Supporting Material is available for this work. For more information, follow the link from the Table of Contents to "Accessing Supporting Material".

Using System Dynamics to analyse Health System Performance within the WHO Framework

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ABSTRACT: The World Health Organization has developed and refined a considerable body of work on Health Systems Performance Assessment, reflected in the World Health Report 2000 on comparing countries' health systems and ongoing worldwide debate. This paper contributes to this debate by presenting an overall System Dynamics (SD) simulation of the key features of the WHO framework, including some feedback interactions among financing, resource generation, service delivery and stewardship, all of which affect healthcare systems performance.

The model is calibrated using Australian healthcare statistics trends over the past 40 years and explores possible futures over the next 40 years. It discusses the current status of work in progress to clarify the wider issue of the contribution of the health system to the overall well-being of individuals, groups and the nation. The gaps in theory and practice and contentious areas for ongoing research and refinement are explored and potential future enhancements of the simulation are discussed.

These enhancements include:

- More compelling and engaging animations with the potential to influence public debate about health policy;
- Including datasets and comparisons among other developed countries;
- Health systems evolution in developing countries; and
- Global health policy options and debates.

KEYWORDS: HEALTH POLICY, SYSTEMS SIMULATION, HEALTH SYSTEMS PERFORMANCE

1 BACKGROUND

Healthcare is a large industry sector in developed countries, with total health expenditure in OECD countries accounting for around 10% of GDP in 2003 [1]. The "health system" of a nation comprises those activities that aim to improve the health of the population, either by providing personal services to the individual or non-personal interventions to groups of the population [2]. The World Health Organization (WHO) broadly defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Therefore, in addition to the health system, many other areas of human and social activity contribute indirectly to the health and wellbeing of the nation, including education as well as environmental and social infrastructure [3].

Given the size and importance of healthcare activities, there have been many attempts to grapple with frameworks for understanding and improving health care performance.

Many of these activities started with observing the impact of medical interventions on individuals, and there has been some conjecture over the relative merits of medical, personal lifestyle, public health and general socio-economic improvements in improving the health status of citizens. Indeed, the French Philosopher Voltaire (1694-1778) remarked, "The art of medicine consists in amusing the patient while nature cures the disease."

Whatever the underlying contributions, over the past century improvements in life expectancy through reduction in mortality rates at all but extreme old age have been spectacular (see Fig.1).

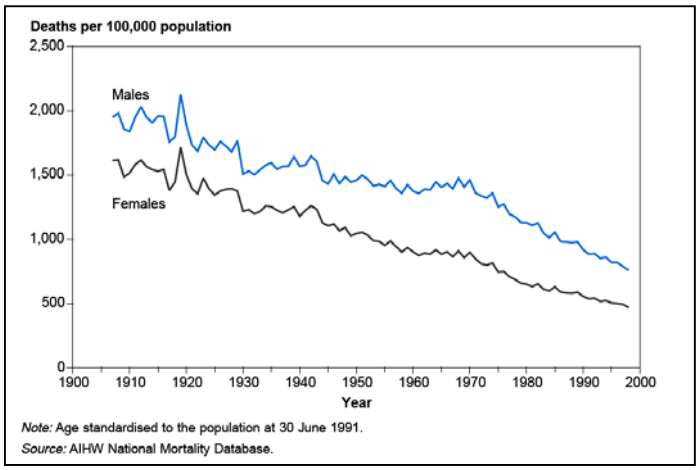

Figure 1. Australian mortality data for the 20th Century [3].

This very success has prompted the search to understand where the limits to improving health and health system performance lie.

An overall synopsis of past and future health care directions is well summarised in the recent Wanless UK Report [4].

"The main trends examined here show that over the last century there has been a big shift in the burden of disease – from infectious diseases of the nineteenth and early twentieth centuries to chronic diseases in the twentieth century and now. The UK (and England) performs poorly compared to other countries on some key measures of health outcomes and chronic disease such as Coronary Heart Disease (CHD), cancer and particularly on respiratory diseases. Chronic diseases, such as CHD and cancer are also strongly related to lifestyle factors such as smoking, poor diet, physical inactivity and alcohol consumption. There is a strong social gradient to the prevalence of many of these risk factors. For example, it is estimated that half the difference in survival to 70 years of age between social class I and V is due to higher smoking prevalence in class V.

