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Short title: The HTA modelling process

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At the time of this study Jim Chilcott was the Technical Director of ScHARR-TAG, the Research Group responsible for this work, and is the guarantor of this study.

Contributions of authors

Jim Chilcott led the project. Jim Chilcott, Paul Tappenden and Suzy Paisley were responsible for the design of the study. Jim Chilcott, Paul Tappenden and Andrew Rawdin undertook all in-depth interviews. All authors contributed towards the qualitative synthesis methods and implementation.

ABSTRACT

Introduction The role of models in supporting health policy decisions is reliant on model credibility. Credibility is fundamentally determined by the choices and judgements that people make in the process of developing a model. However, the method of uncovering choices and making judgements in model development is largely unreported and is not addressed by modelling methods guidance.

Methods This qualitative study was part of a project examining errors in health technology assessment models. In-depth interviews with academic and commercial modellers were used to obtain descriptions of the model development process. Data were analysed using framework analysis and interpreted in the context of the methodological literature.

Results The activities involved in developing models were characterised according to the themes; understanding the decision problem, conceptual modelling, model implementation, model checking, and engaging with the decision maker. Finding and using evidence was frequently mentioned across these themes. There was marked variation between practitioners in the extent to which conceptual modelling was recognised as an activity distinct from model implementation.

Discussion Methodological approaches to addressing model credibility described in the wider modelling literature highlight the necessity to disentangle the conceptual modelling and implementation activities. Whilst interviewees talked of judgements and choice making throughout model development, discussion indicated that these were based upon skills and experience with no discussion of formal approaches. Methods are required that provide for a systematic approach to uncovering choices, to generating a shared view of consensus and divergence, and for making judgements and choices in model development.

INTRODUCTION

Health technology assessment (HTA) models have been described as mathematical models of the natural history, epidemiology and treatment of a disease designed with the purpose of predicting how a technology will affect clinically important outcomes.[1] Such models are regularly used by the National Institute for Health and Clinical Excellence (NICE) in England and Wales and similar structures internationally in supporting health policy decisions and are central to the development and evaluation of complex interventions. The key role that models play is, however, reliant on their credibility, an issue that has proved to be a perennial and intractable cause for concern.[2,3]

At its most mundane a mathematical model comprises a set of outputs of interest to a decision maker, a set of input parameters and a functional relationship between these inputs and outputs. However this simple description implies several accoutrements including; a set of evidence identified as being relevant to the input parameters and functional relationship encapsulated in the model, a set of assumptions regarding the nature of that relevance, and a relationship between the defined outputs and the decision problem being addressed. Many choices and judgements are involved in composing such a model; choices about the nature of the decision problem, the scope and design of the model, choices about modelling platform, about data and so on. The HTA model development process is the process of making these choices, of uncovering modelling options, of evaluating choices and making design judgements and decisions regarding the model. The activities associated with making these judgements are not explicitly addressed by current

guidelines and they are rarely reported, recognised or discussed in reports of modelling studies.[4] This paper is about that model development process and its importance in establishing the credibility of models.

METHODS

The qualitative study reported here was undertaken as part of a wider project examining the understanding of the occurrence of errors in models in the HTA modelling community.[5] Face-to-face in-depth interviews[6] were undertaken between September and October 2008. Whilst the interviews were intentionally flexible and participant-focussed, a topic guide was designed to facilitate their flow. Interviews began with a description of the professional background and organisational context within which respondents worked, progressed to an exploration of modeller's views on the modelling process, followed by a discussion of errors throughout the modelling process and techniques and strategies for avoiding and preventing such errors. During each of the twelve interviews the modelling process was sketched in the form of a process map and validated with the respondent.[7] A synthesis meeting was held with all the authors to draw together and analyse evidence from the process maps. This meeting informed decisions regarding the subsequent qualitative process and identified emergent themes from the interviews. Interview transcripts were analysed using the inductive thematic Framework approach.[8] Respondent validation was provided by obtaining feedback from the interviewees on whether the findings represented their views.[9] This paper reports the qualitative analysis of the elements of the interviews focussing on the model development process.

