

**Experiences of mixed method OR Practitioners: moving beyond a technical focus to  
insights relating to modelling teams**

Fran Ackermann,

Curtin Business School,

Curtin University, Perth, Australia

ORCID: 0000-0003-2381-6611

Corresponding author: [fran.ackermann@curtin.edu.au](mailto:fran.ackermann@curtin.edu.au)

Susan Howick,

Strathclyde Business School,

University of Strathclyde, Glasgow, Scotland

ORCID: 0000-0002-0796-7981

**Abstract:** Complex, real-world problems often benefit from being tackled using multiple OR methods. The ability to combine methods successfully therefore plays a key role in successful OR practice. The research described in this paper aims to augment current understanding of mixed methods modelling, moving beyond the predominant focus on technical aspects of which methods to use and how they can be combined. As such the research sought to explore the *practice* of mixed methods from the perspective of those with mixed methods experience to reflect on all aspects of a modelling intervention and identify generic lessons. The research involved a series of in-depth interviews with experienced OR practitioners (both academic and non-academic) to understand

how they undertake mixed methods work. The paper describes the research methodology employed, the emergent data and the results of the analysis. The analysis reveals that an area of significance hitherto only peripherally addressed was consideration of the modelling team particularly a) additional skills, b) organisational culture and modeller personality and c) the role of the team leader. The paper concludes with some avenues for further exploration regarding teaching, research, and the practice of OR mixed methods work.

**Keywords:** Mixing Methods, Modelling Teams, Practice of OR

## 1. Introduction

Since inception, Operational Research (OR) has supported decision makers addressing a wide range of real-world problems (Kirby, 2003) through developing a variety of modelling methods. However, complexities of real-world problems means that there are times when a single method may not suffice. Multiple OR methods may be required so that different aspects of the problem can be addressed. This, important requirement for using multiple methods to tackle significant complex problems, is highlighted by Hamalainen et al. (2013, p. 624) who note that “model-based problem solving is an increasingly important approach used when tackling problems of high importance. Issues related to climate change and of natural resource management are examples in which *the use of different quantitative and qualitative models* is an essential part of the public policy process” (our emphasis). Thus, the ability to combine and apply multiple methods plays a key role in successful OR practice.

For a number of years researchers have been interested in how methods can be effectively mixed often from a theoretical perspective (for example Mingers and Brocklesby, 1997; Jackson 1999; Mingers, 2000; Mingers, 2001; Zhu 2011; Morgan et al 2017). These theoretical perspectives focus on which methods could be used in a particular context and how these methods can be combined to tackle a problem and, thus, take a technical orientation. However, Howick and Ackermann (2011) observe that there has been “little discussion between members of the community on the *generic lessons* that could be identified from mixing methods *in practice*” (p. 503) and that the benefits from undertaking such research include; providing lessons to inform future practice, identifying areas for future research direction, and highlighting important areas to embed into university and training courses.

This explicit focus on practice is not new to OR, as illustrated by the behavioural OR field (Franco and Greiffenhagen, 2018). Researchers have presented descriptions and evaluations of mixed method interventions practice (Franco and Lord 2011, Myllyviita et al 2014, Small and Wainwright 2014, Espinosa et al 2015, Henao and Franco 2016, Santos et al 2018), however these studies are based on specific methods and cases rather than being generic in nature.

The work discussed in this paper aims to augment this body of work and identify “*generic lessons* that could be identified from mixing methods *in practice*”. Investigating mixing methods *in practice* would allow us to determine whether there are any missing important insights. In addition, these insights may help to identify associated challenges with mixed method work. As such, a research investigation into the nuances of mixing methods in practice – through the lens of those practising mixing methods - seemed an appropriate endeavour.

Before describing the undertaken work, the next section provides a brief review of relevant extant literature before detailing the methodology, presenting the findings, and concluding with a discussion, limitations to the study and future research avenues.

## **2. Literature Review**

The majority of previous work in the *practice* of mixing methods has focussed on two attributes:

(i) A technical description of the models used and how the methods are combined rather than a more comprehensive consideration of the modelling process *in practice* and/or

(ii) An evaluation of a single case study rather than a more wide-ranging focus across multiple experiences potentially leading to more generalisable insights

An exploration of the literature in both areas is presented below.

There are numerous papers which exclusively focus on the technical aspects of mixing. For example, many case studies discuss particular combinations and concentrate on a description of the models used and how they are combined. Typically, there is little, if any, consideration regarding how the use of mixed methods may impact other aspects of the modelling process. In some case studies application of the mix is not even mentioned (Nabli and Chahdoura, 2015) – leaving the reader to ponder its efficacy and relevance. However, OR is a very practical discipline. It is widely recognised that the OR process goes beyond a consideration of what methods to use (see established books on OR practice e.g. Mitchell, 1993; Pidd, 2003; Williams, 2008). As highlighted by Midgley et al. (2013, p.145), “it is widely accepted that the ‘success’ or ‘failure’ of a method in any particular case ... cannot be attributed to the method alone”.

Therefore, when seeking to provide useful lessons about the practice of mixing methods, research should look beyond the methods used and consider the broader modelling process.

An exception is work by Howick et al (2017) which provides a fuller reflection of a mixed methods approach on the modelling process *as a whole based on one case*. This paper highlights a number of learning points with respect to the use of mixed methods *beyond* technical integration. For example, it includes reflections on the design of a mixed methods process, consideration of the different intervention styles of the modelling team, the role of a team leader,

an appreciation of the client's perception of the modellers' role, and the value that the client can gain from the process.

As with Howick et al (2017) above, a large proportion of the mixed method practice literature focuses on single case studies (for example see Howick and Ackermann 2011 for a list of case studies). However, there are two papers in the literature that not only provide a fuller reflection of mixed method approach but also go beyond a single case study.

Firstly, Munro and Mingers (2002) carried out a survey across academics and practitioners regarding the use of multi-methodology in practice. Secondly Howick and Ackermann's (2011) reviewed case studies to reveal generic lessons relating to mixed OR method practice. Both these studies explored the types of methods being used during OR mixed methods interventions and how and why these methods were mixed. Munro and Mingers also considered modellers' backgrounds and sought judgement on the success of interventions. With respect to modellers' backgrounds, they noted that a multidisciplinary background appeared to be normal commenting that some respondents also mentioned the use of teams of people with different skills. With respect to perceived outcomes, Munro and Mingers (2002) concluded that responses noted a high level of both the modeller's satisfaction and the modeller's perception of the client's satisfaction and suggested "a higher level of satisfaction with mixing methods than using particular methods singly" (p. 377). However, as this exploration was undertaken as part of a survey, there is limited understanding of the reasons for the responses and the survey was conducted 20 years ago.

The work by Howick and Ackermann (2011) also report findings in three areas beyond a technical consideration of methods. Firstly, when considering the modellers involved in the case studies they reviewed, they concluded that using modelling teams, rather than individual modellers, was the norm. A second area of interest focused upon the nature of the intervention where they concluded that there was no pattern in the objectives, duration, type of organisation etc. for mixed methods work. The final area was client value. The value of mixed methods work is taken to be the benefit gained from the overall modelling approach as compared to the value gained from the individual methods. For example, Henao and Franco (2016) mention that “the whole intervention *may* have produced greater impacts than each methodology would have individually” (p.14) and Kotiadis and Mingers (2006) note that “each methodology enriched the finding of the other” when using Discrete Event Simulation and Soft Systems Methodology. However, Howick and Ackermann conclude that the value accrued from mixing methods is thinly addressed by the case studies they reviewed and that it was unclear whether benefits could be attributed to the mixed methods process.