Changes over time in the burden of disease have shifted the emphasis of public health from health protection measures to tackle infectious diseases, towards health promotion policy targeting individual behaviour and lifestyle risk factors, as well as the wider determinants of health, such as poverty and education. Although health protection is still an important issue in the context of new, emerging and resurgent infectious diseases (such as HIV, Ebola Virus, vCJD and tuberculosis), and with possible threats to health post-September 11th, this trend seems likely to continue. In addition, there could well be the development of new diagnostic technologies, including those based on genetics, which could also play a role in improving population health. There could also be developments in the use of Information and Communications Technologies to predict future health status, and for directing the use of resources to prevent or minimise demand on health services."

2 A BRIEF HISTORY OF HEALTH SYSTEM PERFORMANCE

Observation of the effects of healthcare on individual patients and population groups commenced around the 19th century. Up to the mid 1960s, a clinical (from the Greek "by the bedside") view of structure, processes of care and outcomes dominated. The economic and system view was enhanced by Kenneth Arrow's landmark 1963 article, "Uncertainty and the Welfare Economics of Medical Care" [5]. Since then a more coherent health systems view has emerged, with health services researchers grappling with the trade-offs among cost, quality and access in healthcare, especially at the national level.

Public Health prevention and health promotion dimensions have also gained a significant place in the systems view of health and health policy.

Over the past 50 years, health systems in different countries (particularly the US and the UK) have taken significantly divergent paths, probably due to a mix of accident and logic in the context of national characteristics and history [6]. Country-level comparisons of health systems have increasingly led to conjecture about overall systems performance [7-12].

Several commentators have noted that health spending behaves as a luxury good, the proportion tending to increase with national prosperity, and that more spending does not necessarily produce more health. In fact there is even support for the notion that over-servicing can result in *poorer* health system performance (see Section 7 of this paper). Debates about what components of healthcare are consumer goods and what components are citizens' rights have become more strident, particularly when debating the relative merits of public vs. private financing and provision of healthcare. More recently the focus has shifted to equity and disparities of health outcomes and access to proven cost effective services.

3 THE WORLD HEALTH REPORT (WHR) 2000 FRAMEWORK

The WHO has established a program to provide a common conceptual framework for health systems performance assessment, to foster the further development of tools to measure its components, and to work with countries to improve health systems per-

formance. This program was established to address the following areas:

- Lack of clarity about the fundamental goal of the health system, namely, improving population health;
- Evidence on how to improve health systems is still lacking;
- To encourage decision-makers to consider the big picture rather than a fragmented piecemeal approach;
- To highlight the importance of health systems platforms to deliver proven interventions; and
- To promote wider participation in national health policy debates [2].

The framework was presented in the WHR 2000 and attracted significant media attention and ongoing debate, including regional and technical consultations [7]. Within this framework the health system is defined as consisting of all actors, institutions and resources that undertake health actions – where the primary intent of a health action is to improve health.

Low levels of goal attainment can be due to inadequate resources or to inappropriate combinations of the available resources. Efficiency relates the levels of goal attainment to the inputs used to achieve them.

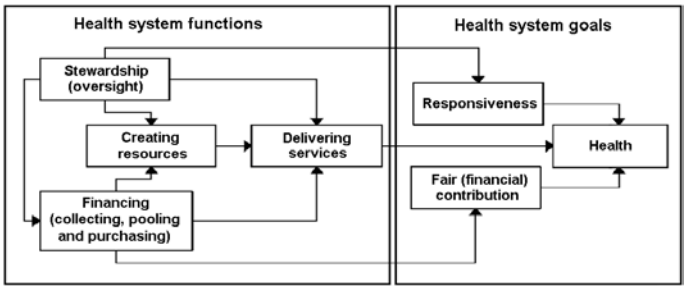

Figure 2. Relationships between Health system functions and Health system goals.

The key goals or performance measures of the system are population health, responsiveness and fair financial contribution. Both overall health outcomes and equity or distributional effects are considered key features of performance for health and financing.