Twelve interviewees were drawn from across the HTA modelling community, four based in outcomes research organisations involved in making submissions to NICE on behalf of the healthcare industry and eight from the academic sector involved in preparing reviews for NICE . Two of the eight academic interviewees also referred to working for commercial clients in a consultancy role. Five respondents came from an economics or health economics background, two from a mathematical background and five had an operational research or modelling background. Eleven respondents focussed on spreadsheet modelling with Microsoft Excel®, other software platforms discussed included the decision analysis software TreeAGE, the discrete event simulation package Simul8, and more broadly Crystal Ball, WinBUGS, STATA, Delphi, Visual Pascal and SPSS.

RESULTS: THE MODEL DEVELOPMENT PROCESS

The analysis of the interview data provides a description of current model development practice as perceived by the interviewees. Process maps were drawn up for each interviewee during the interviews, an example map is presented in Figure 1 and a full set of maps are presented elsewhere.[5]

[Figure 1 here]

A generic structure for the model development process was obtained from a synthesis of the process maps and included five broad activities; understanding the decision problem, conceptual modelling, model implementation, model checking, and engaging with the decision. A sixth group of activities related to finding and using

evidence was frequently mentioned by the interviewees at different points throughout the process presented in Figure 2. A sample of quotes relating to the different activities is included in Table 1.

[Figure 2 here]

[Table 1 here]

Understanding the decision problem

All participants identified the first set of activities in the model development process as generating an understanding of the decision problem. Common themes raised by the interviewees in this phase were familiarisation with the decision problem, defining the research question, understanding the needs of the client and moving towards a modelling approach. This phase of the model development process was characterised by the rapid parallel development of these themes.

In explicitly considering the definition of the research question interviewees focussed on identifying appropriate comparators, interventions, populations and outcomes. This reflects the PICO definition of a scope or clearly focussed question arising from the evidence based practice movement of Sackett and Cochrane.[10,11] Modellers also referred to a set of characteristics related to the decision problem that were broader than that captured by the research question defined by the PICO statement, for instance the disease epidemiology and natural history and the relationship between the intervention under consideration and the broader clinical pathway. Modellers talked of a process of familiarisation with the decision problem that was

typified by an “immersion” in a broad range of potentially relevant evidence surrounding the decision problem including looking at previous models, published literature and seeking clinical expertise.

Some interviewees took the decision problem as received from the client in the form of a ‘draft scope’ or ‘request for proposal’. However most recognised that the received decision problem often did not represent the client’s true underlying need or did not reflect the underlying clinical decision problem. Most, though not all interviewees, took this to imply that a participative approach was therefore necessary on behalf of the analysts in assisting with the development of the description of the decision problem.

There was a marked variation in the extent to which and speed with which analysts moved towards making decision about the modelling methods to be employed, though this was frequently cited as an objective of the familiarisation process. Some interviewees went as far as identifying ‘key things to go in the model’ whilst others immediately jumped to making decisions about modelling methodology and indeed referred to the use of early draft models to aid the familiarisation process.

Conceptual modelling

Five interviewees explicitly discussed conceptual modelling as a distinct activity from model building. The remaining interviewees tended to blur the boundary to varying degrees between model construction and conceptual modelling activities, with three interviewees appearing to conceptualise and implement models as one model building activity. Whilst there was broad concurrence between the modellers on most of the model development process, this variation in the perceived importance of conceptual modelling activities constituted the biggest variation in practice identified.

Where conceptual modelling activities were raised, discussion focussed on developing a description of the model structure, assumption, health states and disease pathways, interpretations of the evidence and the approach to populating parameters. Whilst interviewees referred to developing a description of model structure, one notable omission was a specific discussion about the selection of modelling methodology with most discussions assuming a discrete health state simulation or Markov type model. Many purposes were cited for the conceptual modelling activities including fostering agreement between stakeholders, pitching and justifying a proposed model, supporting validity checking, as well as trying out ideas, getting feedback, “throwing things around” and defining the level of complexity in the model. Techniques used in developing the conceptual model included developing written documentation, diagrams, sketches and/or clinical/disease pathways, memos and model mock-ups.

Whilst all modelling exercises clearly entail conceptual activity the important distinction revealed by the interviews is the extent to which this is perceived as a separate activity from the model implementation. Three respondents that implied no distinct conceptual modelling, conceptualised and implemented models as one activity. These participants frequently referred to developing “skeleton models” as a basis for eliciting information from experts, for testing ideas or to generate an expectation of final model results. Conversely some of the respondents would not begin model implementation model until a conceptual model had been agreed or “signed-off” by the client or experts. For one respondent in particular the vast majority of the model development process concerned understanding the decision problem and conceptual modelling, with the implementation of a spreadsheet coming right at the end of the process.

