EVALUATION OF THE QUALITY AND USE OF COMPUTER SIMULATION MODELLING IN HEALTH CARE SERVICES

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ABSTRACT

Simulation modelling is a powerful tool for both small and large populations and has been applied to a wide variety of health care problems. Although sufficient research on modelling has been done over the recent years, this paper attempts to assess the value of the same. Precisely, the paper evaluates the extent, quality and value of computer simulation modelling in health care delivery and services. A narrative review is carried out of world literature from the period of 1980 to 1999, making a total of 182 papers. The inclusion criterion was to collect papers which contained a computer simulation model in a stochastic system or research related to population health care delivery.

Keywords: Simulation modelling, Health care services, Systematic review

Introduction

Models of computer are utilised extensively in the process of management systems. These models offer assistance in attaining knowledge about the system and are implied in order to predict result based on changes in respective strategy. This is particularly significant as the respective system gets very complex and/or experimentation turns up impossible. As there is an increase in the use of and capability of computer technology, the techniques of modelling developed in a rapid pace and as such many approaches are getting available in the current scenario, added by analysis of decision, as the processes initiated by Markov, systems dynamics, mathematical modelling and simulation modelling. Intrinsic mode of uncertainty related to health care demands and results with health care policy along with management based on relevant evidence, and the same needs to get designed in order to cope up with the wide ranged complexity of the systems. Self evident specifies that computer modelling needs to get valuable aspects for offering evidence related to the way the same can cope up with stochastic problems, and can stand as an alternative towards the process of learning through doing or varied kinds of practical research.

A determined approach remains discrete in the process of simulating modelling
(DESM) added by being closely connected to methods as suggested by Taylor and Lane, particularly as there are the ‘multiple variables that stands potentially in terms of producing enormous connections as well as effects’. Sector for health care abounds detailed complexity that has wide ranged results attained from any determined change in policy. Simulation modelling is capable of dealing with detailed complexity through the process of simulating histories of life of people and further estimating the effect on the population from summation of effects on individual. Every person form the population (entity) comprises simulation model that gets tracked by option network. Each point of decision stands varied for selection process being available as well as results depending over instances like the features of entity as well as resources, former movement by model, added by the selection of other entities as made. In terms of stochastic system, selections made by the process of random sampling get noted by the probability distributions. Maximum part of respective models follows the trend to fulfil demands as used for DESM, through further remains inclusive of instances like Monte Carlo simulation. Through simulating process in the individual, by system, respective models turn up more comprehensive and further closely resembling reality as the Markov models, where transition probabilities are counted between health states being applied equally over all the members as in the pre-defined cohort. DESM’s individual nature turns simulation modelling apt to modelling for a smaller population. In accordance to latest developments in the field of software as well as computing, there can be the expectation for simulation modelling that is necessary and can remain as a routine for modern management as well as for evaluation initiated in the health care. However, in spite of the modelling in some of the selected areas in the sector of health care, the utilisation and the value remain unclear. Model’s quality never gets routinely assessed and there remains no formal investigation that is initiated for the establishment of the derivations as translated in terms of policy. There is no comprehensive mode of systematic review that can be used of modelling for health care planning that has
been published. Former reviews get confined to determined modelling types or application, without any critical appraisal of the quality related to modelling researches or assessing impacts of these on policy. Thus, we had a systematic review for assessing value and quality of model for computer simulation of people in health care sector.

**Methods**

*Strategy to Search and Paper Selection*

We have searched Medline, Embase, INSPEC (including literature on physics, electronics & computers & electronic engineering and information technology), Science Citation Index, MathSci, CINAHL (Cumulative Index to Nursing and Allied Health Literature), INFORMS Online (online information service covering Operations Research and Management Sciences, @ http://www.informs.org), and SIGLE (System for Information on Grey Literature in Europe) in terms of papers that were published in the span of 1980 and 1999.

Necessary text words get combined and the subject headings to the database are about the illustration for simulating modelling under the setting of health care being searched. The foremost strategy for search gets validated through the application of 14‘key’ researched papers that were known to the authors and refinements are done to develop the level of sensitivity, added by citation under cross-referencing. Table 1 displays final strategy for the search and exemplifies results led from Medline search within the span of 1997 to 1999.

