Use of simulation modelling for health care decisions: what outputs do health economists require?

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Abstract

Operational Research techniques such as Discrete Event Simulation are designed to be applicable to a wide range of subject areas. While the general principles are much the same regardless of application, each subject area has its own particular needs in terms of the type of questions being answered. This discussion paper considers a number of case studies, including the author's work on management of dyspepsia, with a view to determining which outputs from a simulation are of most use to health economists.

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1. Introductory Remarks

This paper discusses the role of modelling, with particular reference to simulation modelling, in economic evaluation, as an input into the health care decision making process. The statements of general principle and good practice made herein result from a distillation of the author's reading and experience. Before discussing specific modelling techniques and their application, some general remarks on the context of modelling may be helpful.

1.1 Decision Problems

A decision problem exists whenever the following conditions are satisfied. Firstly, there must be a decision maker who is capable of making an effective choice between a number of alternative actions. Secondly, there must be some means of evaluating the possible outcome of any possible action. Thirdly, some of the outcomes must be better, in some sense, than some other outcomes.

If any of these conditions are not satisfied, then there is not a decision problem. If there is only one feasible course of action to be taken, then there is no decision to make. If there is no means of evaluating the possible outcomes of actions, or no reason to prefer one to another, then there is no basis on which to make a choice.

Note that the conditions for a decision problem do not include a "best possible" outcome. In many cases, where the number of possible actions is large, it may be easy to find a "good" solution quite quickly, and the extra effort required to find the "best" solution may be greater than the extra benefit obtained.

The means of evaluating the outcome of any course of action may depend on the decision maker's point of view and may incorporate attitude to risk.

How well the decision leads to a satisfactory outcome depends on the accuracy of the estimates of the consequences of each possible course of action. The outcome may be unsatisfactory because of inaccurate prediction of the consequences. Alternatively, the measure used to assess outcomes may not be a true reflection of the decision maker's wishes.

1.2 Mental Models and Formal Models

The statement "it is impossible to take a decision without using a model" may be taken as a (somewhat broad) definition of a model. To take a decision on the basis of experience is to use a mental model. Mental models can be very useful in many situations because the process of including all available information is largely automatic. However, they have some serious limitations.

Firstly, the decision maker's experience may not be truly representative of the situation considered. This may happen because important factors have changed over time without the decision maker being aware of this; for example, new treatments may have become available. It is also possible that the decision maker's experience is distorted by a small number of special cases taking undue prominence in the mind.

Secondly, there are difficulties in passing on experience from one person to another. While an experienced person will naturally take relevant factors into account in a practical situation, he may find it difficult to list all possible relevant factors.

The advantage of formal models is that, at least in principle, everything in the model is made explicit. Here too, there are dangers. If the model is not adequately documented, then key assumptions may not be apparent to the user of the model. It is good practice to include a complete list of parameters with their sources in the listing of a model. Anyone using the model should be able to vary these parameters and thus see the effect of such changes. What can easily be lost here is the fact that any dependency between two variables that is omitted from the model, for however good a reason, is effectively a zero parameter, and cannot usually be changed. It is thus important for anyone reading a model description to realise that any connection not explicitly listed is not part of the model.

1.3 Some remarks about dyspepsia

For convenience, the case studies quoted below will all be concerned with the management of dyspepsia. Dyspepsia is a chronic condition which has a number of possible causes, including duodenal ulcer, gastric ulcer and gastro-oesophageal reflux disease. Dyspepsia which does not fall into any of these categories is known as non-ulcer dyspepsia. At any given time, a patient may have more than one of these dyspepsia types. It is generally agreed that symptoms are largely independent of the disease category; ulcers, and some (but not all) forms of reflux disease may be identified by endoscopy. Symptoms may be relieved by various medication, the main types of which are classified as antacids, H_2-receptor antagonists, prokinetics and proton pump inhibitors. The effectiveness of these depends on the underlying condition.

An important breakthrough in the treatment of dyspepsia was the identification of the role of the bacterium *Helicobacter pylori*. This bacterium may be acquired in childhood and is associated with duodenal and gastric ulcers. Various combinations of drugs have a high probability of successful eradication of *H. pylori*. Eradication of the bacterium greatly reduces the risk of duodenal and gastric ulcers. There are tests available for the presence of *H. pylori*, varying in sensitivity and specificity.