There was no discussion among the interviewees of formal methods in conceptual modelling. Whilst meetings with clinicians / experts were frequently discussed, formal or semi-formal methods for structuring such engagements were not discussed. Two interviewees suggested that the conceptual modelling skills were usually learned through experience and were hard to teach.

Use of information in model development

Interviewees referred to evidence being used to understand, shape and interpret all aspects of model development and being obtained from both literature and subjective judgement of clinicians and methodologists. An important source of evidence cited for both understanding the decision problem and conceptual

modelling was previous models. However, concern was raised that over reliance on existing model structures, designed for addressing different decision problems, may lead to inappropriate models being used, could stifle innovation and might lead to a failure to develop a shared understanding of the current decision problem between all stakeholders.

The majority of the interviewees highlighted the existence of a complex iterative relationship between model structuring and data identification and use, whereby the model structure determines the data requirements to populate the model and the availability of evidence in turn influences the structure of the model. This process of arriving at a model structure that provides an adequate framework for relevant evidence that remains true to that evidence but has sufficient complexity to address the decision problem is the essence of the modelling activity. Several respondents mentioned that separation of the systematic review and modelling functions within a team hindered model development, preventing the above iterative dynamic. Two respondents explicitly recognised the importance of joint working between modellers and the other members of the research team and discussed developments within their groups to support this process.

Virtually all discussions concerning the process of identifying published literature focussed on clinical efficacy evidence; very little discussion was held concerning methods for identifying, selecting and using non-efficacy evidence. This was true for specifically for evidence pertaining to parameters in the model including costs or health-related quality of life, but also true for evidence used in generating an understanding of the decision problem, and for evidence used in conceptual

modelling. Across all interviewees, it was unclear who holds responsibility for identifying, interpreting and analysing such evidence and how such activities differ from the identification and use of clinical efficacy data.

Model implementation

All respondents mentioned model implementation. The most common theme raised in the discussion was the impact of refining and redefining the conceptual model structure during implementation. This issue was primarily concerned with the strengths and weaknesses associated with the practice of merging the conceptual modelling and model implementation activities but also related to constraints imposed by software, skills or experience. One respondent specifically highlighted the dangers of implementation by evolution whereby “skeleton models” are discussed, amended and develop iteratively. Interviews suggested that model building was less iterative for those who agreed the conceptual model prior to implementation.

One respondent specifically highlighted the absence of a formal specification and design process analogous to that common within software development projects. Thus a key link between the conceptual model and implemented model was almost completely absent. Such activity would usually include producing a formal model specification, including selection of software platforms, details of how the model would be programmed, where parameters would be stored and linked, model housekeeping and specification of model validation.

Model checking

Interviewees made reference to activities relevant to model checking occurring throughout the model development process, though most interviewees placed the emphasis clearly towards the end of the modelling process. Model checking has the potential to trigger major iterations in the whole development cycle, as represented in Figure 2. The tenor of comments reflected a minimalist approach to model checking activities.

Model checking activities were discussed as either preventing errors from entering the model or identifying errors that have occurred. It was noted that often the same activity was described as being used prospectively to avoid errors or retrospectively to identify errors. Activities were identified as either strategies, expressed by interviewees in terms of goals, for example ‘ensure mutual understanding’ or specific techniques of implementation. Current strategies for avoiding errors focus on ensuring mutual understanding within the analysis team and between the team, clients and stakeholders. Strategies include engaging with clinical experts, clients and decision-makers and producing written documentation of the proposed model. It should be noted that the activities involved with explicit conceptual modelling were also explicitly linked to strategies for avoiding errors in models. Techniques include using diagrams and sketches, talking through skeleton models with experts, ensuring transparency in reporting. Other strategies mentioned by the interviewees focused on skills and training of analysts. Techniques for avoiding errors included standardised housekeeping approaches in model implementation. Methods reported for identifying errors focussed on checking face validity of the structure of the model

and outputs, checking the internal consistency and model input values, double-programming, and peer review. Whilst these methods were clearer than the avoidance strategies, in terms of what should actually be done, they were often focussed on identifying symptoms indicative of a potential error rather than being diagnostic of a definite and specific error. The use of the above activities appeared to be partial with a great deal of variation between interviewees and certainly not framed within an overall strategy for structuring complex problems.

