupy, to investigate the norms and values that are expressed. Roles are taken to be the social positions people occupy, which might be institutional (teacher) or behavioural (clown). Norms are the expected, or normal, behaviour in this context. Values are the local standards used to judge people's norms. The idea of this analysis is that the analyst should try to understand how people play out their roles.

The political analysis requires the examination of the problem situation as a political system, in an attempt to understand how different interests reach some accommodation. This is an explicit recognition that power-play occurs in organisations and needs to be accounted for. Needless to say, this analysis needs to be undertaken carefully and, maybe, covertly. Even when sitting in a bar there is little point asking people what their power-ploys are! Eden and Ackerman (1998), discussing problem structuring using cognitive mapping, suggests an approach based on power:influence grids. Here, this idea is modified slightly into the power:interest grid shown in figure 2. In simple terms, power is the ability to get things done or to stop things happening and this is very different from only having an interest in what is happening.

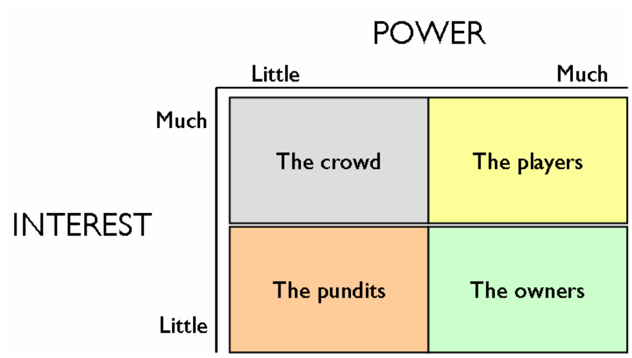

Figure 2: A power:interest grid

Figure 2 uses a sporting analogy to get this distinction across. For example, in a football game, the players have the most power to affect the outcome and, one hopes, the most interest in doing so. On the other hand, the crowd has a great interest in the outcome but, short of invading the pitch, has little direct power to affect the outcome. If the team is owned by a remote group interested only in the financial results, it may be reasonable to regard them as having much power but little actual interest. Finally, the TV pundits may be paid to do a job but have little real interest or power. It should be clear that the players are crucial, since they have high power and interest. This does not mean that the other stakeholders can be ignored, however, and a stakeholder analysis is always profitable.

Following investigation of the problem situation, figure 1 shows that an SSM study requires the construction of models of purposeful activity from the declared worldviews. Two aspects of this merit discussion here. First, it is important to realise what is meant by a model in SSM, which is not the same as a simulation model. A model in SSM is something that captures the essential activity needed in an idealised implementation of the system of interest. These are usually developed from root definitions, which is a concept discussed later in this paper. Secondly, note the reference to declared worldviews. The aim of the social and political analysis is to understand the different worldviews of the people and groups involved in the problem situation. SSM takes for granted that there may be different worldviews – that is, people may legitimately disagree about the ends and means of a study. The different viewpoints are teased out and represented in root definitions, of which more later.

4.2 Human Activity Systems

SSM aims to help people to understand and, possibly, to design human activity systems. In exploring what this means it is important to realise that the idea of a system is employed in SSM somewhat differently from its everyday use. Rather than assuming that systems, as such, exist, they are taken as useful conceptualisations or convenient fictions. In these terms, human activity systems have the following characteristics.

- **Boundaries** - Some things are inside the system, others are not and constitute the environment of the system. Note, though that the boundary may not be obvious. For example, in a call centre, is the location from which someone calls to be part of the model?
- **Components** – There is more than a single element within the boundary. A boundary that contains nothing is not a system and nor is a boundary that contains a single element.
- **Internal organisation** - the elements are organised in some way or other and are not just chaotic aggregations.
- **Behaviour** – the system is recognised as such because it displays behaviour that stems from the interaction of its components; that is, this behaviour is not just from those individual components.
- **Openness** - The system boundary is permeable in both directions and there is communication and interaction across the boundary. The cross-boundary exchanges constitute the external relations of the system.
- **Human activity** - What people do, and how they do it, are prime concerns of SSM. It follows from this that human activity systems are dynamic as a result of human action.
- **Human intent** - People are not just machines that do things. What they do has meaning and significance for the individuals and groups concerned. Why people do things is often at least as important as what they do and how they do it.
- **Limited life** - they are not eternal, and their life may be quite short.
- **Self-regulation** - A process of regulation, control or governance, which maintains it through time, is a characteristic of an open system. These systems may be in equilibrium but this stability is not the same as stasis.

