System dynamics applications to European health care issues

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Taking a European perspective, a review is made of some system dynamics models which address health care issues. Suggestions are made for the types of role which these models should take, bearing in mind the strategic orientation of system dynamics modelling. Examples are described of qualitative models where influence diagrams are the main analytical tool. Quantitative system dynamics models have a contribution to make in epidemiological studies and have been used to analyse the AIDS epidemic. A detailed example of one aspect of model formulation is given. This concerns the AIDS incubation time distribution and shows how real-world complications arising from virological staging and treatment effects are handled in a model of AIDS spread.

Keywords: system dynamics; health care; managerial learning; public policy; HIV/AIDS

Introduction

As a component of the public sector, health care looms large. All European governments provide the great bulk of health care through the public purse and in the UK this means an estimated budget of £45 billion for 1998 (or approximately 6% of GDP)\(^1\) and employment for around one million people.

The health service in the UK has, over the past ten years, undergone something of a transformation in operation. It has witnessed the introduction of the ‘internal market’ and the distinction between ‘purchasers’ of health care, mainly in primary care, and ‘providers’, such as hospitals and medical specialities. Funding problems have been endemic: an ageing population and the costs of modern health technology have served to bring into sharp focus the political issue of the extent to which general tax rates ought to be raised to finance the burgeoning health budget.

In this climate there is a pressing need for tools of assessment and evaluation for both strategic and tactical issues. Operational Research and statistical techniques have a long track record of use in health care settings, pertinent examples being in out-patient appointment systems and departmental facilities management.\(^2\)–\(^5\) Yet OR techniques, despite their track record of success in health problems, have primarily addressed tactical and operational matters. With system dynamics there exists a modelling methodology which is suited to handling strategic policy matters and it is the purpose of this paper to provide illustrations of just what can be achieved in this regard within a health care framework.

The paper is organised as follows. A review is made of possible roles which system dynamics models can take with special reference to health care matters. Following this, coverage is given to qualitative (influence diagram) approaches in three health applications: community care, short-stay psychiatric patients and the waiting list phenomenon. Finally, a more detailed account is provided on one facet of a quantitative system dynamics model in the field of epidemiology, namely the formulation of the incubation distribution within the author’s model of the spread of AIDS.

What follows is not claimed to be a comprehensive review of health care modelling. For a start its geographic focus is solely the UK and Europe. However, given this context, an attempt has been made to collect all the health-related references arising in the mainstream constituency of system dynamics literature. The purpose of the paper is to review current work but also to stimulate the system dynamics community into becoming more involved in what is a topical feature of most societies, often with a large budget commitment: health care is always in the public eye.

Roles for system dynamics models in health care

Projects for which system dynamics is most properly utilised adopt a vista congruent with the methodology; a vista appropriate to a strategic orientation. This is synonymous with examining aggregate flows of people and resources in the region, hospital or whatever. Therefore studies which inherently involve patient flows and money flows at a strategic level of aggregation are obvious candidates for a system dynamics framework to the analysis.
Three examples in this category are the studies by Wolstenholme on community care planning,6,7 by Coyle on management of a hospital for short-term psychiatric patients8 and by van Ackere on hospital waiting lists.9 All are discussed in more detail below in the context of qualitative modelling. This has been done in the light of the strengths offered by all of them at the qualitative level.

There are two main purposes for developing system dynamics models in the health care context and these thoughts may go some way towards the formulation of a research agenda.

The model as a tool of persuasion

There is a role for model-based persuasion at the national or regional level. In a climate characterised by lack of understanding a model can be used to fill a vacuum. Scenarios generated by a model can act as a catalyst to insightful thinking. Examples might be:

(i) an input into the debate on the most appropriate interval for breast cancer screening together with the age groups to be screened.

(ii) the timing of a vaccination offensive against whooping cough, a childhood disease characterised by cycles of infection amongst those children who have missed the usual immunisation offered during their first twelve months of life or for whom the protection was not effective.

(iii) supporting a case for an enhanced or initial budget to deal with or counteract the consequences of a specific trend or likely eventuality. For instance, provision of needle exchanges to combat the spread of AIDS amongst i.v. drug users and their partners, or money to provide better sex education amongst 14–18 y olds.