Management of a new case of uncomplicated dyspepsia consists of an initial investigation followed by treatment. Investigation may consist simply of trying the various forms of medication, or may involve automatic endoscopy, or an *H. pylori* test followed either by endoscopy or immediate eradication for all patients testing positive.

2. Alternative Model Types

In this section, the main types of model used in health care decision making will be described and illustrated by means of case studies.

2.1 Decision Trees

The simplest type of decision model is the decision tree. It is appropriate for use when there is no interaction between individuals, and the number of possible paths taken by any individual is sufficiently small that all of them can be considered separately. An important assumption behind the use of decision trees that is usually justified but often overlooked is that the entry rate into the model is independent of the choice of strategy. Decision trees are normally managed without an explicit time scale, but with the general principle that time flows forward as one moves along the tree from root to branches.

Case Study 1 – *Helicobacter pylori* Eradication Regimens

Duggan *et al* (1998) consider strategies for eradication of *H. pylori*, applied to *H. pylori* positive patients with duodenal ulcer disease. Two combinations of drugs are considered: omeprazole, clarithromycin and metronidazole (OCM) compared to omeprazole, amoxycillin and metronidazole (OAM). OCM is slightly more expensive, and more effective, than OAM. Four strategies are considered: either of OAM or OCM may be used once only, or a single application may be followed by a confirmatory test, and failures treated with OCM in either case. Figure 1 shows the possible strategies.

Two different strategies for dealing with ulcer recurrence are considered. In each case, the results reported for each strategy are the cost per patient, percentage success rate for eradication and cost per successful eradication. The most effective strategy is "OCM up to twice". For the other strategies, the incremental cost is calculated as the additional cost per additional success. This is then converted into the time taken for relapse treatment costs to equal the difference in costs between the strategies, both by simple division and discounting future costs after one year at 6% per year. One-way sensitivity analysis and extreme scenario analysis are carried out; for these, only the discounted payback times are reported.

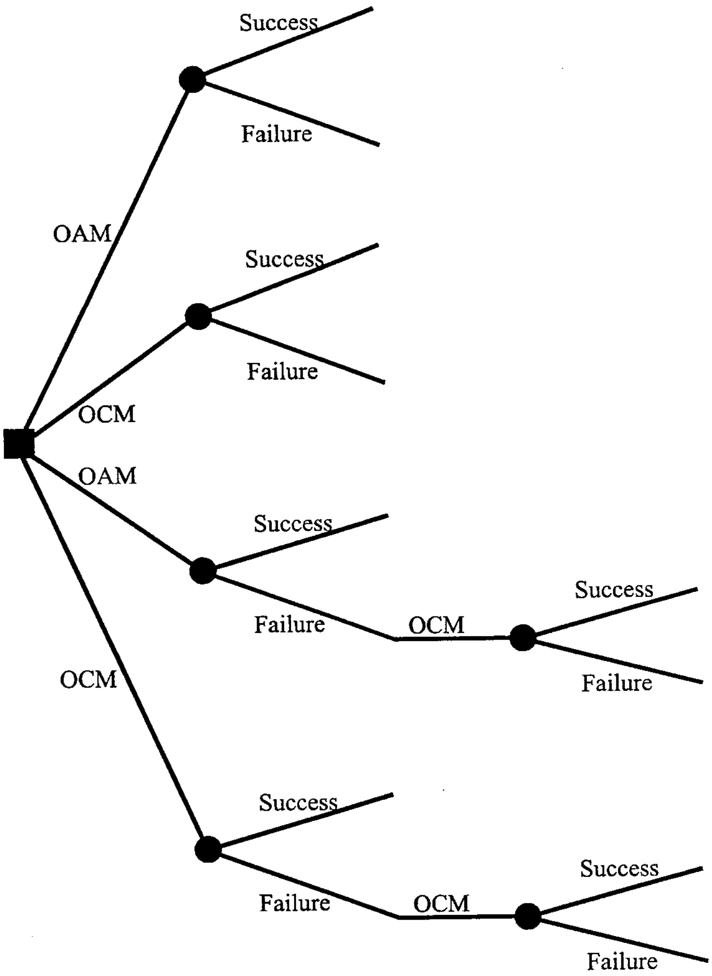

Figure 1 Eradication strategies for *Helicobacter pylori*

2.2 Markov Models

When the number of possible paths becomes too large for all of them to be considered separately, the different branches of a tree may be joined together. The assumption that is then made is that progress from any particular point is independent of how that point was reached. The model is defined in terms of a number of different states in which an individual can be at any time, together with the probability of passing from any given state to any other state. While it is not strictly necessary to do so, Markov models are usually defined in terms of a fixed time cycle.