4.3 Root Definitions

The idea of a root definition is to provide a minimal definition of a system, viewed partly in input:output terms, to enable discussion between stakeholders about what is required. A root definition is in some sense neutral, in that a particular structure is required that separates the definition and its supporting worldview from the stakeholder(s) to whom it belongs.

A root definition consists of six elements as follows (taken from Pidd, 2003, pp 125-126):

1. **Customers**. These are the immediate beneficiaries or victims of what the system does. It can be an individual, several people, a group or groups. This is very close to the total quality management (TQM) notion that the customer is the next person to receive the work in progress. The customers help define the main external relations of the system being conceptualised.
2. **Actors**. In any human activity system there are people who carry out one or more of the activities in the system, these are the actors. They form part of the internal relations of the system. There may be several actors or several groups and their relationships also form part of the internal relations of the system.
3. **Transformation process**. This is the core of the human activity system in which some definite input is converted into some output and then passed on to the customers. The actors take part in this transformation process and, ideally, a root definition should focus on a single transformation. The transformation process is an activity and its description therefore requires the use of verbs.
4. **Weltanschauung**. This is the, often taken for granted, outlook or world view which makes sense of the root definition being developed. It is important to specify this because any system definitions can only make sense with some defined context. Thus a root definition needs only a single Weltanschauung.
5. **Ownership**. This is the individual or group responsible for the proposed system in the sense

that they have the power to modify it or even to close it down. This can overlap with the actors of the system or the customers.

6. **Environmental constraints**. All human activity systems operate within some constraints imposed by their external environment. These might be, for example, legal, physical or ethical. They form part of the external relations of the system and need to be distinguished from its ownership.

The mnemonic CATWOE, is often used to summarise these six elements, taking the initial letters of the above six terms.

To illustrate its use, consider a study (Gunal, Onggo and Pidd, 2007) conducted for a police force that began with a request for help in improving the performance of its Contact and Response Centres (CaRCs). CaRCs are the primary point of contact between members of the public and the police force. People needing help or wishing to report and incident phone an emergency number and are connected to the nearest CaRC in which a call taker talks to them and types a database entry which is passed for response. The calls are graded by their severity so as to enable an appropriate response. The response is requested from local police units by radio operators who are also housed in the CaRC. The initial issue that presented itself was the poor performance of the CaRCs in answering the phone. The police force had agreed targets for answering calls but was nowhere near meeting them. Some callers had to wait a long time and some even complained about receiving an engaged tone. Neither was impressive for an emergency service that was contacted by fearful or endangered citizens who may need help.

5 USING ROOT DEFINITIONS

5.1 Root Definitions for the CaRCs

The main stakeholders in this study were the admin branch of the police force who had asked for help from the simulation team, members of the public, the staff and officers who manned the CaRCs and the officers with responsibility for the CaRCs. A root definition (CATWOE) could be constructed for each. Note, however, that these root definitions are not representative of the actual stakeholders of this simulation study but are used to illustrate the structure and point of root definitions. Consider, for example, members of the public who might call a CaRC, seeking help from the police. How might such people see a CaRC in terms of a root definition?

- **Customers**: clearly, most members of the public would see themselves as the main beneficiaries of a properly run CaRC.
- **Actors**: it seems likely that any member of the public who thought about this would regard the staff and officers of the CaRCs as the principal actors.
- **Transformation**: a member of the public is likely to see a CaRC as existing to receive calls that are transformed into appropriate and timely action.
- **Weltanschauung**: the previous three elements only make sense within a worldview that sees responsive policing as important for public safety and security.
- **Ownership**: since the CaRCs are funded through the police budget, it is clear that the owner is the police force itself.
- **Environmental constraints**: the CaRCs must operate within defined budgets, using available technology and responding in such a way as to provide an appropriate level of service.

Thus, seen in these terms, the CaRCs are a system that takes calls from the public and provides an appropriate and timely response for the benefit of the public who see such a response as necessary. The CaRC is run by the police force using staff and officers who operate within defined budgets using available technology.

As a slight contrast, discussions with the officers who manage the CaRCs may lead to a root definition something like the following.

- **Customers**: it is possible that the managers of the CaRCs might see the police force itself as the customer, for the CaRCs allow the force to provide responsive policing. This does not mean that these officers would ignore the needs of the public, but they may have different customers in mind.
- **Actors**: it seems likely that managers would regard the staff and officers of the CaRCs as the principal actors.
- **Transformation**: as mentioned in the discussion of customers, the transformation might be to turn information from the public into responsive policing.
- **Weltanschauung**: in the light of the previous elements, a worldview that makes sense is that the police force must engage in responsive policing.
- **Ownership**: since the CaRCs are funded through the police budget, it is clear that the owner is the police force itself.
- **Environmental constraints**: the CaRCs must operate within defined budgets, using available technology and responding in such a way as to provide an appropriate level of service.