Both Munro and Mingers (2002) and Howick and Ackermann (2011) are useful in highlighting areas for potential research into the practice of mixing methods. Both identified a) potential learning opportunities around modellers and modelling teams and b) the perceived value of an intervention – suggesting useful dimensions/foci for further research. In particular, Howick and Ackermann note that in-depth interviews with experienced modellers “could help to advance knowledge in this area” (Howick and Ackermann, 2011, p 506).

The above review suggests that research into mixed methods tends i) not to go beyond technical details about the use of the methods, and ii) that to date the wider implications have been thinly addressed and have been typically single case dependent, not allowing for generalisable learning across a range of practice. Thus, the work described in this paper sought to understand mixed methods through the lens of the practitioner – teasing out and appreciating not only the ‘what’ (methods to be mixed), but ‘how’ (the nature of their combining), ‘where’ (the problem situation), and ‘who’ (clients, stakeholders, modellers) to gain generalised insights that could be of benefit to those seeking to undertake mixed methods OR interventions.

Recognising that focusing solely on the literature’s suggested avenues risked potentially missing insights the research sought to allow those with experience of mixed method practice to reflect on all aspects of a modelling intervention to allow generic lessons to emerge across the entire experience. Returning to the extant literature, a framework to help guide reflection across a mixed method intervention was sought. Howick et al (2017) present such a framework – identifying themes to use when evaluating mixed methods projects. Howick et al. (2017) reflect on how their proposed theme set compares to others– for example, Midgley et al. (2013) and Ormerod (2014a) - noting that they demonstrate a degree of consistency and that Ormerod’s evaluation themes map onto Midgley et al.’s themes of Context, Purpose, Method and Outcome. In addition, Howick et al (2017) provide an additional theme with respect to the Modelling Team. This theme aligns with Munro and Mingers (2002) and Howick and Ackermann’s (2011) work proposing the modelling team as an area for future research. Due to the framework’s focus on mixed method work, whilst also having similarity to other themes presented in the literature, Howick et al.’s themes were chosen to frame the work described in this paper.



### **3. Research method**

As noted above, this research aimed to explore the nuances of mixing methods in practice – through the lens of those practising mixing methods. Consistent with this aim, the research methodology was qualitative in nature as an interpretist paradigm would enable perceptions and subjective data to be elicited and examined. Interviews were seen as the most appropriate means of capturing rich data as they would enable subtle tacit experiences to be surfaced. Having a semi structured approach would allow for comparability across interviewees whilst also enabling interviewees to drill down to more nuanced material. Figure 1 illustrates the research method adopted.

Figure 1 about here

#### *3.1 Capturing the data*

A purposeful sampling approach was adopted to identifying the interviewees (Miles and Huberman, 1994; Creswell and Creswell, 2018) to target information-rich participants, participants who have considerable knowledge of the research topic (Patton 2014) and who could therefore offer detailed insights needed for in-depth qualitative inquiry.

Two specific sampling strategies were deployed. The first was criterion sampling whereby participants were selected on the basis of them having been involved in at least two real world projects for a client where multiple OR methods had been combined. It was believed to be important to draw from both academic and practitioner participants as there might be different nuances to be gained. The second strategy was snowballing. This strategy was applied when

recruiting practitioners by sending a request to the Heads of OR and Analytics Forum<sup>1</sup> to identify potential interviewees.

To identify appropriate academics the researchers turned to the literature to identify academics who had experience in using mixed methods in practice focussing on those who had published at least two journal articles that involved a mixed methods case study. This ensured that the academics fulfilled the criteria of having at least two practical experiences. We began with authors identified through Howick and Ackermann's (2011) review paper. As this review only considered articles published until 2008, the list of academics was extended by reviewing OR journals for case study work published from 2009-2016. Journals that were reviewed included Journal of Operational Research Society, Omega, European Journal of Operational Research, Interfaces and OR insight as they were seen to attract case study articles. This resulted in the identification of 11 academics. Eight of the 11 academics were identified from the 2011 review paper, although their second article may not have appeared until after 2008 and thus captured by the second search. Two of the academics were the authors of the paper and from the remaining nine, eight academics agreed to be interviewed.

The final number of participants identified was 15 – 8 academics and 7 practitioners (two of the practitioners worked in the same organisation and were interviewed together). All except one of the interviewees were based in the UK. Whilst this number was smaller than initially envisaged 15 participants provided a viable number for the study as illustrated by Kvale and Brinkmann (2009 p.133) who note that “In common interview studies, the number of interviews tends to be around 15 +/- 10”. In addition, the 15 participants had an average of 25 years of OR modelling

---

<sup>1</sup> <https://www.theorsociety.com/who-we-are/related-organisations/horaf-heads-of-or-and-analytics-forum/>

experience and so were well grounded in OR practice. Practitioners were in the areas of health, defence, consultancy, police and justice services (and thus reflected a mix of public and private organisations). The academics were based in 7 universities.

Alongside this activity the researchers developed a set of questions forming the interview protocol. Analysis and learning based on 30 case studies from the literature (Howick and Ackermann, 2011) formed the basis for the questions which were clustered into themes presented by Howick et al (2017) relating to; the context, the methods used and the nature of the mixing of methods, the modelling team, project outcome and benefits and lessons.

To tease out nuanced practice, each interviewee was asked to respond to the questions based on their experiences of two specific projects. No guidelines were provided regarding the selection of projects aside from requesting that the projects could easily be recalled to elicit rich data. The consistent use of a set of semi structured questions for both projects ensured that interviewee intra comparability would be possible as well as inter comparability. To test the questions a pilot interview was conducted and minor changes made to the questions and process.

The duration of each interview was between 60-90 minutes and was either conducted face to face where possible or via Skype. In one instance the interviewee requested that questions were answered via email with one round of follow up questions being asked to ensure comprehension by the researchers. In the majority of interviews both researchers were present to ensure a common understanding and a comprehensive coverage. All face-to-face and skype interviews were recorded with permission and subsequently transcribed in preparation for analysis.

As noted above, participants were asked to discuss two projects which involved mixing OR methods. Although multi-methodology has been a popular term used in the literature to represent

multiple methodologies (or parts of them) being combined in a single intervention (for example Mingers and Brocklesby, 1997; Jackson, 1999; Mingers, 2000; Mingers, 2003; Pollack, 2009; Zhu, 2011), the work described in this paper uses broader terminology. Similar to previous work (Howick and Ackermann 2011, Howick et al 2017), participants were informed that the term ‘mixing methods’ was being used to represent the mixing of any OR tools, techniques, methods, methodologies and/or paradigms within a single intervention. This aimed to capture a broad range of experiences, which it was hypothesised, reflects practice.