We have compiled active researchers from National Research Register\(^7\) and contacted those who are known to us in the UK, along with those from Netherlands for supplementing electronic search and further noting down unpublished and recent research works. We have selected abstracts as per title as well as keywords. To clarify doubt there is the inclusion of an abstract for further review. 3 members of review team analysed selected abstract in the process of identifying papers that are suitable for next full length text review. Every reviewer analysed all the abstracts in an independent way and outcomes are thereby compared. In case of any discrepancy, conservative
approach is selected and entire text of respective paper gets requested.

**Inclusion criteria**

We considered those papers that are in peer-reviewed journals or are published in conference with –

1. Computer-simulation model for the individuals under stochastic system, and
2. Setting or topic in relation with population health or respective health service.

Papers with two reviewers remain independent for agreement and are part of this research. In case of any doubt, there is a third reviewer considerably arbitrated.

**Critical appraisal**

Selected two reviewers appraised all the papers as per the criteria. Determined appraisal remains systematically noted under standard proforma (Table 2), which gets developed from formerly published format.
interventions are not for the assessment and results get considered. Review over necessary literature is needed for the justification of research and illustrate elements added to knowledge content and further resolve the matter of current uncertainty. In case the same gets attained, the research gets clearly noted in terms of determined objectives. Part B of Appraisal Proforma is estimated as per the validity of respective model. It is important that the reviewer gets enough satisfaction towards the model meant for relevant research design for answering research question and basic parameters being specified, added by the justification related to statistical distributions over parameter data. Reliability and validity of data sources must get explicitly discussed, added by assumptions of model being discussed, supported and reasonable with evidence. Enough implementation of the model for the estimation of model range results with precision. Part C of Appraisal Proforma examines accumulated results as well as conclusions of the research. On a generalised basis the derivations and assessment of potentially remain significant as needed. Lastly, the research impact for the delivery or policy of health care development is noted in papers. For the attainment of ‘qualitative overview’ for the researches with highest quality-papers are with greatest weight, whereby every paper gets judged against determined 10 criteria (as in Table 3) as well as awarded 0, 1 or 2 (from poor to good) for quality criterion. Total scores assigned for every paper to one of 4 categories: A, B, C or D.

**Extraction of Data**

We have extracted following data: author, title, ID, topic, date and setting, question of research, model/software, with main derivations and comments over quality, journal, country, journal, grade, type, validation, utilisefulness, and generalizability and implementation evidence are noted.

**Results**

**Overview**

Reviews’ flow chart as in Figure leads to the assessed abstracts with 990 full-text papers. 182 papers are within the criteria added by appraisal, comprising 17 papers noted with personal contact. 4 databases
(Medline, Embase, INSPEC, HealthSTAR) are with 90% appraised papers. We noted 5 wide areas:

- hospital scheduling and organization,
- infection and communicable disease,
- costs of illness and economic evaluation,
- screening and
- Miscellaneous.

Total published papers are increasing in due course of time, with 2/3rd after 1990. 60% papers were from the USA, yet proportion of the UK/European papers increased after 1990. Quality papers remained variable, yet 2/3rd of papers get rated in 2 higher quality categories. Some suggestions related to developments in quality are maintained, whereby 60% were of higher quality before 1990 to 70% from recent papers. All the UK papers attained higher quality score against the US papers, and many were published before 1980s. There was an increasing trend in relation with publication within researches under clinical/health services, added by decreasing trend under non-medical operational research journals with conference proceedings. There seemed to be no difference in quality papers among the clinical or health services research journals along with non-medical journals, yet quality standards as in full text conference remained low. Table 4 sums up data over quality assessment, publication year, and country of origin and journal type for 182 papers.