An example where a fully developed system dynamics model has been used to persuade is that documented by Bronkhurst et al.10 Their model addresses the supply and demand for the dental health care system in the Netherlands. Demand represents a variety of demographic, pathological, psychological, sociological and economic processes, whereas supply concerns the availability of dentists, dental hygienists and associated factors which affect their productivity. The team have been working on this study for over a decade and, for good reasons, have moved from a simple model containing just 20 state variables (levels) to one of 440 state variables.

In order to gain acceptance of the model with their clients (a committee of representatives of those groups most active in the field of dental health care) the researchers engaged in a reconstruction of the detailed model with them. This activity, which they call ‘quasi’ participatory model construction, took a large investment in time but had the benefit of convincing the clients that, at least partially, it was their model. In fact, little fundamental change occurred in the model as a result of this exercise, but the clients would then hopefully be less resistant to assimilation of the insights gained from the study.

The model as a frame for evaluation of tactical studies

The second main purpose for a system dynamics model would be in offering a bigger picture within which tactical initiatives could be better evaluated. It is no use spending time and money devising a new system for bed management on a geriatric ward if part of the problem is basically that patients have nowhere to go, (see the review of Wolstenholme’s work below). The hospital management might feel that ‘something must be done’ about the problem but unless they are prepared to widen the boundary of their mental model they are merely fire-fighting: tackling the symptoms and not the cause.

OR studies at the tactical level have, in many cases, been highly successful. But what is occasionally lacking is some consideration of context. Without this, it is possible to initiate a tactical study, which apparently is a great success, only to find that in a year’s time the contextual situation has changed which renders all the excellent operational research work ineffective. It is here that a system dynamics model could prove its value. Elevating the boundary of a model, to a point where it encompasses all the dynamic influences necessary to comprehend the totality, is the normal modus operandi of system dynamics.

There are rare instances of studies where both operational and (later) highly aggregated models are separately employed. One such instance concerns personnel planning in the Dutch health care system. The purpose of the study was to shed light on issues surrounding the future provision of rheumatologists.11 The team employed discrete event simulation techniques to build a group decision support system at the tactical level and, once acceptance and justification at this level was achieved with the clients, then moved on to develop a system dynamics model for national planning. In other words a bottom-up approach was adopted.

It is worth noting that this is the exact opposite of what can occur when system dynamics models are deployed. Having demonstrated the benefits of policy changes at the strategic level, there is often then a need, working with the clients, to operationalise the sub-structure which would implement the chosen policy.12 In other words a top-down approach is employed.

Qualitative methods

At the qualitative level system dynamics provides a focus for structuring an issue and also as a vehicle for subsequent debate. Although the first two decades of system dynamics practice saw the emergence of influence (causal-loop) diagrams, it was not until the early 1980s13 that a case
was made for employing such diagrammatic tools as a sole tool in systemic investigations. The traditional view that a system dynamics study should, *ipso facto,* lead to a formal model being simulated on a computer ignored the fact that system dynamics already possessed, in the influence diagram tool, a ready means of illustrating the often devious effects of circular causality. The modelling community needed alerting to a latent potential within their midst. Today there is less of a tendency to overlook the utility of influence diagrams. Indeed, at least one book has appeared illustrating the ways in which systems thinking, using only qualitative influence diagrams, can help in structuring thinking and debate in management.

**Community care**

Within the health sphere Wolstenholme has demonstrated the power of qualitative modelling. His study concerned an evaluation of the potential consequences of government legislation in 1993 which caused a transfer of responsibility for community care of the elderly to local government Personal Social Services Directorates which had a cash limited budget imposed upon them. Prior to this date purchase of community care was the responsibility of the Department of Social Security. The intention behind the change was that public funds could be saved if the flow of patients into community care was slowed down.

Figure 1 portrays the most important message arising out of this study, although other issues arose too. The reader is referred elsewhere for these. The inner (negative) feedback loop is the intended consequence: as the funds available diminish, social services will not accept any more discharges from hospital care. Previously, hospital consultants had unfettered discretion to discharge patients according to their clinical judgement.

The outer loop in figure 1 demonstrates an unintended consequence. Hospitals have a limit of available beds and this limit is not easily changed. With discharges limited by funding, so admissions to hospital are inevitably restricted and waiting lists of elderly people will rise. These cases waiting for admission are still in the community and are still, therefore, a drain on the community care budget. There is thus a re-inforcing effect of strain on the social services cash-limited budget and they will be even more reluctant to accept fresh discharges of the elderly from hospital. The positive (outer) loop clearly shows the key to it all: community care costs arise not just from those who have been discharged from hospital but also from those waiting to be admitted.