Simple Markov models involve homogeneity assumptions both in terms of population and in terms of time. These can often be overcome by increasing the number of states. If a single state in a Markov model is such that an individual may remain in that state from one cycle to the next, then each individual's waiting time in that state necessarily follows a particular shape distribution.

Case Study 2 – Management of Recurrent Peptic Ulcer Disease

Delaney and Hobbs (1998) consider the management of known cases of Peptic Ulcer Disease (either duodenal or gastric ulcer). The principal concern of the paper is the accuracy requirements for *H. pylori* tests. As part of the analysis, conventional treatment for PUD is considered as a Markov process; failure of eradication therapy and false negative results from *H. pylori* tests lead to the same process. Figure 2 shows the transition diagram for this process.

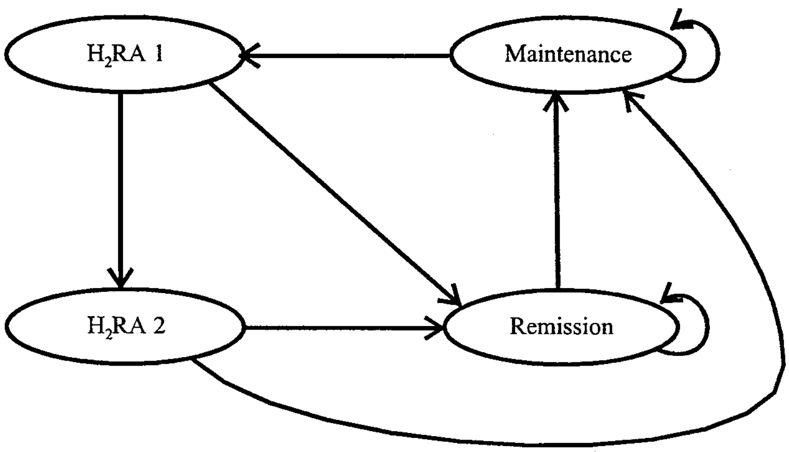

Figure 2 Markov process for recurrent peptic ulcer disease

The Markov process has a cycle time of one month. It is assumed that patients may have one or two prescriptions of full dose H_2-receptor antagonists; separate states are needed for first and second dose. The output from the Markov process is the expected number of recurrent ulcers over a period of up to ten years; this is then fed into a cost-effectiveness analysis. The results for the base case and for sensitivity analysis are given in terms of payback periods.

2.3 Discrete Event Simulation

When there is significant interaction between the individuals in a system, decision trees and Markov models are inadequate. Discrete Event Simulation (DES) is a powerful tool which allows for any amount of interaction between the parts of a system. Time can be handled realistically, and activities which take substantially different lengths of time present no problem. Pseudo-random numbers are used as appropriate to select from any distribution of waiting time in a given state or to choose where the individual goes next. Most importantly, individuals can wait in a given state until any desired set of conditions are satisfied. Additionally, individuals can be given attributes which can affect their progression through the model without having to create extra states.

Because DES allows highly detailed models to be built comparatively easily, it is sometimes thought that DES is only appropriate for complicated models. This is simply not true: any system involving waiting for facilities to be released or matching individuals to available parts (for example, in transplantation) is best modelled using DES.

Case Study 3 – Management of Uncomplicated Dyspepsia

A simulation model has been constructed to follow an individual through a complete lifetime, using the principles of Discrete Event Simulation. Full details of the model may be found in Barton *et al* (1999). The model includes as suitably rare events complicated ulcers, requiring hospital treatment, and gastric cancer, the incidence of which may be affected by *H. pylori* eradication. The model also allows for patients self-treating. Figure 3 shows the states through which a patient may pass.