### *3.2 Analysing the data*

The first step in analysing the data was to identify the codes – constituting the nodes in an NVivo database (which was used throughout the analysis). This involved a third researcher, one not involved in the interviews, reviewing and coding one academic and one practitioner transcript. This resulted in an initial set of NVivo nodes using an open coding process (Glaser and Strauss 1967). These codes were a mix of a priori codes from the literature that informed the interview questions and emergent codes that surfaced from a review of the interview content. The NVivo nodes were subsequently used by the other two researchers who had conducted the interviews – with each coding one of the previously coded interviews. The process involved each of the selected sample transcripts being read through (as well as listening to the audio) with the sections of the transcript illustrating the codes identified and marked. This might be a single sentence or 2-3 sentences where it was important to capture the richness. Thus, the academic and practitioner transcripts were each coded by the third researcher plus one of the interviewing researchers. Comparing the two sets of double coded transcripts, allowed the researchers to explore inter-coder reliability ensuring a sufficiently high level of agreement (Miles and Huberman 1994), and where there were differences in understanding, work to refine the NVivo nodes (representing the

codes). Following this a revised set of NVivo nodes emerged. All three researchers subsequently coded a further two transcripts each and reflected on the degree of convergence of coding. A further set of minor revisions to the NVivo nodes were made and these were then used to code all of the interviews (those earlier coded interviews were recoded). The final node hierarchy is presented in Appendix I and step 4 of the research method flow diagram (Figure 1). This hierarchy reflects the high level, predominantly literature informed nodes with the detailed levels reflecting a mix of emergent and a priori codes.

Following the coding process, the two researchers involved in the interviews individually reviewed the material contained in the NVivo nodes to identify common characteristics which would form the basis of the findings presented in section 4. Initially, each researcher randomly choose, and reviewed, a different node (step 6 in the flowchart). As shown below, each parent and child node comprised a number of statements with the parent node typically having less as effort was made to ensure the nuance and detail was retained. Figure 2 shows a small section of the NVivo database with the nodes relating to the modelling team along with the number of files each node appeared in (first numerical column) and the total frequency (second numerical column). Thus, for the node 'identifiable leader', material relating to the node appeared in 11 files (each project discussed comprised a file, and each interviewee discussed 2 projects) and was mentioned in total 15 times illustrating that in some of the interviews it appeared more than once.

Figure 2 About Here

After reviewing the first two nodes, the approach to reviewing the node material used by each researcher was examined and a consistent method agreed upon. Both researchers subsequently reviewed a further node which when compared revealed that the characteristics they had individually identified were the same albeit with slightly different nuances. After some further

discussion regarding the method, the two researchers split up the remainder of the nodes, reviewed the material and summarised the common characteristics that emerged from the data. These were then considered alongside the literature to seek to highlight new insights which are presented in the next section.

#### **4. Findings**

As noted, the research was aimed at eliciting a deeper understanding of the *practice* of mixing methods. This aligns with calls from the Behavioural OR (BOR) field which focuses on the behaviours ‘*that influence what components of OR are used, how they are used and for what purpose*’ (Brocklesby 2016 p.796) as well as attending to Franco and Greiffenhagen’s call for understanding and unpacking the complex nature of OR interventions (2018).

As mentioned in section 3.1, four themes formed the basis of the interview questions (context, methods used and nature of the mixing of methods, modelling team, project outcome and benefits and lessons). On review of the transcript analysis, it became apparent that three of the four themes revealed little new material beyond that already noted in the literature. For example, under the theme of methods used and nature of the mixing of methods, the rationale for mixing methods echoed many of the observations noted in existing work ranging from attending to different aspects of the problem, to more robust outcomes etc. (Howick and Ackermann, 2011; Mingers and Brocklesby, 1997; Mingers, 2000; Mingers 2003; Jackson, 1999). The fourth theme, relating to the modelling team, did present new insights. As noted in the introduction, both Howick and Ackermann (2011) and Munro and Mingers (2002) highlight the importance of the modelling team as part of mixed methods work and call for research into understanding how they work. This request is echoed by Velez-Castiblanco et al (2016) who note that descriptions of OR process provide little in the consideration of team dynamics and Keys (2000) when he

comments “analysis fails to address questions concerning the development of process both by individuals and analysts *as a group*” (p. 311 our emphasis). This is particularly relevant for those working in the mixed methods field as typically mixed methods modelling is carried out by teams of operational researchers (Mingers, 2003).

This section will therefore focus on an examination of the insights gained from the interviews on the theme of modelling teams. However, a few additional insights gained from the other themes will be discussed at the end. Quotes have been used to illustrate the points and add further nuance. These quotes were selected based on their ability to illustrate the insights that had emerged from the data analysis along with ensuring representation from the range of interviewees. Each quote has been provided with an identifier e.g. A7 or P3 reflecting the cohort i.e. A= Academic and P = practitioner and the number identifying a particular academic or practitioner (the numbers have been allocated randomly and do not represent the order of interviews).

## **4.1 Modelling teams**

The analysis of the interview material addressing modelling teams revealed three interconnected sub-themes namely: the skills required by the modelling team members, personal inclinations and organisational culture, and the significance and requirements of a project lead. Each of these will be reviewed before concluding with a summary.

### 4.1.1 Modelling team skill requirements

Half of those interviewed explicitly mentioned that members of the modelling team were chosen because of their expertise in particular modelling approaches noting that being able to learn and

practice more than one method is challenging. For example, it was noted that *just to be aware about one and know about one, up to date with one, is difficult*” (A4). This resonates with the literature that notes it is demanding for an individual modeller to become proficient in a mixed methods approach. For example, Mingers and Munro (2002 p.369) comment that “Hard methods require a good analytical mind and background familiarity with mathematics and computing skills, while soft methods require people skills and the ability to facilitate often stressful and contentious workshops.” One interviewee noted that *“it’s easier to come in with the sort of scientific bit, and get the other bits as you develop, rather than come in without the scientific stuff and then try to acquire it”* (P1) suggesting that moving from hard to soft is easier than vice versa.

On deeper examination, there are additional nuances. Firstly, interviewees (3) noted that the modelling approaches used in combination can be quite wide ranging, sometimes extending beyond traditional OR modelling methods. For example, it was noted that the teams came from *“quite disparate backgrounds e.g. philosopher, psychiatrist, risk assessor”* (P4) (touching on the multi-disciplinary characteristics noted by Mingers and Munro’s 2000 survey) and another interviewee discussed a project involving a *‘team of four involving an expert process mapping person, expert project manager’* (P2) and that they *‘deliberately kept policy people with analysis people’* (P2). This suggests that bringing different world views together is desired. The interviews confirmed the widening of the ranges of tools, techniques adopted extending the findings of Mingers and Munro (2002).

In addition, recognising the contingent nature of the modelling skill availability, it was noted in the interviews (3) that *team skills change over time as staff move on* (P4) and therefore available mixes change. This was seen as both a positive and negative outcome. As new staff join the



organisation, new mixes become possible widening the range of possible solutions. However, losing staff may result in no longer being able to support clients who value a particular mixed approach. Training staff in key modelling skills to ensure longevity of the skills becomes an important management option.