Engaging with the decision

The majority of interviewees referred to model reporting as the final step in the model development process. This stage typically involved report writing, preparation of journal manuscripts and engaging with the decision maker in supporting the decision making process, for instance participating in committee meetings. Two aspects of engaging with the decision making process were recognised, firstly a process of building credence in the model amongst the decision maker and secondly a process of experimentation in exploring the implications of the model for the decision or policy recommendation. The importance of the first aspect of building credibility was highlighted strongly by some of the interviewees with this phase frequently feeding back into model checking and validation. One interviewee highlighted the need for further research in this area focussing on developing methods for most effectively presenting results to ensure that key economic messages are communicated effectively.

DISCUSSION

Early guidelines on HTA modelling explicitly recognised the lack of an established approach to model development, acknowledging that little was known about the processes and decisions involved.[12,13] Subsequent methods documents have focussed on standards of reporting, transparency, the definition of a reference case to increase methodological comparability between models and on frameworks for critical appraisal of models.[14,15,16,17,18,19] but have not directly addressed the model development process.

This study has led to the identification of a five stage HTA model development process, comprising; understanding the decision problem, conceptual modelling, model implementation, model checking and engaging with the decision. This process broadly captures the views of the modellers interviewed in this study, the major point of variation being the degree to which practitioners engage in a set of conceptual modelling activities explicitly differentiated from the model implementation activities. However, since there must be some conceptual activity involved in the modelling process, it is not immediately clear whether identifying this explicitly really matters. Whether this is one of those points of practice where we should celebrate the diversity of modellers or whether we should be trying to seek some uniformity.

In seeking an answer to this question it is useful to refer back to the motivation for the original study, namely to explore methods for identifying and avoiding errors in models.[5] In discussing the definition of what constitutes an error in a model the HTA modellers frequently made reference to an overarching concept of 'fitness for

purpose' that was broader than straightforward mechanical errors in model implementation but included matters of judgment and choice. Several interviewees raised the concepts of 'verification' and 'validation' and where these terms were used interviewees were asked to provide definitions. The HTA modellers were wholly consistent in their definitions and these were perhaps best captured by one interviewee who equated validation with addressing the question "is it the right model?" and verification with the question "is the model right?". These perspectives of the HTA modellers resonate strongly with a key strand of methodological literature from the modelling domain. In 1979 the Society for Modelling and Simulation International (SCS)[20] and more recently Sargent[21] considered the underpinnings of model credibility and defined the distinction between model verification and validation, see Box 1. The interviewees' concept of 'fitness for purpose' is almost a precise corollary of the SCS 'model credibility', though it should be noted that the term 'credibility' did not occur in any of the interviews. Furthermore, whilst the HTA modellers' notion of validation appears to conflate the SCS definitions of credibility and validation, the interviewees concept of verification matches almost precisely with the SCS definition. However this common agreed definition of verification relies on there being an explicit and complete description of the conceptual model. Where the description of the conceptual model is absent or incomplete this separation between the concepts of verification and validation breaks down. Thus formal approaches to disentangling model credibility or fitness for purpose require us to disentangle the conceptual modelling activities and programming activities. This is necessary to allow us to develop quality assurance mechanisms that recognise the fundamentally different nature of these activities.

[Box 1 here]

‘Understanding the decision problem’ and ‘conceptual modelling’ form fundamental modelling activities in the process. A common aspect of the interview discussions for these two activities is the focus on general principles rather than methods. For example whilst interviewees noted that “mechanisms for ensuring clarity were useful” none of the interviewees referred to any specific mechanisms beyond ensuring adequate clinical input. Methods are required that provide for a systematic approach to uncovering choices, to generating a shared view of consensus and divergence, and for making judgements and choices. To date the HTA domain has been successful in drawing on Operational Research or decision science methods including decision analysis, simulation and utility theory. A further set of methods that may provide some traction in addressing the above problems are the Operational Research techniques for structuring complex problems. Three potentially relevant methods that may provide a starting point for further development are Soft Systems Methodology, cognitive mapping and Strategic Choice Approach.