Further detailed enhancements of the ideas represented are described elsewhere. These enhancements include the construction of a formal computer model which covers all the states present in community care (nursing homes, residential homes and domiciliary care) together with a management flight simulator, allowing the model to be used in an interactive gaming mode.

A principal outcome of Wolstenholme’s study is to expose how unintended effects can cause the hospital waiting list to increase. Perhaps not surprisingly other authors have also explored the waiting list phenomenon using systems thinking ideas, although the reader should be aware that it is a well-researched issue in health care studies using other approaches.

**Short-stay psychiatric patients**

An early study by Coyle considered the problem of short-stay psychiatric patients. As part of the construction of his diagrammatic model he sets out three types of influence link: a physical flow, controls applied by system managers and, finally, behavioural responses. The latter are behavioural forces upon which managers have only indirect control. A prime example here, and in the context of the chosen patient grouping, is the effect that the duration and method of treatment seems to have on the delay before a patient recycles for further treatment and, indeed, whether recycling takes place at all.

The influence diagram shown as Figure 2 is adapted from figure 4 from Coyle. Loop 1 is the managerial loop. Here the admission rate has, of necessity, to be reduced as the hospital nears capacity: essentially the admission rate has to be regulated such that the hospital is acceptably full. Loop 2 is the patient loop: as the waiting time for admission increases this will, in turn, increase the fraction of patients who recycle in the system and reduce the recycling delay (not shown). Loop 2 is positive and its activation following a lengthening of the waiting list is an unwelcome eventuality for hospital managers.

An interesting parallel can be drawn here with Wolstenholme’s model in Figure 1. In the former case we have a critical variable ‘community care costs’ which it is desirous to contain. It certainly cannot exceed the cash limited...
This cost variable is increased by the costs of new hospital patients discharged into community care, but also, and this is unanticipated, by the extra numbers on the waiting list who cannot get into hospital.

In Coyle’s model the equivalent critical variable is the ‘waiting list’. It is increased by new cases but also by recycling patients. This is the unanticipated phenomenon here and it is set in train by actions of the system managers, firstly through an increase in the waiting time and, in addition, by the duration (and quality) of treatment afforded to hospital cases. For new cases, the shorter this duration is, in general, the greater the propensity for a patient to recycle. But patients admitted after a long waiting time will often be in a worse condition than had they received prompt admission and so the duration of treatment is necessarily lengthened. This amplifies the initial problem: fewer people can be admitted and the waiting time gets even longer.

The purpose of Coyle’s model is nothing more than to open up a debate, at the system level, on how to better manage the situation. He suggests two improvements which are embodied in two further (negative) controlling loops—shown as loops 3 and 4 in Figure 3. Loop 3 reflects the notion that admissions might be governed by the waiting time, the idea behind this being that the hospital must find a bed for anyone who has waited more than an agreed period. In this eventuality, loop 1 would have to be set aside as a means of controlling admissions.

In order to be able to achieve the benefits of loop 3 the hospital would, of necessity, be required to discharge patients to make room. So we see that loop 4 would be brought into play. It is suggested that perhaps quarterly meetings might be set in train which bring together GPs, hospital doctors and administrators in an effort to decide how to balance out the effects of loops 1, 3 and 4 in Figure 3. Furthermore, these meetings should be furnished with regularly collected local statistics on waiting lists, eschewing national and occasional data. Unless some attempt is made to co-ordinate the actions of the main system players, the system will underperform considerably. Rarely will the systemic effects of individual interest groups be consonant with effective overall performance.

A further interesting insight which emerges from this study concerns measurement of average treatment duration (length of stay). As shown, this is influenced by medical opinion but opinion perhaps which is not informed by the most relevant information. Life cycle monitoring of patients is called for and this is an exceedingly difficult task to perform adequately. Doctors need to be made aware that a simple comparison of a patient’s condition at two displaced points in time (admission and discharge) ignores factors like the waiting time previously suffered by that patient. An appreciation is required that a patient’s condition is, only in part, determined by the way the clinician manages the treatment. System dependent influences will also be confounding the situation.

Figure 2 Influence diagram showing the two main loops involved in the management of short-term psychiatric patients (due to Coyle).

Figure 3 Enhanced influence diagram introducing two new controlling loops in the management of short-term psychiatric patients (due to Coyle).