Another nuance mentioned was the need for those in the modelling team to “*speak the language*” of the modelling approaches “*and understand the data*” (P5). This, to a degree, has been noted in the literature. For example, Velez-Castiblanco and colleagues comment that multi-disciplinary teams “don’t have shared methodological language” (2016, pg. 974). Whilst Velez-Castiblanco and colleagues were particularly focused on multi-disciplinary teams it is true also for those operating within the OR discipline. Other examples of language challenges include one interviewee noting “*the fact that he knows both sides of the coin, he knows the simulation and the optimisation...And that’s why maybe phase one for (name) and (name) didn’t go as well, because (name) could never speak the simulation language, she couldn’t get her head round it. She was an optimisation person, whereas (name) can do both and can do both really well.*” (A7). The ability to speak different languages is also highlighted by Kotiadis and Mingers (2006). They discuss a competence to support moving between paradigms as the ability to move between languages and cultures.

The skill of being able to ‘see’ the big picture (i.e. understand how the different modelling approaches complement one another) was also seen as important. This required modelling team members to be able to both effectively engage with specific aspects of each modelling approach as well as challenge the insights gained from each modelling approach and paradigm. It has been noted in the literature that a “precondition for the successful combination is that facilitators are familiar with both methods and are fully involved throughout the whole process” (Marttunen et

al 2017, p. 6). The interviews added both depth and breadth to this consideration. One interviewee noted, there are *'advantages of having the other person looking at the project providing dialectical contributions'* (A4) – in essence providing a 'devil's advocate' role increasing the robustness of the ensuing outcomes. This skill to some extent relates to the next subsection on personal appetite and organisational culture and also project lead as project leads often took on this role.

#### 4.1.2 Personal Inclinations and Organisational culture

Along with skills, personal inclination or appetite emerged as a key consideration as noted by 9 interviewees. For example, *'being willing to have a go with other people who have different sets of expertise and different skills'* (A1) or *"having an interest in a variety of things is a strength"* (A5) is important.

Adding to this is the observation that different modelling competences appear to manifest in different working styles. It was noted that *'SD<sup>2</sup> people are more interested in the process, the insights it generates, DES not so much'* (A8) suggesting complementarity of personality preferences. This extends discussion presented by Ormerod that approaches to modelling are highly dependent upon the skills, knowledge, personal style and experience of the modellers involved (2008).

Personal inclination ties into the establishment of an organisational culture conducive to mixing methods. One interviewee noted, mixing methods is *"the normal thing to do"* (P4) in their

---

<sup>2</sup> SD is System Dynamics and DES is Discrete Event Simulation

organisation. It was also noted that “*working in the team gives confidence in mixing methods in the future*” (P4) and “*we try to introduce the juniors*” (P5). Building appetite for mixing methods was augmented by one interviewee commenting on a project whereby a team member was a student and noting that “*unless you give somebody a chance to do it, they are not going to learn*” (A3). Mixed methods teams not only helped instil the mixing methods mindset but also worked to encourage the development of skills. It was felt by many of the interviewees that working in a team gives confidence in mixing methods both in the present and future.

Another reoccurring observation made by interviewees (5) was the significance of team dynamics. For example, “*choose your colleagues well – those you get on with, whom you respect*” (A1). When considering aspects of team dynamics that are specific to mixed methods work, and building on the learning point above, some interviewees discussed an integrated mode of working where the modelling team worked together on the overall approach, learning about how the different methods complemented each other. This again requires that the modellers had the skills and inclination to be able to understand and sympathise with each other’s methods. This was seen as important as reflected by one interviewee who noted “*this sort of model you are doing isn’t my particular bag but I can see you are building a good model and it answers questions*” (P3). Another interviewee noted “*a lot of time was spent with (name) and me ...doing that together so that we’d try and create - what’s the word - we’d try and get those compatible with each other. .. If she’d have issues in the map she’d tell that to me to try and implement, but when I found problems in the model I’d go back and say, ‘Well, come on. This doesn’t make sense’ and we’d look at the map again.*” (A6) and thus mixed methods teams need to move to a more “*receptive mode than directive mode*” (P3). This appetite for integrative modes of working had logistical implications (in terms of undertaking the work). For example,

interviewees noted that the team worked side by side throughout the entire intervention “*most of what we did we did as a team*” (A6) or “*we would sit together and go through the model and check parts, and change things together, and so on*” (A3). In contrast, two practitioners noted that the different models (and therefore modellers) that were involved in the modelling intervention were quite separate from one another. “*We would bring people in, you know, just drop someone in for a very specific chunk of it... We sort of boxed it off.*” (P1). As such different team working patterns were evidenced depending on availability and possibly appetite.

Although it is important in any group for team members to be able to work together, this is particularly the case in mixed methods work where modellers with different expertise need to understand the work of other modellers, appreciate the value that it brings, be prepared to change their own models depending on how they are merged with other models and work across paradigms. As such, trust emerged as a critical component reflected in interviewee statements (5). For example, “*if one said ‘I think that is not going to work’ the other asked why rather than ‘you don’t know what you are talking about’*” (A1). It was important for team dynamics to be able to challenge each other intellectually. Many of the interviewees discussed different aspects of respect and trust including that being gained based on a previous relationship with other team members, through working together, being based in the same organisation and being aware of previous work undertaken by the other team members, making comments such as “*it is important that personal relationships are reasonably good between different members*” [P7]. Trust was also reflected in maturity as well as competence e.g. “*One of my best students, I trust him, he was older and more experienced* (A2).

Building good trusting relationships within the team could be facilitated by encouraging the team to *“sit together and go through the model, check parts, change things together”* (A3). Another way of developing trust was to *“get together early, as a partnership team, that set the direction, a touchstone we always went back to”* (P2). This suggested an emphasis not only on building trust but on shared direction and ownership. In addition, respect between modellers can allow them to challenge one another: *“the minute you use two methods then having two people not only allows you to be able to play to each other’s competencies but challenge each other’s competencies.”* (P3). Challenging each other’s work can provide benefits through testing the rigour of the modelling approach. However, gaining sufficient trust and respect for all members of a team to enable such challenges can be demanding when modellers may not have previously worked together and may have different working styles (Howick et al, 2017). Some of the interviewees noted that this trusting and respective behaviour allowed for a more fluid approach to be taken as illustrated by comments such as *“we were recognising that we were ‘developing’ things as we went along”* (A5).

Effective team dynamics also related to continuous learning (5 interviewees). As one interviewee noted, he had an appetite to learn *“SSM<sup>3</sup> I always have someone who knows [name] or [name] because I wouldn’t really dare do it myself but I’m learning because I want to learn”* (A2). Another commented working on mixed methods projects enabled cross paradigm learning for example *“encouraging the development of process skills e.g. [name] who is engaging more and more and developing confidence”* (A7). This interest in learning new methods was not only noted by academics but also by the practitioners.

---

<sup>3</sup> SSM is Soft Systems Methodology

#### 4.1.3 Significance of the project lead

Team culture and skills management were closely associated with the importance of having a modelling team leader. Nine interviewees explicitly commented on the importance of a leader within the modelling team. Whilst there was a range of modelling team sizes (from 2 to 9 modellers) it was noted that even in the smaller teams the leader was a key consideration. It was recognised that some of the leadership tasks were not mixed methods specific such as taking ownership and responsibility for the project, acting as the main contact with the client, leading the design of the intervention.