Soft Systems Methodology provides a method for structuring enquiry and defining a problem domain, captured by its simple CATWOE mnemonic checklist (see Box 2).[22] Comparing the PICO statement and the CATWOE mnemonic raises a number of issues. Firstly the CATWOE definition is broader than the PICO definition of scope and captures many of the ingredients discussed by interviewees within the realm of problem familiarisation. Further this approach makes explicit a number of issues that appear to be assumed within the HTA context, thus for instance the interviews stated or implied that the role of HTA decision modelling was to estimate the cost

effectiveness of interventions. This assumption may well be appropriate in the majority of assessments where the problem customers and actors are within the health domain and subject to direct influence of health commissioning policy makers. However in more complex systems for example involving public health it may be important for modelling to capture the specific economic perspective of owners of a system.

[Box 2 here]

Another Operational Research method used for achieving clarity in problem structuring is cognitive or causal mapping.[23] This method provides an approach to elucidating the causal linkages between constructs within a problem domain. The approach was originally developed as a tool for mapping the cognition of an individual expert which in itself would justify its relevance. However the technique can equally be used to map the expert judgment of groups or text based evidence and has been used in other domains of public sector policy analysis.[24] The focus of cognitive mapping on retaining and managing complexity as opposed to simplifying complexity out of the problem suggests its usefulness for supporting judgments about the appropriate level of detail to include in a model. Two examples demonstrating the potential of cognitive mapping are the 'Foresight' obesity modelling that has informed recent national strategic policy making,[25] and a review on improving health outcomes for looked after children undertaken for the NICE public health programme. (Publication withheld until NICE public health evidence consultation).

Strategic Choice Approach provides a method for making choices under uncertainty. It allows “more confident progress towards decisions by focusing our attention on possible ways of managing uncertainty”.[26] The method identifies three types of uncertainty in choice and focuses on achieving transparency in the method for choosing; including criteria for choice, the judgments underpinning our choice and the process for uncovering options. A pilot study of the use of the Strategic Choice Approach in making decisions about model structure has been undertaken as part of a HTA for NICE.[27] This pilot study identified and evaluated model options for linking short term trial outcomes to long term economic outcomes and examined the feasibility of using such an approach in this setting.

This investigation arose from a qualitative study investigating the occurrence of errors in HTA models. Interviewees were asked to describe the model development process purely in order to provide a framework or structure for the subsequent discussion of the creation of errors in models. However, it emerged from the analysis that the model development process itself, including the choices and judgements involved in constructing the model, were fundamentally important in determining the credibility of a model for decision making. This paper has identified a description of the modelling process that provides a starting point for clarifying the nature of these choices and judgements and the development of methods for approaching these choices and judgements systematically.

Table 1: Interviewee quotes illustrating model development activities

Quote	Modelling activity
"You start by just immersing yourself in whatever you can find that gives you an understanding of all the basics. What is the disease, where does it come from, what's its natural progression, who gets it, why. Then begin to focus down on what is the decision problem, what are you looking to compare with what, under what circumstances?"	
"In the NICE situation, you've read your scope you think you know what it's about. But then you start reading… and you think, "Oh! This is more complicated than I thought."	Understanding the decision problem
"you get an RFP (request for proposal) which is by no means clear…and it wont be very helpful to rush off and start to develop any kind of model on that platform… you answer the question that they asked and they then decide that was not the question they had in mind so certain processes of ensuring clarity are useful"	

“it’s the process of becoming knowledgeable about what you are going to be modelling…reading the background literature, knowing what the disease process is, knowing the clinical pathway that typically or pathways typically that patients experience within the situation you are modelling. Going to see clinical experts to ask questions and find out more and gradually hone in on an understanding on the clinical area being studied in a way that enables you to begin to represent it systematically”	
“…I think it’s a judgement call that modellers are constantly forced to make. What level of simplification… is appropriate for the modelling process? I think what’s very important is to continually refer back to the decision that you are hoping to support with your model. So don’t try and answer questions that aren’t going to be asked…”	Conceptual modelling
“So every aspect of what you… need to programme and populate is… in people’s brains to various degrees… if you get all that agreed, then the actual implementation in Excel should be pretty straightforward. But if that process has taken you 90% of your time, then… you build a model pretty quickly."	
“I don’t think… that I can sit here and write out how you build a model. I think it’s something which comes with experience”	