Figure 4 Simplified influence diagram showing how the waiting list can regulate demand (due to van Ackere).
Waiting lists in the context of public and private health care

A final example of qualitative system dynamics models in health care is due to van Ackere and Smith, whose work is set at the national level, is not predicated upon any particular patient group or medical condition, and explores the trade-off between NHS and private medical care.

As mentioned above, examination of the waiting list is central to this research also and it is interesting to contrast its role in each of the three studies reviewed. In Wolstenholme’s analysis, he reveals the problem of an escalating waiting list which emerges as a result of the implementation of a national policy change on a totally unconnected aspect. Coyle’s work positions the waiting list as a crucial variable in the model and he demonstrates, for a specific patient group, how admissions policies and treatment duration can, in fact, conspire to affect the waiting list adversely in the guise of recycling patients. Van Ackere’s model, on the other hand, makes the waiting list the raison d’être for her study reflecting general concerns reviewed elsewhere. She considers the policy issue of government directly funding initiatives to tackle lengthy waiting lists. Leakage to the private health sector, as allowed for in this model, could have been grafted onto Coyle’s model too, where it would impact mainly on the variable dealing with the fraction of patients recycled.

The fundamental hypothesis in van Ackere’s model is that the attractiveness of private sector health care grows as waiting lists for NHS care increase. This effect is portrayed in the influence diagram shown as Figure 4. To this diagram van Ackere adds in a pressure for resources loop (not shown), which represents a possible government policy response when the waiting lists become really excessive. Simulating this eventuality reveals temporary resource injections designed to reduce or clear NHS waiting lists will create the response that more people are attracted to the NHS and the problem reappears.

An influence diagram is a useful means of portraying, in broad-brush form, the major components of system influences and, by implication, the chosen model boundary. In appraising the suitability of a model it is important not to lose sight of the wood for the trees. We should firstly be concerned to assess if anything has been omitted which might crucially affect the system, rather than become bogged down with an appraisal of the veracity of what is extant, an important task though that undoubtedly is.

Suppose, for instance, we extend van Ackere’s initial model to include the activities of consultants who undertake private health care work in addition to their NHS contracts. The model boundary is therefore enlarged and the resulting influence diagram may look as depicted in Figure 5. Including a major resource, consultants’ time, within the model creates a positive loop. Now, an increase in the waiting list may be reinforced, rather than regulated, by the presence of private sector health care.

Figure 5 Enhanced influence diagram showing a wider view of the causes and effects of the waiting list phenomenon.

Obviously the extent to which, in reality, the additional positive loop operates is open to debate, but it serves to underline the mind-expanding aspect of model conceptualisation in applying system dynamics. Clearly there are consultants who work for both the NHS and private practice and, within limits, there are only so many hours in a working week for them to function effectively. Were they to devote more attention to private patients it may mean that more of their NHS duties are delegated to clinicians below the rank of consultant, which in turn may make for a higher fraction of recycling patients as alluded to by Coyle.

On the other hand, if NHS consultants were prevented from taking on private sector work the effect of the positive loop would not arise, but the alternative of private health care may not be as attractive should that sector not be able to offer sufficient consultants’ time. It might exhibit the same phenomenon as evident in the NHS unless the private sector can recruit enough consultants to keep pace with demand.

There is no doubt that the activities of consultant clinicians are an important consideration at the interface between private and state sector health care. Developing influence diagrams in stages can therefore be seen as a means of propelling the qualitative strategic debate forward or, alternatively, showing up gaps in knowledge which may require further investigation (or detailed statistical analysis) to enable a formal quantitative model to be structured and parameterised.

Quantitative models in epidemiology

Given the mathematical principles which underly system dynamics simulations, it is hardly surprising that it is particularly appropriate for modelling the epidemiology of infectious diseases. Indeed, in systems terms, the coupled positive and negative feedback loops (with a dominance switch at a certain point in time), as they
describe any infectious epidemic, are exactly equivalent to the same system structure used for modelling diffusion of a new technology or the introduction of a new product into a consumer market.