However, within a mixed methods context, the need for someone to oversee the integration of the different methods alongside the other tasks was repeatedly raised. One interviewee described modellers having regular meetings to discuss “*the interaction effect*” and how “*the interaction (had) ...to be prodded*” (A7) by the leader. The same interviewee stated that: “*one of my potential values ... was understanding the limitations of both tools under the circumstances they were being adopted in, and in the terms of the decision-making context ... my focus was on making sure that (the modellers) were bringing it back to being something that was actually usable, not just something that was done.*” (A7). A practitioner noted “*you are the facilitator of the modelling team, you bring them together, help them structure their conversations*” (P3). The leader appears to have a key role in effective integration. This is briefly touched on in a case study in the literature (Howick et al 2017) however interviewee comments both elaborated and reinforced the importance.

Furthermore, the project leader was considered to need to possess a wide range of skills/competences. One interviewee (who had been a project lead) noted he “*filled in the gaps all the time, doing client liaison, organising meetings, asking the awkward questions in meetings,*

*suggesting crazy ideas some of which worked*” (A1) whereas another interviewee commented that the project leader was *“an overseer, front man, client facing person”* (A6) and a practitioner noted *“you are a facilitator of the modelling teams, you bring them together, help them structure their conversations”* (P3). With respect to mixed methods, the range of leadership competences is expanded including requiring them to fill in the gaps in terms of modelling skills and assist with the integration of models.

Alongside the client and model integrator focus was for those in the role *“to interest them in doing things that we need doing”* (P3). This was associated with *“issues relating to the maintenance of teams and the management of teams – the continuity”* (A7) of staff and thus relating to one of the considerations regarding skills mix in section 4.1.1. The consideration also ties in with 4.1.2 namely personal inclinations of team members.

Additionally, one interviewee noted the role took on an enhanced project management flavour commenting on the need for establishing *“project management on all such projects”* (P2).

Project management duties included client management, and team composition (a number of the interviewees noted that there were both ad hoc (often expert) members alongside those who were the regular team). Thus, project management included knowledge management elements. The analysis revealed that it was important for the project leads to *“know who is around, what skills they have (and preferences)”* (P4) to be able to deal with different kinds of models and situations and glue together the people who have the expertise in different areas to meet project requirements. Thus, working in a mixed methods mode, project management duties were increased.

The final point to note was that, for at least a couple of the interviewees, the existence of people with these capabilities is scarce – one interviewee noted that the *“role of the integrator, that is*

*[name] bringing together [the different techniques] is a rare thing” (P4).* In coordinating the work, the leader may need to have a broad understanding of multiple methods to be able to appreciate the links between the different methods and be able to communicate the work as a whole as well as the separate activities to the client and other stakeholders along with managing the team.

#### 4.1.4 Summary

Table 1 reflects a synthesis of the insights gained from the interviews. Whilst some of these touch on insights already noted in the mixing methods literature and/or OR modelling in general they present an extended and integrated set. As noted in the beginning of the section, the three sub-themes are inter-related – for example becoming proficient in mixed methods approaches will enable the modelling team members to speak ‘different languages’ (an example of intra-subtheme linking) or the project lead interests the team in a mixed methods approach which could relate to both personal inclination and organisational culture (inter subtheme linking).

TABLE ONE SHOULD APPEAR HERE

Table 1. Summary of the insights about modelling teams

#### **4.2: Methods used and the nature of Mixing Methods**

The interviewees’ responses touched on many of the topics already in the literature in relation to the other themes however some additional nuances emerged for methods used. One interviewee commented that one of the reasons for mixing methods was the fact that one of the methods “*was used as a recording device*” (A1). Another noted that they used “*mapping for the clarification of project objectives*” (P4) suggesting that the combination could be for project management purposes as well as resolution of the problem.



Another nuance that emerged related to adoption of the outcomes by the various stakeholders. One interviewee observed that soft OR/mapping provided a degree of procedural justice<sup>4</sup> as stakeholders *“found the mapping sessions incredibly powerful democratic, they felt empowered”* with MCDM providing the procedural rationality *“The evaluation was what it was all about, trying to allocate a particular value to an activity. And they saw that as a scientific thing”* (A2) and another commented that mixing methods helped to *“Gain buy in with multiple key stakeholders”* (A1). Building on this it was noted that *“mixing methods is ideology as well as realism and getting engagement - capturing that complexity shows them that you really understand their world”* (A8).

A final observation made relating to the mixes employed was how they are perceived. One practitioner noted *“I see bits of different methods but to an external person they see [name of modelling approach]”* (P4). The appreciation of the mix to the client varied with one interviewee noting *“I don’t think they’re interested in the fact that you’re using two different methods”* (A8) whereas another interviewee commented *“the client decided to explore the extent to which they could be eventually mixed”* (A4) suggesting different appetites. The lack of awareness of the use of mixed methods was also true of the modelling team as they *“may mix methods without being aware of it e.g. any simulation project, stand-alone DES project, you do some problem structuring, and you may do it deliberately or not”* (A8).

It is worth noting that points raised in this section also have implications for the insights noted in table 1. For example, they place demands on the project lead. If mixed methods are used to support project management, the project lead will need to be proficient in these methods. Also, if

---

<sup>4</sup> For details on Procedural Justice see Kim and Mauborgne (1995)

mixed methods can help gain stakeholder buy-in, then this has implications for client management.

### **4.3 Project outcomes and benefits**

The value added of mixing methods i.e. appreciating the benefits of the intervention was less developed (both in the interviews and literature). Value is in the eye of the beholder and as noted by Eden and Ackermann (1996) mixing methods can be seen by the client as being very valuable but by the other participants as being problematic as the outcome of the modelling has resulted in some participants' power being reduced.

Nevertheless, there were some interesting fragments. The first was the number of interviewees that noted that one of the benefits of using mixed methods was the training opportunities. For example, the mix enabled "*client training staff as well as solving problem*" (A1). This reflects the challenges experienced in familiarising staff and touches on apprenticeships (Ackermann 2015). In four instances the client (or members of the client organisation) undertook some of the modelling effort.

Interviewees discussed benefits that were gained from the use of individual methods. It was also noted that value can be gained from the process of mixing, which goes beyond the value gained from individual methods. For example, "*...the value was by having these two things talk to one another*" ... "*the output of the optimisation wouldn't be there unless the simulation was there.*" (A7). However, it does not necessarily always occur. Interviewees struggled to answer the questions regarding value gained from the integration as opposed to the individual modelling components. One explanation is that methods may be used in sequence with one another (Morgan et al 2017; Schultz and Hatch 1996) and have limited impact on each other. "*What I*

*would have liked to be able to spot is, whether the impacts were synergistic... they were not synergistic in that sense. They were just additive. One thing did this, fulfilled a particular objective. This other thing fulfilled another objective. But I didn't get an objective square, you know what I mean or to the power of 3 which I would have liked to but maybe because they were used sequentially. If they had been used somehow in a different manner, they would have achieved something more systemic in their impact.” (A2).*

Finally, there were the ‘academic’ benefits – learning and trying out new methods. *“Perhaps it all could have been done with SCA<sup>5</sup> alone but it is generally a bit plodding following traditional approaches and not necessarily in the traditional order. You're trying to imagine the future and do new things in new ways with new technology – one needs to get creative, even inspired” (P6).*

Again, the above has implications for the insights included in table 1 and the modelling team. For example, if there is an expectation or desire from a client to enable their staff to be trained, then this has implications for the skills of the modelling team (in terms of transference) and the project lead (in terms of scheduling and design). In addition, trying out new methods links to being flexible in terms of integration and the methods that are used.