“there is a danger that…if you just slavishly adopt a previous structure…and everybody does the same there’s no potential for better structures to develop or for mistakes to be appealed”	Use of information
“I divide it between design and populate… the populating being locating the information to actually parameterise those relationships and then going back and changing the relationships to ones that you can actually parameterise from the data that’s available, and then changing the data that you look for to fit your revised view of the world”	
“I think things are … kind of trying to be changed. I’m not seeing a systematic review… as something separate from modelling; now they are working together and defining what [it] is… that we are looking for together.”	
“…whether its adding something in or taking something out there is the worry at the back of your mind that its going to affect something else in a way that perhaps you don’t observe … there is a danger if you make the decision to include or exclude definitively that you might regret it later on…”	Model implementation

"…you don't want to keep on rebuilding your model, … most of the big issues I see are all about the sort of thought processes behind defining that decision problem, defining the structure, defining the core set of assumptions... if we can get agreement about that, the implementation of it is really straightforward."	
"Either the intuition or the modelling or the data is wrong and we tend to assume that it is only one of them … I think you tend to assume that once they're [clinical experts] not surprised by the thing then, that means you have got it right."	Model checking
"So we do just enough … just enough but not as much as you'd want to do"	
"we need to pay more attention to understanding how our models are understood and how we present them…in ensuring everyone has a clear view of what's being said. There are ways in which model outputs can be more transparently depicted and the key messages conveyed to users more clearly."	Engaging with the decision