Furthermore, the presence of delay functions, so routinely used in many system dynamics models, means that the methodology can be offered as having the potential for more transparent analysis of the spread of infectious diseases characterised by long incubation periods than the corresponding mathematical methods. There is a lot of current interest in such diseases, stemming initially from analysis of the AIDS pandemic (discussed in more detail below) but, in the UK particularly, arising from the epidemic of bovine spongiform encephalopathy (BSE) in cattle and a possible consequent epidemic of new-variant Creutzfeldt–Jakob Disease (nvCJD) in humans. BSE arose, almost certainly, out of feeding ruminant-derived protein to cattle in the early 1980s, whilst nvCJD is now widely thought to have originated in the consumption of infected meat by the individuals affected. BSE has an incubation period averaging five years whilst that for nvCJD could be as long as ten years.

The developing interest in epidemiological modelling generally is well-covered in the literature within the past ten years and insofar as it applies to infectious diseases of humans.20,21 The latter reference is a reasonably recent account of research in this field of mathematical modelling. The work associated with the author is the only item covered which uses the methodology of system dynamics, but it is interesting to note that Jacquez et al, researchers from mainstream epidemiology and located in North America, recently published a paper22 where they described an AIDS-spread model formulated in STELLA. The AIDS model with which the author is associated had included all the complications in the Jacquez model some years earlier.23 Only two other European references of applying system dynamics to AIDS modelling have been uncovered,24,25 although its adoption for modelling infectious diseases in general was prophesied by an eminent mathematical epidemiologist in the 1970s.26

The author’s work in AIDS modelling using system dynamics has progressed from the first phase which saw the development of a transmission model to allow better understanding of the dynamics of the epidemic and to specify data collection needs.27 As new knowledge emerged from the worldwide research effort on AIDS, particularly of a virological and sociological nature, this was duly reflected in changes in model structure. The second phase involved fitting the model’s basic structure to time-series data on reported AIDS cases, whilst the third (and current) phase concerns the costs and consequences for resources employed in the UK’s fight against AIDS.

Fitting the model to data enabled projections of future incidence to be offered and estimates made of relevant parameter values.28,29 Moreover, fitting a system dynamics model to real-world data is one example of model optimisation, a subject which is being given increasing attention in the field.30,31 The heuristic search employed for optimisation in the AIDS modelling work is described in detail elsewhere.32

Within the framework and context of this paper, it is impossible to fully describe all aspects of the system dynamics models of AIDS spread with which the author has been associated, although a number of references have been given. Rather one example has been selected where the system dynamics formulation has reaffirmed the power of the methodology to embrace real-world complications in a more transparent manner than is allowed by conventional mathematical approaches.

**AIDS incubation period**

The time lapse between HIV infection and subsequent diagnosis with AIDS is a crucial component of any model used in AIDS epidemiology. Estimates of its form and parameters have been offered in a number of studies. Two things are clear: the average incubation duration is of the order of ten years and this average duration has lengthened relatively recently arising from the effects of treatment now routinely offered to anyone diagnosed HIV-positive.

In a system dynamics model the use of one of the DELAY functions would be an appropriate choice for handling the incubation distribution. These functions offer a series of exponential delays from first-order upwards.

They generate a family of Erlang distributions,33 a first-order delay yielding an Erlang type 1 distribution which is equivalent to the negative exponential. Because these distributions can be represented in linked integro-differential equation form, they can overcome the problem faced by the mathematician who has to produce models involving both calendar time and biological time. When a crucial parameter of the distribution (the mean) is also varying with calendar time arising from treatment effects, mathematical models become a lot less tractable.

In earlier studies of AIDS spread, mathematicians suggested that the Weibull would be appropriate for the distribution of incubation time, possibly arising from its widespread use in survival studies. Mathematical epidemiologists need to work with the distribution’s hazard function \( h(x) \) which is such that \( h(x) \, dx \) is the probability that an event occurs in \((x, x + dx)\) given that it has not occurred yet. In the case of the Weibull, the hazard is linearly increasing for a shape parameter \( m = 2 \) and totally flat for a shape parameter \( m = 1 \). Either of these cases makes the Weibull an easier function to handle mathematically. However, with data accumulated over the years it has become apparent that distributions of the gamma form are more appropriate since the hazard of AIDS is now known to increase but then flatten after eight years post-seroconversion.34 An Erlang distribution is merely a gamma...
distribution with an integer shape coefficient and exhibits (for type 2 and above) a hazard function which increases at a decreasing rate, see Figure 6.