**Organization and Hospital Scheduling**

This section comprises (52%) 182 papers in review. 73 (78%) originated in the US, with higher proportion over older papers for the relevant topic against other topics (as in Table 4). Patient scheduling along with admissions policies turned up as popular topics meant for modelling, outpatient clinics, walk-in clinic and operating room scheduling. These models assessed trade-off among patient’s waiting times and assessment timings of the staff in case developments are made, either in terms of waiting times or time used by staff as per booking systems. Various systems in health care delivery are modelled with results assessed by productivity, patient’s waiting times, time used by staff and costs. Models comprise
schedules for medical resident staffing, out-patient pharmacies, university infirmary, and use of surgical staff as well as facilities in the urban terrorist-bomb incident. Modelling in need of bed and key level of efficiency tradeoffs among availability of bed, use and waiting lists lead to various alternative configurations for the estimation through expensive schemes. Our review adds papers in relation with emergency bed planning, planning in-patient bed and planning for coronary care unit.

Location assessed for ambulance services relies various factors like densities of population, accident, road transport systems and the distribution as in hospital and trauma facilities. All such data are from current ambulance records and from records for lives saved under different scenarios. Emphasis on potential improvements of organization and care delivery were noted by many papers. Identification of critical trade-offs for making decision is counted. Irrespective of this, very few papers are for models of implementation.

**Table 3 Quality criteria summary sheet**

<table>
<thead>
<tr>
<th>Quality criterion</th>
<th>Score</th>
</tr>
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<tbody>
<tr>
<td>Clarity of aims and objectives</td>
<td>1</td>
</tr>
<tr>
<td>Intervention(s)/scenario(s) modelled adequately defined</td>
<td>2</td>
</tr>
<tr>
<td>Outcome measures defined and appropriate</td>
<td>3</td>
</tr>
<tr>
<td>Model adequately described</td>
<td>4</td>
</tr>
<tr>
<td>Parameters specified</td>
<td>5</td>
</tr>
<tr>
<td>Quality of data sources</td>
<td>6</td>
</tr>
<tr>
<td>Explicitness and appropriateness of assumptions</td>
<td>7</td>
</tr>
<tr>
<td>Evaluation/validation criteria defined</td>
<td>8</td>
</tr>
<tr>
<td>Presentation of appropriate results with estimation of precision</td>
<td>9</td>
</tr>
<tr>
<td>Results interpreted and discussed in context</td>
<td>10</td>
</tr>
</tbody>
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| Overall (category D <1, C 1–1.9, B 1.4–1.9, A 1.6)                              |       |

**Quality criteria summary sheet: scoring criteria**

<table>
<thead>
<tr>
<th>Quality criterion</th>
<th>Score</th>
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<tbody>
<tr>
<td>Clarity of aims and objectives</td>
<td>1</td>
</tr>
<tr>
<td>Intervention(s)/changes under test adequately defined</td>
<td>2</td>
</tr>
<tr>
<td>Outcome measures defined and appropriate</td>
<td>3</td>
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<tr>
<td>Model adequately described</td>
<td>4</td>
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<tr>
<td>Parameters specified</td>
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<tr>
<td>Explicitness and appropriateness of assumptions</td>
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<tr>
<td>Validation of model</td>
<td>8</td>
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<tr>
<td>Presentation of appropriate results with estimation of precision</td>
<td>9</td>
</tr>
<tr>
<td>Results interpreted and discussed in context</td>
<td>10</td>
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**Diseases: Infectious and Communicable**

Seven of the research papers were about the diseases that were infectious and communicable in nature and dealt with control and prevention of HIV/AIDS and various STD that considers the behaviour of humans’ basic determinants for the spread. Models of simulation dealt with
complex concerns in order to confirm effective application of immunization, by developing understanding about the biases that inherent in respective field trials or by following various in order to deliver vaccine to respective population, and prevents no social infections.

**Evaluation of Economy and Costs**

Screening papers (noted below) included costs in 17 research papers. Most of them were published from 1995, to reflect cost containment towards the health services. Various researches considered direct costing concerned and used direct costs. Few cases were about clinical or otherwise operational results as modelled as well as costs get applied to the outcomes, further the costs get integrated in the form of model. Few get generalized to other settings. There are alternative kinds of clinical interventions that get assessed under five papers and McHugh get assessed for costs related to alternative staffing arrangements meant for nurses. The relevant researches get used in determined manner along with costs wit results that shows room for modelling over sub-populations for the identification of optimal strategies.