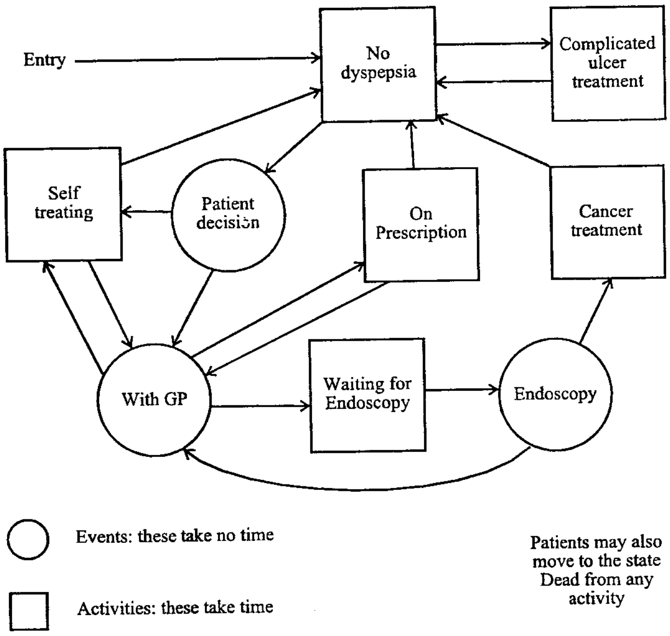

Figure 3 General dyspepsia management model

Note that in this model, patient attributes can carry the details of type of medication and number of prescriptions undergone, so that On Prescription can appear as a single state.

The model allows any of five investigation strategies to be combined with any of five treatment strategies, or it may be run in interactive mode, allowing the user to play the role of the GP and make a choice at each consultation. For any individual, the main outcome measures are the total cost of investigations and treatments and the benefit in number of dyspepsia-free months after first consultation.

In statistical mode, the model is run for a large number of patients combining one or more of the investigation strategies with one or more of the treatment strategies. Average cost and benefit figures for each strategy can then be determined within suitable confidence intervals. From these, the incremental cost-effectiveness ratio can be calculated. Other outputs available include lifetime risk for each type of condition, both overall and classified according to initial *H. pylori* status.

Automated sensitivity analysis includes one-way analysis, and random analysis, which selects a value for each parameter somewhere within its given range, with a bias towards values near the base case values. In each case the output gives the list of parameters actually used in each run, together with the list of non-dominated options, highlighting on screen those cases where the list differs from the base case.

Since, at the time of writing, this model is still under construction, other forms of output may well be included in later reports.

3. Discussion

A properly constructed simulation model for any but the simplest of situations is capable of providing a huge variety of output. There is a limit to how much the reader can be expected to take in, and therefore the modeller must select from the possible output available. Generally there will be a base case presented in full detail, followed by some sensitivity analysis, in which only the differences in results are listed. Some other considerations in developing and presenting simulation models are listed here as discussion points.

Appropriateness of Model Technique

It is important that the choice of model used to represent any decision process should be made according to the needs of the practical situation. It is poor modelling practice to start with a modelling technique and go round looking for places to use it. Equally it is poor practice to use an inadequate model simply because the audience is more familiar with that type of model. As a general principle, the simplest adequate model should be used.

Credibility of Results

It is not sufficient to report the results alone. The modeller must report in sufficient detail what was done to ensure that the results are credible. How much detail is required depends on the audience for which the report is aimed.

Data Requirements

Any model requires suitable data from which to calculate its parameters. If the model is being used to determine which of a limited number of policy choices is preferable, then it is possible to use the model with existing data before a study. Multi-way sensitivity analysis can be used to determine the effect of varying the parameters within plausible ranges consistent with known facts. In extreme cases, probabilities can be allowed to vary across the whole range from 0 to 1. If the decision is the same for all such variation, then there is no need to gather more data. Indeed, a good model can direct the search for data by identifying which are the critical parameters. If, however, the model is being used to estimate the total cost of some policy over a period of time, then the data requirements are considerably more stringent. In this case, sensitivity analysis will give a range of possible costs, which may have to be narrowed by the collection of more data.

In general, a simple model requires less data than a more complicated one. However, even this statement needs to be treated with caution. As stated earlier, simplifying a model is effectively equivalent to setting some parameters of the more complicated model to zero. It may be that the decision to be made is not robust to changes in these parameters, within the range consistent with existing data. In such cases, more data must be gathered before the simplification can be justified.

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