## **5. Discussion**

As was noted in the introduction, when dealing with mixed methods *practice* much of the extant literature has focused on technical aspects and/or been focused on single cases. This work therefore sought to look at the wider implications of a mixed methods approach on the modelling process. Analysis of the data collected from the interviews revealed that the majority of new

---

<sup>5</sup> SCA is Strategic Choice Analysis

insights centred on modelling teams with some additional nuances for two of the other themes. Additionally, there was confirmation of the insights already noted in the extant literature.

### *Extending the demands on OR modellers*

Based on the interview data it became apparent that working in a mixed methods arena increased the demands on OR modellers across the spectrum. This was illustrated in Table 1.

Ormerod (2008, 2014b) provided a compilation of OR competences. The multi-faceted set of skills required by a mixed method modelling team resonates and elaborates Ormerod's (2014b) reflection on the ongoing development of OR skills. The findings note extensions to the designing and managing process. In addition, context knowledge was also seen as a necessary and important component of mixed methods work by the interviewees. For example, one of the interviewees noted that it was important that they had a *'dedicated director in the area who lives and breathes health and knows all the acronyms'* (P5).

The findings also align with the views of Fildes and Raynard (1997) in terms of challenges when working in a mixed method arena as well as with Mingers and Munro (2002). Franco and Lord comment "Applying both methods in a single intervention, however, requires a different set of modelling skills on the part of the analyst, particularly with regards to how data is collated, coded, and manipulated" (2011, p. 364). Therefore, approaches to modelling are highly dependent upon the skills, knowledge, personal style and experience of the modellers involved (Ormerod, 2008; Morgan et al., 2017) and bringing together the right mix of skills in a modelling team is seen to be an important aspect.

Whilst some of the findings build on Ormerod's research on OR competences it is noted that Ormerod was considering competences at the individual level whereas this work dealt with the

modelling team. It is recognised that skills and competences are individual and the findings illustrate that OR modellers are increasingly needing to go beyond standard OR skills. However, given the focus on teams, it is important to note that it is not necessary to have each member skilled in the particular method's application but rather have an overarching understanding of its mechanics allowing effective discussions. There is a need to speak the common language for effective integration. This has clear implications for training – whether that be through university courses or on the job apprenticeship learning.

*Attending to personality and culture.*

This relates to the significance of attending to the necessary organisation culture and individual personality considerations when embarking upon mixed methods modelling. Identifying appropriate members who have both technical skills and an appetite to integrate becomes a key challenge. This reflects a psychological as well as cognitive appetite. This builds on work by Tomlinson and Idama (1986) who looked at the personality traits of OR workers and O'Keefe's (1989) comment on the need for a mixture of cognitive styles in OR groups. Alongside this is instigating an organisational culture where mixed methods modelling is valued – one that nurtures mixed methods teams. Such support for mixed methods modelling teams may constitute training in areas such as team working and organisational behaviour as well as recognising the many roles necessary and selecting teams based on mixed skills and appetite. This development of team/organisational cultures amenable to mixing methods may be instigated through encouraging a willingness to continuous learning – tapping into modellers' curiosity and enquiry. Thus, organisations need to pay attention to developing staff over time

*Ensuring the presence of a project lead.*

This centres on the important role a project lead plays. Here organisations are recommended to recognise that there is an increased range of skills demanded in the role from both a technical and processual foci. Viewing training from a more holistic angle – one that attends to both process and content may be one approach to ensuring the development of these individuals. The significance of a project lead was touched on by Howick and Ackermann (2017) and this work both confirms and elaborates their findings.

## **6. Limitations**

As with any research this work has its limitations. The first centres on those interviewed – both in terms of quantity and background. Whilst 15 is not a large number, participants had significant experience in practising mixed methods. Accessing practitioners is always difficult and having only 15 interviewees in total may have resulted in limited insights. However, it is the view of the authors that the sample both revealed new insights and reflected some form of saturation given the last 1-2 interviews raised minimal new areas of insight. Also, the interviewees may have chosen a biased selection of projects – those that were relatively successful. Specifically requesting interviewees to include projects that were less successful may have yielded different insights. That said, interviewees were allowed to choose their projects and not all ended up with overtly successful outcomes (Eden and Ackermann, 1996).

The interviewee questions derived from the literature might also have been, to a degree, idiosyncratic. That said, when interviewees were asked if there was anything to add few could identify missing considerations. Interviewees took different approaches/angles/topics when reflecting on the cases selection and, in several occasions, interviewees spoke for well over an hour suggesting that they did not feel constrained.

The final concern centres on the volume and nature of the findings. It was interesting to note that interviews with academics, overall, were deeper – a not altogether surprising finding given many of them have the legitimacy and interest for reflecting on practice. Furthermore, on reflection, it was realised that practitioners are not a single category but rather comprise in-house practitioners (5) and consultants (2) with different demands and context. Thus, particularly in relation to consultants, a small sample has been interviewed leading to potential un-representativeness.

Due to each of the above limitations, the insights may only represent the experiences of those interviewed. However, the authors feel that the insights presented above were raised by a number of interviewees and were sufficiently detailed to give a degree of saturation (Glaser and Strauss 1967).

## **7. Future work**

The insights gained have implications for practice, research and teaching and thus provide avenues for further work in each of these areas.

The increasing complexity of problems that decision-makers face mean that mixed methods work is becoming the norm and novice OR modellers need to be prepared for this type of modelling. The insights into the skills, roles, cultures, and personalities required by mixed methods modelling teams helps extends existing knowledge on effective mixed method modelling. Apprenticeship working has been suggested as a way in which novice OR modellers can gain an appreciation of effective mixed methods work. Those teaching OR modelling are also encouraged to consider how this can be taught. Sharing best practice, and learning from one another within organisations, could be augmented by considering specific learning from undertaking mixed methods work. This

learning is likely to be useful throughout an OR intervention as mixed methods work increases the demands on a modeller across the OR process.

From a research point of view, this paper has highlighted a number of implications of mixed methods work, in particular resonating with Behavioural Operational Research (BOR), (Franco and Hamalainen 2015, White 2016, Brocklesby 2016). Its focus on human decision-making behaviours, whilst currently positioned at participants, is also relevant for modelling teams. There are therefore several avenues for researchers to explore such as how teams of modellers can build the skills required to undertake effective mixed methods work, ensuring a culture that allows the team to work effectively together ensuring trust and engagement with each other's models and how the role of a project lead impacts a modelling team.

Finally, although this paper has highlighted a number of benefits accrued from undertaking mixed methods work, it also reveals challenges (e.g. extensiveness of skills) that are associated with mixed methods work. It is therefore beneficial for any modeller to be aware of these challenges before commencing a client intervention.