**Screening**

We have appraised a total of 44 papers with modelled screening. Further this topic attained increased range in popularity for span of time. 37 out of 44 papers get published since in the year 1990. Papers considered here are having high quality.
Figure Flow chart of review.
Screening lends simulation modelling, very well. Concerns of frequency, various performed tests and investigation threshold can be assessed that might not possibly remain under experimentation. In various screening programmes, there are more testing that gets intuitively connected with increased mode of effectiveness. Still, the same remains as the greater cost, also for development of policy and an evaluation of economy. In respect of the appraisal of screening papers, there is the element of cost.

The application of simulation modelling gets widely recognised for cancer screening. MISCAN model (or the MIcroSimulation Screening Analysis) implies Monte Carlo micro-simulation towards a huge number of life histories as per epidemiology related to disease, and is supported for many years in terms of modelling cervical as well as breast cancer screening. Implication of cervical screening comprises cost-effectiveness researches over screening policies, and includes other screening tests, like Human Papilloma Virus screening.
Screening models for breast cancer gets compared to alternative programmes of screening as well as life studies quality in Netherlands, with predicted age range with cost-effectiveness along with screen interval for older people. MISCAN used the model extensively with diversified breast screening concerns in various other countries, that counts relative cost-effectiveness for the breast screening as in the UK, Spain and France against Netherlands, with cost-effectiveness related to breast screening as in Australia, Germany, Italy, Spain and application of ‘MICROLIFE’, that remain partly-populated with MISCAN data, in New Zealand. MISCAN is recently implemented over the population of the UK and noted the way the model gets used in terms of predicting reduction in terms of mortality as expected from the domain of screening as well as proportion for total breast cancer mortality, attributing on screening. A current application of MISCAN gets compared to the effectiveness meant for two colorectal strategies for screening (faecal occult-blood vs flexible sigmoidoscopy), assessed by years related to lifesaved. Some of the screening models on cancer gets reviewed as in two papers modelling that has the effect over screening meant for ovarian cancer, added by the evaluation of the policies related to cervical screening in Wales and England. Modelling gets implied on an extensive way for the screening related to the diabetic retinopathy. As per the model by Javitt PROPHET (Prospective Population Health Event Tabulation), for the simulation effect as well as assessment towards cost of 5 screening as well as strategies treatment related to the diabetic retinopathy related to type I diabetes. The same work gets followed by more published papers, reining model and further extending the use to type II diabetes, with retinopathy over prematurity.

Miscellaneous
This section covers the papers with disparate topics. As for instance, Bronnum-Hansen utilised discrete condition of simulation towards the mode of validating epidemiological model PREVENT. As for Warneret al. the determined model is for the effect related
to smoking cessation policy, added by Zenios et al. utilised Monte Carlo simulation in order to investigate equity as well as efficiency implications through alternative strategies, for the allocation of transplantation of kidneys.