Thus, in these terms, the CaRCs are needed to support responsive policing and are organised so as to provide a good responsive service, operated by staff and officers within budget and technology constraints and owned by the police force.

5.2 Root Definitions for the Simulation Study

As well using root definitions to capture how different stakeholders might see the CaRCs, the same approach can be used to think through the simulation study itself. Consider, for example, the admin branch of the police force who commissioned the work. Perhaps they are concerned to ensure that the CaRCs meet performance targets as part of an effort to show that this is an excellent police force. With this in mind, a possible CATWOE for a simulation study might be as follows

- **Customers**: since the admin branch commissioned the study, they would probably see themselves as the customers.
- **Actors**: members of the admin branch are likely to see the simulation modellers as the main actors, assisted by themselves.
- **Transformation**: in these terms, the transformation is to move from being unsure why performance is poor to knowing what could be done to improve it.
- **Weltanschauung**: the previous three elements only make sense within a worldview that believes that a simulation model will provide useful performance information.
- **Ownership**: since the simulation modelling is commissioned by the admin branch it is clear that they are the main owners as well as being customers. It is, though, true that the modellers could also close down the project.
- **Environmental constraints**: the simulation modelling must be completed within agreed budgets and timescales, possibly using agreed software.

Seen in these terms, the simulation project is one commissioned by the admin branch so that they may develop ways to improve the performance of the CaRCs within agreed budgets and timescales in the belief that a simulation model will enable them to do this.

What about the staff and officers who work in the CaRC? How might they see the simulation project. For simplicity we will assume that they share the public's view of the CaRCs, but not the admin branch's view of the modelling project. Hence, a possible CATWOE for their view of the modelling project might be as follows.

- **Customers**: the admin branch.
- **Actors**: admin branch and simulation modellers.
- **Transformation**: to move from a situation in which staff and officers in the CaRCs use their expertise to manage the CaRCs to one in which a more technocratic approach is used.
- **Weltanschauung**: the people who don't run CaRCs always think they know best how to improve their performance.
- **Ownership**: admin branch, and certainly not the staff and officers who work in the CaRCs.
- **Environmental constraints**: the project will have to be completed with whatever cooperation and time they can give in their over busy working lives.

Seen in these terms, the modelling project is one commissioned by the admin branch and only possible with the help of CaRC staff and offices, which may change the way they work in ways recommended by people who have never worked in a CaRC.

6 USING ROOT DEFINITIONS TO SUPPORT CONCEPTUAL MODELLING

It would be possible to develop root definitions for the other stakeholders and this could be done to capture their different views of the CaRCs and also of the simulation project itself. In this way, it is possible to tease out different worldviews and assumptions about the operation of the CaRCs and of the modelling project. It ought be clear that gaining this understanding may be crucial in gaining the co-operation that will be needed if the work is to proceed with any chance of success. It may, of course, be argued that any experienced analyst will intuitively think through such issues – but, the perfect never have anything to learn.

Old hands in the simulation community will remember when developing a model always involved writing code, whether in a general purpose language or a simulation language. That was a tedious and error prone process which forced the modeller to think very hard before writing code and provided an incentive for the development of tightly defined models for specific tasks. Contemporary simulation tools rightly free us from this drudgery, but their ease of use brings a temptation to dive straight to the keyboard and mouse and, later, to go on enhancing models. Like most temptations, this can result in initial pleasure but subsequent regret. Developing a conceptual model before diving for the computer can help reduce the appeal of this temptation.

Robinson (2004) defines a conceptual model as a non-software specific description of the simulation model that is to be developed, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model. This is a rather broad definition that might be better thought of as the conceptualisation of a simulation model and a simulation project, rather than a conceptual model. Leaving aside these semantics, however, it should by now by clear that such a conceptual model depends heavily on the degree to which the modeller has an understanding of the appropriate simplifications required in the simulation model. Together with an appreciation of the project context within which the simulation model will be developed and used.

It should be clear from the earlier discussion that problem structuring approaches aim to assist an analyst in developing this understanding and appreciation. It should also be clear that this is true of informal methods such as critical examination as well as of formal approaches such as SSM.

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