## References

- Ackermann, F. (2012). Problem Structuring Methods 'in the dock': Arguing the case for Soft OR'. *European Journal of Operational Research*, 219, 652-65
- Ackermann, F. (2015). Teaching Soft OR Methods: What, Why and How? In the *Wiley Encyclopaedia of Operations Research and Management Science*, Wiley 1-9
- Ackermann, F., Andersen, D.F., Eden, C., & Richardson, G.R. (2011). 'ScriptsMap: A tool for Designing Multi-Method Policy-Making Workshops'. *Omega*, 39, (4), 427-434



Ackermann, F. & Eden, C. (2011). Strategic Management of Stakeholders: theory and practice. *Long Range Planning*, 44, 179-196

Andersen D.F., & Richardson G.P. (1997). Scripts for group model building. *System Dynamics Review* 13, 107–30.

Argyris, C., & Schon, D. (1978). *Organizational Learning: a theory of action perspective*. Reading, Mass. Addison-Wesley.

Brocklesby, J. (2016). The what, the why and the how of behavioural operational research: An invitation to potential sceptics. *European Journal of Operational Research*, 249(3), 796-805.

Corbett, C. J., Overmeer, W. J. A. M., & Van Wassenhove, L. N. (1995). Strands of practice in OR (The Practitioner's Dilemma). *European Journal of Operational Research*, 87(3), 484-499.

Creswell, J. W. & Creswell J.D. (2018). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. Fifth Edition, Sage, Thousand Oaks, California.

Eden, C., Ackermann, F., & Cropper, S. (1992). The Analysis of Cause Maps. *Journal of Management Studies*. 29, 309-324.

Eden, C. & Ackermann, F. (1996). 'Horses for Courses - A Stakeholders View of GDSS' *Group Decision and Negotiation*, 5, 501-519

Eden, C. and Ackermann, F. (2004). Use of soft OR models by clients - what do they want from them? In M. Pidd (Ed), *Systems modelling: Theory and Practice*, (pp. 146-163) Wiley, Chichester

Fildes, R. & Ranyard, J.C. (1997). Success and survival of operational research – A review. *Journal of the Operational Research Society*. 48, 336-360.

Franco, L.A. & Greiffenhagen, C. (2018). Making OR practice visible: Using ethnomethodology to analyse facilitated modelling workshops. *European Journal of Operational Research* 265 (2), 673-684.

Franco, L.A. & Hamalainen, R.P. (2015). Behavioural operational research: returning to the roots of the OR profession. *European Journal of Operational Research* 249 (3), 791-795

Franco, L. A., & Lord, E. (2011). Understanding multi-methodology: Evaluating the perceived impact of mixing methods for group budgetary decisions. *Omega*, 39(3), 362-372.

Franco, L.A. & Montibellar, G. (2010). Facilitated modelling in operational research. *European Journal of Operational Research*. 201 (3), 489-500

Franco, L.A. and Rouwette, E.A.J.A. (2011). Decision development in facilitated modelling workshops. *European Journal of Operational Research*. 212 (1), 164-178

Glaser, B. G., & Strauss, A. L. (1967). *The Discovery of Grounded Theory*. Chicago: Aldine.

Hamalainen, R.P., Luoma J., & Saarinen, E. (2013). On the importance of behavioural operational research: The case of understanding and communicating about dynamics systems. *European Journal of Operational Research* 228 (3), 623-634.

Harwood, S.A. (2011). Mixing methodologies and paradigmatic commensurability. *Journal of Operational Research*, 62(4), 806-809.

Henao, F., & Franco, L. A. (2016). Unpacking multi-methodology: Impacts of a community development intervention. *European Journal of Operational Research*, 253(3), 681-696.

Howick, S., & Ackermann, F. (2011). Mixing OR methods in practice: Past, present and future directions. *European Journal of Operational Research*, 215(3), 503-511.

Howick, S., Ackermann, F., Walls, L., Quigley, J., & Houghton, T. (2017). Learning from mixed OR method practice: the NINES case study. *Omega*, 69, 70-81.

Huxham, C., and Cropper, S. (1994). From many to one – and back. An exploration of some components of facilitation. *Omega*. 22 (1), 1-11

Jackson, M. C. (1999). Towards coherent pluralism in management science. *Journal of Operational Research Society*, 50 (1), 12-23.

Jackson, M.C. (2011). The multi-methodology debate: a response to Harwood. *Journal of Operational Research*, 6 2(4), 811-813.

Keys, P. (2000). Creativity, design and style in MS/OR. *Omega*, 28, 303-312.

Kim, W. C., & Mauborgne, R. A. (1995). A Procedural Justice Model of Strategic Decision Making. *Organization Science*, 6(1), 44-61.

Kirby, M. W. (2003). *Operational research in war and peace: The British experience from the 1930s to 1970*. London: Imperial College Press.

Kotiadis, K., & Mingers, J. (2006). Combining PSMs with hard OR methods: the philosophical and practical challenges. *Journal of the Operational Research Society*, 57(7), 856-867

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. Los Angeles: Sage.

Marttunen, M., Lienert, J. and Belton, V. (2017). Structuring Problems for Multi-Criteria Decision Analysis in practice: A literature review of method combinations. *European Journal of Operational Research*, 263, 1-17

Midgley, G., Cavana, R. Y., Brocklesby, J., Foote, J. L., Wood, D. R., & Ahuriri-Driscoll, A. (2013). Towards a new framework for evaluating systemic problem structuring methods. *European Journal of Operational Research*, 229(1), 143-154.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An expanded sourcebook* (2 ed.). London: Sage.

Mingers, J. (2000). Variety is the spice of life: combining soft and hard OR/MS methods. *International Transactions in Operational Research*, 7(6), 673-691.

Mingers, J. (2001). Multi-methodology: Mixing and matching methods. In J. Rosenhead & J. Mingers (Eds). *Rational analysis for a problematic world revisited* (pp 289-309). Chichester: Wiley.

Mingers, J. (2003). A classification of the philosophical assumptions of management science methods. *Journal of the Operational Research Society*, 54(6), 559-570.

Mingers, J. (2011). Clarification or confusion: response to Harwood. *Journal of Operational Research*, 62 (4), 809-811.

Mingers, J., & Brocklesby, J. (1997). Multi-methodology: Towards a framework for mixing methodologies. *Omega*, 25 (5), 489-509.

Mitchell, G. (1993). *The Practice of Operational Research*. Wiley: Chichester.

Morgan, J. S., Howick, S., & Belton, V. (2017). A toolkit of designs for mixing discrete event simulation and system dynamics. *European Journal of Operational Research*, 257(3), 907-918

Munro, I., & Mingers, J. (2002). The use of multi-methodology in practice: Results of a survey of practitioners. *Journal of the Operational Research Society*, 53(4), 369-378.

O'Keefe, R. (1989). The Implications of Cognitive-style Findings for Operational Research. *Journal of the Operational Research Society*, 40 (5), 415-422.

Ormerod, R. J. (2008). The transformation competence perspective. *Journal of the Operational Research Society*, 59 (11), 1435-1448.

Ormerod, R. J. (2014a). The mangle of OR practice: towards more informative case studies of 'technical' projects. *Journal of the Operational Research Society*, 65(8), 1245-1260.

Ormerod, R. J. (2014b). OR Competences: the demands of problem structuring methods. *EURO Journal of Decision Process* 2, 313-340

Patton, M. Q. (2014). *Qualitative Research and Evaluation Methods: Integrating Theory and Practice. Fourth Edition*, Sage, Thousand Oaks, California.