In some ways it is fortunate that the Erlang distribution has been shown to be appropriate because it is not possible to render other distributions into integro-differential equation format. If some other distribution needs to be used then the system dynamics model would have to be decomposed into, say, quarterly cohorts of infectives and the chosen distribution’s density function employed to propel each cohort through to AIDS. This would make for a much larger model and non-trivial formulation problems. These problems are not insuperable as has been demonstrated in a model used to recover the form and parameters of the AIDS incubation distribution from data of AIDS incidence in blood transfusion cases in the USA.35

Viral pathogenesis: two peaks in viral load

A further modelling complication arises from knowledge about the viral pathogenesis of HIV. Quite early on in AIDS research, virologists were able to confirm that, around the time of seroconversion in the host, there was a substantial peak in viremia (measure of viral load). This fell to almost negligible amounts as the immune system responded and the patient would then exhibit an asymptomatic period of, may be, eight years or longer duration. Eventually, however, the immune system would be progressively overcome and the patient would become quite ill, with levels of viremia increasing towards another peak consistent with a condition permitting a diagnosis of AIDS-Related Complex (ARC) and, ultimately, AIDS itself. Figure 7 gives a representation of this profile. Relative to the long asymptomatic period, the early and late stages are of quite short duration.

Now if this knowledge is faithfully incorporated into a model, and assuming that levels of viremia are equivalent to levels of infectiousness, then the incubation distribution needs to be disaggregated so that the HIV-infecteds at each stage of biological time can be assigned different probabilities of transmission to a susceptible. These probabilities will reflect the high-low-high profile of assumed infectiousness.

This means that use of a DELAY3 function is not possible assuming as it does that each cascaded component first order delay is of equal duration. Of necessity, therefore, a series of level divided by life formulations were adopted with the life representing the average sojourn time in the previous stage. Figure 6 shows the resulting density and hazard functions for this incubation distribution which assumes exponential removal from each stage and average residence times of 1, 8.5 and 1.5 years respectively. It is interesting to note that with this unequal staging the hazard of AIDS flattens off at around eight years post-seroconversion, in line with the results of recent research referred to above.34

Treatment effects

Finally, consideration is given to treatment effects on the incubation distribution. There have been phases of pre-AIDS treatment offered to seropositives. The early zidovudine therapy, despite initial optimism, was eventually shown not to be effective in delaying progression to AIDS. Primary prophylaxis for Pneumocystis carinii pneumonia, however, has met with considerable success in reducing the extent of this particular condition as an AIDS-defining illness. The most spectacular success, however, has occurred since mid-1996 with the introduction of triple-combination antiretroviral therapy, a trio of retrovirals which the patient is required to take on a regular basis and indefinitely. Provided the regime is faithfully adhered to, this seems to virtually clear virions (infectious virus particles) from plasma; indeed,
the reduction occurs within the first two weeks following the initiation of treatment.

In order to re-structure that part of the model handling the incubation period, it was necessary to introduce the state of being on treatment following initial infection. Figure 8 shows the revised arrangement. A fit of this model to AIDS incidence in Greater London, using data to end-1995, reveals that the average sojourn time in the state ‘on-treatment’ is 11.1 y as opposed to 9.4 y in the asymptomatic phase for those not on treatment.

Notice that both routes involve cases passing through the final phase of HIV pathogenesis. This, much shorter, period is characterised by patients having rapidly increasing viral loads and equally rapidly declining CD4 lymphocyte counts (a measure of the health of the immune system). If HIV in an infected person eventually overcomes the ability of the combination of antiretrovirals to clear it from the host’s system then the outcome, in that person passing through the final stage (advanced HIV disease), will be no different to an untreated patient passing through the same stage. It is just that an untreated case will reach this stage more quickly.

Conclusions

This overview of system dynamics based modelling of health care issues has shown that, at least on this side of the Atlantic, the literature is not vast, certainly as compared to studies modelling organisational and managerial issues. However, new work is in the process of publication and it is proposed to have a special issue of the System Dynamics Review devoted to health and health care dynamics appearing within the next twelve months. This future contribution to the literature will, however, embrace a geographical perspective much wider than just Europe, the focus of the current paper.

There is a clear potential for system dynamics to be employed in support of health care policy and, as the millenium approaches, health care is a subject not far off the top of the European political agenda. Moreover, readers from the health care (rather than modelling) community will have learned of the variety of issues which are capable of being addressed. If some fresh coalitions can now be forged between health care professionals and the system dynamics community, then this paper will have proved its worth.

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