Figure 1: Example modelling process map captured at interview

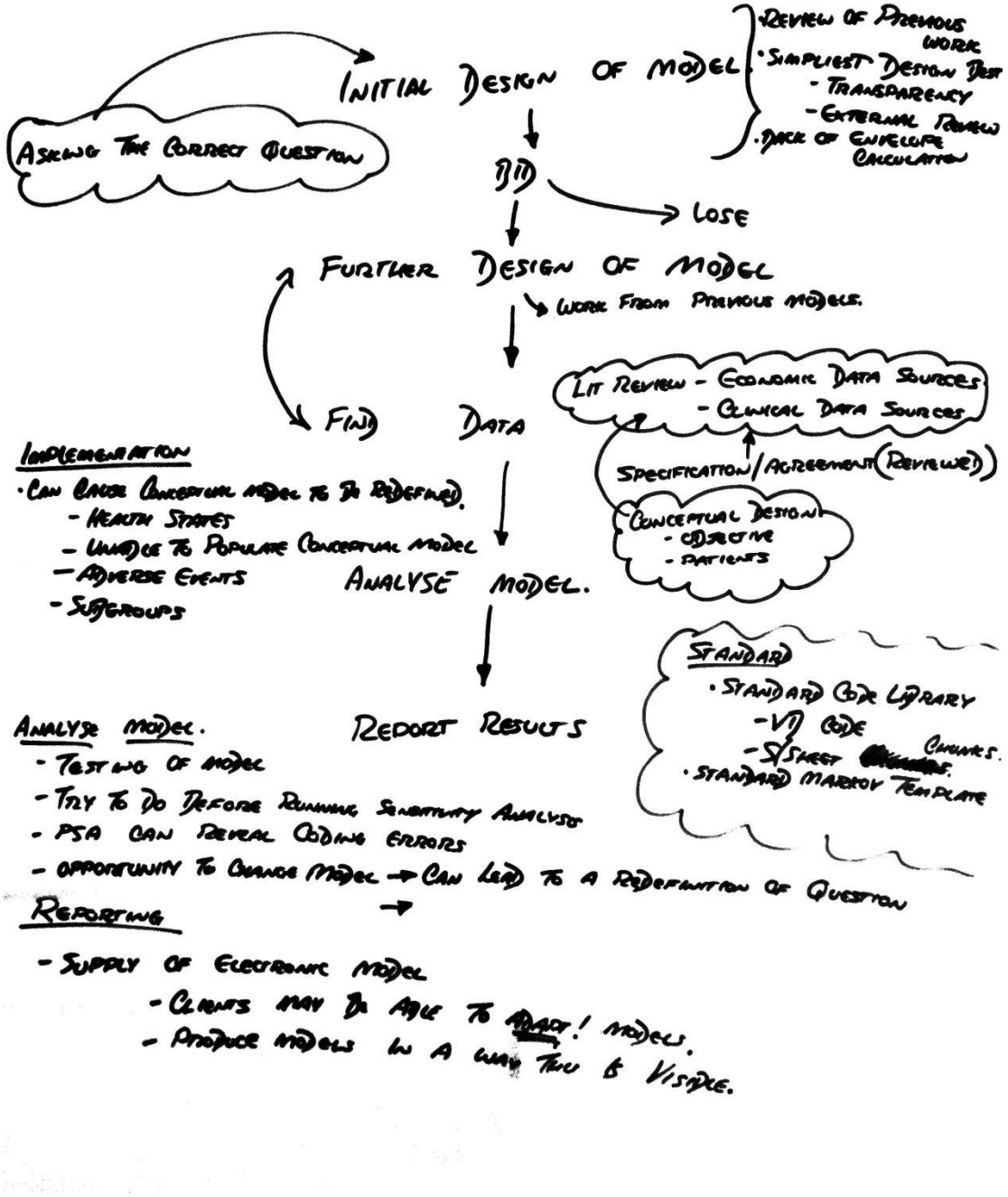
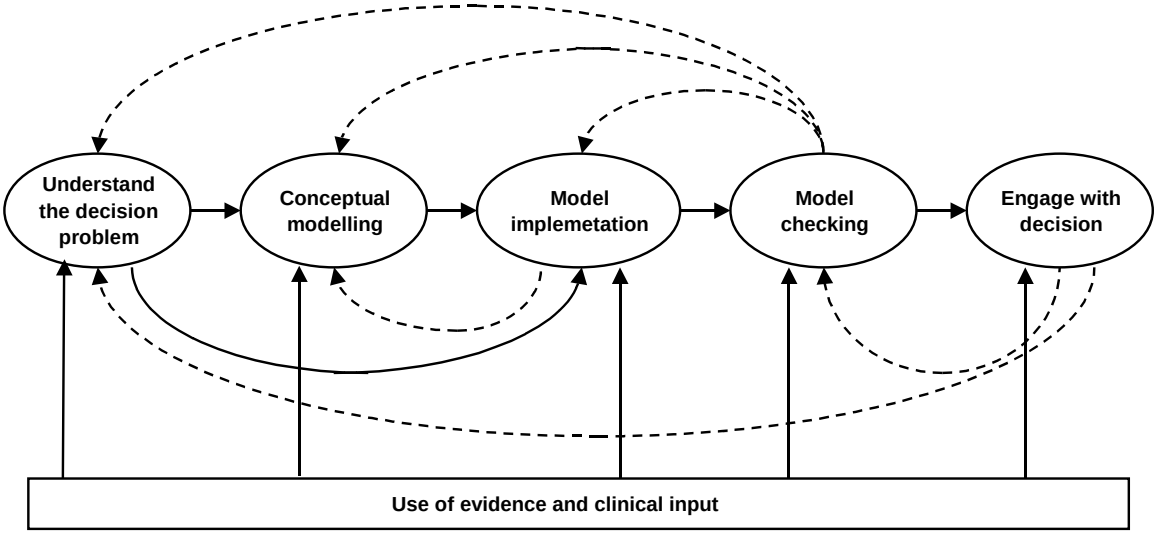


Figure 2: The model development process



Box 1: Society for Modelling and Simulation International (SCS) definition of validation and verification[20]

Validation	substantiation that a computerised model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model
Verification	substantiation that a computerised model represents a conceptual model within specified limits of accuracy

Box 2: CATWOE checklist for structured investigation of a decision problem

C = Customers

- Who is on the receiving end?
- What problem do they have now?
- How will they react to what you are proposing?
- Who are the winners and losers?

A = Actors

- Who are the actors who will 'do the doing', carrying out the solution?
- What is the impact on them?
- How might they react?

T = Transformation process

- What is the process for transforming inputs into outputs?
- What are the inputs? Where do they come from?
- What are the outputs? Where do they go to?
- What are all the steps in between?

W = World View

- What is the bigger picture into which the situation fits?
- What is the real problem you are working on?
- What is the wider impact of any solution?

O = Owner

- Who is the real owner of the process or situation you are changing?
- Can they help you or stop you?
- What would cause them to get in your way?
- What would lead them to help you?

E = Environmental constraints

What are the broader constraints that act on the situation?

What are the ethical limits, the laws and so on ?

What are the financial, resource constraints?

How can you release these constraints?

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