Pidd, M. (2003). *Tools for Thinking: Modelling in Management Science*. Wiley: Chichester

Pollack, J. (2009). Multi-methodology in series and parallel: strategic planning using hard and soft OR. *Journal of the Operational Research Society*, 60 (2), 156-167.

Reason, P., & Rowan, J. (1981). *Human inquiry. A sourcebook of new paradigm research*. Chichester: Wiley.

Schultz, M. & Hatch, M. J. (1996). Living with Multiple Paradigms: The Case of Paradigm Interplay in Organisational Culture Studies. *Academy of Management Review*, 21(2), 529-557.

Seidman, I. (2013). *Interviewing as Qualitative Research: A Guide for Researchers in Education and the Social Sciences*. Teachers College Press, NY.

Tomlinson, R. & Idama, A. (1986). The Personality of OR Workers – Are they Different? *Journal of the Operational Research Society*, 37, 1039-1045.

Velez-Castiblanco, J., Brocklesby, J., & Midgley, G. (2016). Boundary games: How teams of OR practitioners explore the boundaries of intervention. *European Journal of Operational Research*, 249(3), 968-982.

White, L. (2016). Behavioural operational research: Towards a framework for understanding behaviour in OR interventions. *European Journal of Operational Research*, 249 (3) 827-841

White, L., Burger, K., & Yearworth, M. (2016). Understanding behaviour in Problem Structuring Methods interventions with activity theory. *European Journal of Operational Research*, 249(3), 983-1004.

Williams, T.M. (2008). *Management Science in Practice*. Wiley: Chichester.

Zhu, Z. (2011). After paradigm: why mixing-methodology theorising fails and how to make it work again. *Journal of the Operational Research Society*, 62(4), 784-798.

## **Appendix I: NVivo Nodes**

### **Context to the Intervention**

- About the project client
- Characteristics of the problem situation
  - Prompt or driver for the project
  - Scale of intervention

### **About the Modelling Team**

- Its operation
  - Location of the Project Team
  - Task Allocation
- Membership
  - Identifiable leadership
  - Include members outside of the modelling team
  - Rationale for inclusion of individual members
- Recruitment of individual members
  - By snowballing using existing networks
- Requisite size
- Respect for one another's contribution

### **Applying a Mixed-method approach**

- Choice of specific mixed method approach
  - General approach to mixed method modelling
  - In full, or partial, use of methods
  - Influenced by client demand

- Influenced by modellers' confidence or experience in mixing methods
- Influenced by pragmatism – chosen to meet the project objectives
- Methods complemented one another
- Parallel or sequential use
- Recognition that it is bespoke rather than blind adherence to script
- Client or stakeholder acceptance of Mixed Method approach
  - Client or top management support (resource/political)
  - Stakeholder acceptance due to mixed methods
  - Stakeholder acceptance of soft methods and their outputs
- Developing Mixed Methods skills
- Good modelling practice
- Specific modelling approaches used (e.g. SODA, SSM, VIM, SD, DEA)
- Visibility of methods
  - Backroom
  - Visible/Interacting with client

### **Post Intervention**

- Client use of method or solution
- Conducting post intervention reviews
- Learning or Insights gained for future interventions
- Perceptions of success of interventions
  - Measuring success
- Publishing
- Theoretical lessons from modelling



Figure 1: Flow chart illustrating the research method employed

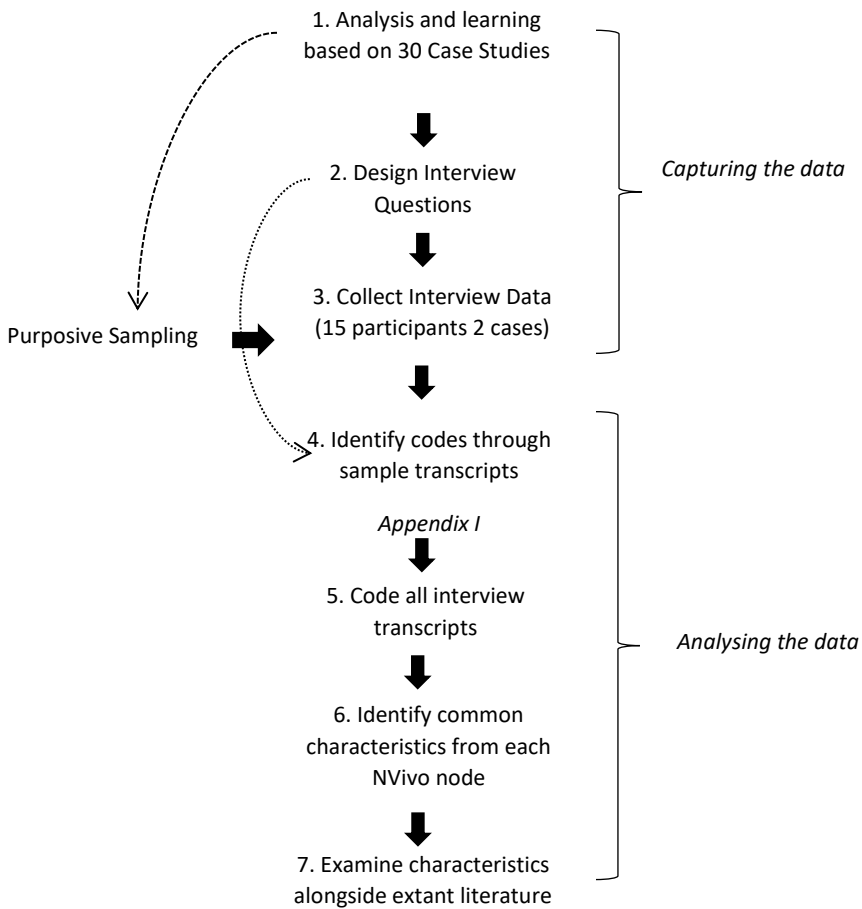


Figure 2: Small section of the NVivo database relating to modelling team.

2_About the modelling team	0	0
its operation	2	2
location of the project team	3	3
task allocation	24	51
membership	2	2
identifiable leadership	11	15
includes members outside of the modelling team	9	16
rationale for inclusion of individual members	20	49
recruitment of individual members	7	9
requisite size	15	16
respect for one another's contribution	11	17

Table 1: Summary of insights about modelling teams

Skills	Culture and Personality	Project Lead
<ul style="list-style-type: none"> <li>• Members gain proficiency in a mixed methods approach</li> <li>• Members willing and able to speak the different modelling languages</li> <li>• Teams able to adapt to continual refreshment as modelling skills change over time</li> <li>• Team members ability to see ‘the big picture’</li> </ul>	<ul style="list-style-type: none"> <li>• Team members require a personal inclination (openness) for mixed method working</li> <li>• Organisational culture conducive to mixing</li> <li>• Different logistic modes available for team working</li> <li>• Team members respect and trust one another</li> <li>• Flexibility in terms of integration and methods used</li> <li>• Appetite for continuous learning with respect to mixed methods</li> </ul>	<ul style="list-style-type: none"> <li>• Project lead oversee/manage the integration of mixed methods</li> <li>• Project lead interests the team (in the mixed methods approach)</li> <li>• Project lead manages enhanced project management demands</li> <li>• Project leads possess a wide range of skills/competences – process and content/modelling</li> <li>• Project lead/integrator skills are rare and thus require development</li> </ul>