**Discussion**

As per the current systematic review, the basic aim is to estimate quality and extent of simulation modelling for the sector of health care and the health of population as a whole, instead of the report with results from models being appraised. Simulation modelling turns up as a popular tool for hospital scheduling (units for individual and whole systems) prior to 1980, especially in the US. This is followed by refinement over the techniques of modelling by 1990s, when researches illustrated modelling in the sector of health care being substantially attaining extension in a very wider way. Hospital scheduling is very popular, added to this is the screening being the principal interest domain, as used in the theoretical methodology, for answering research questions. Moreover, simulation modelling in reference to communicable disease and incorporating costs offer the application of comparison over alternative strategies. Estimations related to quality of simulation modelling remains as the basic part of particular review. There is a critical appraisal over the epidemiological researches for the calculation of validity as well as generalizability over the published papers as aught widely, in undergraduate and post-graduate level. Assessment of proformas to the systematized process gets agreed as per criteria that gets utilised and made available on a wider basis. Still, there is no criteria noted as available in terms of aiding critical appraisal added by the judgement of determined quality meant for researched papers on simulation modelling. With the process of increasing numbers of such research works, emphasis are led on policy development related to implementation of policy model that might not appear robust, as we suggest criteria for critical appraisal as well as assessment of quality being essential. The process of critical appraisal gets used to the mode of adaptation from formerly developed peer-reviewed proforma. This has been estimated and further refined in the process of appraisal and we derived robust
analytical process for the evaluation of such researches. Concentrations were over the quality based wide ranged published papers whereby any modelling paper must have minimum clarity and objectives for information related to the model, necessary data, relevant assumptions, elements of validation as well as outcomes. In general, the difference among ‘A’ and ‘B’ grade researches is that the former offered in-depth data added by the validation of model and further presented precision over the outcomes, along with balanced interpretation as well as discussion related to core derivations. However, 1/3\textsuperscript{rd} of the papers are noted to be with lower quality there still remained a general trend towards the increased quality in due course of time, that is liable to reflect decreasing conference proceedings along with increasing papers as published under peer-reviewed journals by 1990s, during evidence-based practice and the phase of critical appraisal over quality of respective papers, which were in context of health care. In general, the papers reporting under the model of screening showed higher quality rather than the papers related to hospital scheduling, and relevantly reflecting focused interest in respect of cancer screening models. It was difficult to attain conclusions related to relative quality for the papers in other areas, as least were about the communicable disease, evaluation of economy and miscellaneous sectors. It is necessary to note or otherwise judge data offered in the published papers, irrespective of the actual model or otherwise conducting research. Due to pressure over the space constraints in the journal, added by complexities over various studies of modelling, there are some papers that never were justified towards the undertaken modelling research. Implementation of criteria bases assessment for paper quality must guide researchers for the minimisation of content related to the journal paper with quality. Papers noted in review are of wider journal periphery; whereby less than 1/3\textsuperscript{rd} of the works are found in respective journals. Thus, there is no ‘natural home’ meant for the reporting over the modelling in context of health care as well as may partly considering lack of uptake for the derivations related to health care modelling by the selected clinicians, managers working for health service and
policy developers. The review aims on practical modelling (instead of aspects like methodological descriptions). We derived that publication gets governed in terms of subject area rather than employed method. Publication journal is subject to reflect author’s interests as many older researches conducted operational researchers added by published non-medical journals, otherwise those presented in conferences. Recently, simulation modelling gets inclusive of clinicians in modelling periphery and as a result, some proportion related to modelling papers get published under clinical/health services journals.

Devising the selected search strategy in terms of review is complex. Our experience over electronic searching, concludes enough potentiality towards relevant MeSH headings under current Medline and Health STAR thesauri, being confusing and also in indexers. We followed trade-off search strategy with higher specificity meant for lower sensitivity. A determined search term as noted in 17 papers gets identified from relevant declaration of personal contact for ‘models, theoretical’aspects with 68 000 references. Thus, there are very limited modelling search strategies that are liable to approach 100% sensitivity (till specificity gets very low) along with futuristic systematic reviews under the field of modelling that has reference list and contact details of researchers. Irrespective of increasing count of quality papers in medical/health services journals, it was hard to derive conclusions over the modelling value in terms of health care as implementation remained scant. This needed evidences for outcomes meant for the implementation of the model, added by assessed changes in problematic parameters under determined models, estimation magnitude is meant for the meaningful change, added by further insights related to system meant for evaluated implementation. We faced the inability in assessing model value in determined review due to instances like omission in various published papers within necessary timescale. There are various modelling studies that get published prior to validation and implementation as carried out (and further assessed). We can probably conclude with the funded volume of work from health care modelling domain that has testament
towards necessary value. Moreover, many researches assess model for the value.

Conclusions
Simulation modelling has been identified as a powerful tool that is applicable for wide research works in the sector of health care. Research works are published about modelling in respect to health care that is growing substantially in the recent past. Research works are from varied fields yet are developing in trend. In respect to potential of kind of simulation modelling, there is the evidence-based policy meant for the scope of clear health care domain, yet results for the implementation and value of the model demands more research. We hereby will offer report and the results as appraised by the research for future publications.

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