Transformation of Markov Models for Cost-Effectiveness Analysis into the System Dynamics Methodology: Analysis and Case Study

Patrick Einzinger, dwh Simulation Services, Vienna, Austria
Ruth Leskovar, Institute for Analysis and Scientific Computing, Vienna University of Technology, Vienna, Austria
Claudia Wytrzens, Institute for Analysis and Scientific Computing, Vienna University of Technology, Vienna, Austria

ABSTRACT

Markov cohort models are one of the standard methodologies for conducting cost-effectiveness analyses of health care interventions of chronic diseases. The system dynamics (SD) approach, where a model consists of stocks and their interconnecting flows, is rarely used, but in principle it can be used to conduct the same type of analysis. The authors show that a simple transformation from the transition probabilities of a Markov model to relative rates always leads to an equivalent system dynamics model. Here the stocks match the Markov states, because they store the same number of patients as in the corresponding state. The authors demonstrate an approach on an exemplary cost-effectiveness analysis for a smoking cessation programme for chronic obstructive pulmonary disease (COPD) with a simplified Markov model based on Menn (2009). Both the Markov model and the system dynamics model lead to nearly identical results. However, the latter offers more flexibility as it can incorporate interactions between different patient groups.

Keywords: Chronic Obstructive Pulmonary Disease (COPD), Cost-Effectiveness Analysis, Incremental Cost-Effectiveness Ratio (ICER), Markov Model, System Dynamics (SD) Model

INTRODUCTION

Cost-effectiveness analyses are commonly used as the basis of decision making for different kinds of medical technologies (e.g., drugs, vaccination programmes, and other treatments). Therefore, cost-effectiveness analyses are often used as the basis of decision making for different kinds of medical technologies (e.g., drugs, vaccination programmes, and other treatments). Therefore,
A cost-effectiveness analysis compares the effects and the costs of different treatments, for example by calculating the ICER (incremental cost-effectiveness ratio). Various types of models allow for a cost-effectiveness analysis as long as they generate the cumulative costs and effects of an intervention as output.

The ICER is defined as

\[ ICER = \frac{C_2 - C_1}{E_2 - E_1}, \]

where \( C_i \) describes the costs and \( E_i \) the effects of treatment \( i \) (the actual treatment). Accordingly, \( C_2 \) and \( E_2 \) are the costs and effects for treatment 2, i.e., an alternative intervention (Briggs & Sculpher, 1998).

One possible modelling methodology for conducting cost-effectiveness analyses are what are known as Markov models. They are commonly used to model the progression of chronic diseases through several disease stages. But this type of model is not the only possible way of simulating such a chronic disease. The system dynamics (SD) methodology, for example, is also well-suited to this task. To show the similarities and differences between these two types of modelling as well as the generic transformation process from a Markov to an SD model, we simulated the progression of the chronic disease COPD for a cohort of patients using both modelling methodologies and conducted a cost-effectiveness analysis.

The basic model is a simplified version of Menn’s (2009) Markov model for COPD with two different treatments, the routine treatment on the one hand and a smoking cessation programme on the other. We transformed this model into an SD model such that advantages, disadvantages and various possibilities for expansion can be shown.

Furthermore, we searched the literature in the PubMed database in order to get an overview which methodologies are used for COPD models. The search term “(copd) AND model” resulted in about 2000 publications. Out of these, around 100 abstracts were included and five papers describing different models have been selected to be presented here in more detail to show other studies.

One of these studies used a model that is very similar to the available model of Menn (2009). The corresponding study performed a cost-effectiveness analysis with the help of a Markov model and a Monte Carlo simulation with the two cohorts “smokers” and “ex-smokers”. There are some expansions like the possibility of changing the state of smoking, adding another discounting rate and one additional state (Atsou, Chouaid, & Hejblum, 2011).

Another cost-effectiveness analysis was performed to see the differences between the two chronic diseases COPD and asthma in the context of low- and middle-income countries (Stanciole, Ortegón, Chisholm, & Lauer, 2012).

Furthermore, one cost-effectiveness analysis was simulated to find out the effects of treatment with tiotropium bromide on patients with moderate to very severe COPD. The simulation was performed using a Markov model. (Zaniolo, Iannazzo, Pradelli, & Miravitlles, 2012)

Another Markov model was used – in contrast to ours – to perform a cost-utility analysis and was conducted to research a new method to test the arterial puncture of COPD patients. (Oddershede et al., 2011).

However, not all models of the studies were Markov models. One study used a decision tree to analyse advanced directives of COPD patients, which specify the care required in the case of an acute illness (Hajizadeh, Crothers, & Braithwaite, 2010).

In summary, many studies on COPD exist, many of which include simulation models and cost-effectiveness analyses and most of them use Markov models.

**Description of the Study Case COPD**

COPD is a common chronic disease of the lung. The various stages of the disease and therefore COPD itself are irreversible (GOLD, 2010).
Quantum Computation Perspectives in Medical Image Processing
[www.igi-global.com/chapter/quantum-computation-perspectives-medical-image/40645?camid=4v1a](www.igi-global.com/chapter/quantum-computation-perspectives-medical-image/40645?camid=4v1a)

Online Nurse Education
[www.igi-global.com/chapter/online-nurse-education/13041?camid=4v1a](www.igi-global.com/chapter/online-nurse-education/13041?camid=4v1a)