Goal attainment is measured relative to the inputs (resources) available. Dimensions of responsiveness include respect for persons, client focus and range of choices.

Factors that affect demand and utilisation include population characteristics that affect the need for health care, such as demography (age/gender), ethnicity, risk factors, diseases and other health conditions. Health behaviours also influence use of health services which can then modify population characteristics. Such behaviours include consumer expectations, awareness and knowledge, health service attractiveness and access features of perceived quality, responsiveness, availability and cost and choices of competing interventions and providers of complementary or alternative therapies.

4 CURRENT STATUS OF HEALTH SYSTEMS PERFORMANCE ASSESSMENT

The recent comprehensive WHO review identified some key issues that need further investigation:

- There is a considerable lag between introducing an intervention and its impact on outcomes;
- There are ongoing challenges with data quality and availability, especially of long consistent time series;
- Comparability of data definitions across countries needs improving, particularly in the area of responsiveness;
- The time frame required for analysis and reporting of performance depends on multiple competing purposes; these include policy design for strategic decision-making, program implementation and management, monitoring of outcomes or achievements and evaluation of what works and what does not in health systems;
- The contribution of poverty to inequality needs more explicit linkage; and
- Health system performance assessment needs to be directly relevant to health policy [2].

5 RATIONALE FOR THIS MODEL

Health systems performance assessment explores how *structure* determines *behaviour* in a system of complex interactions, and is therefore a classic system dynamics problem. From our previous health sector experience we concluded that the WHR2000 framework needed to address the inherent two-way, rather than over-simplified one-way module interactions, and also the feedback interactions among supply and demand.

For a recent detailed analysis of the medicines component of the Australian health system over a time frame of 40 years, we needed to address the wider structural components of the health system to quantify the benefits of medicines use particularly in

avoiding hospitalisations and in contributing to overall economic growth.

We hoped to demonstrate the potential contribution of the system dynamics approach to addressing some of the specific deficiencies of the WHR2000 framework by introducing feedback interactions and delays between resourcing and service delivery.

Given the recent formation of the Health Policy Special Interest Group of the System Dynamics Society, raising awareness of the WHO Health Systems Performance Program in the SD community may also increase the potential for wider applicability and adoption if country level SD work could be seen to extend this established framework.

We were familiar with the data sources of reasonably long data series available for Australia, and wished to develop a simple country-specific exemplar to reproduce past historical trends over the past forty years and provide a basis for exploring policy design over the next forty years, which is the accepted timeframe for political discussion of our inter-generational equity issues.

6 MODEL DESCRIPTION

The initial version of the model addresses the solid causal loops shown in Fig. 3 below. The dotted lines will be the subject of future iterations.

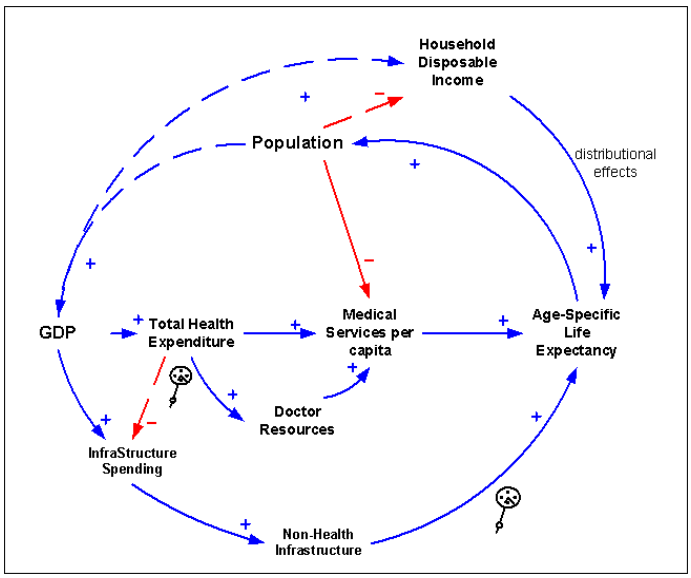

Figure 3. Causal Loop Diagram of the model.

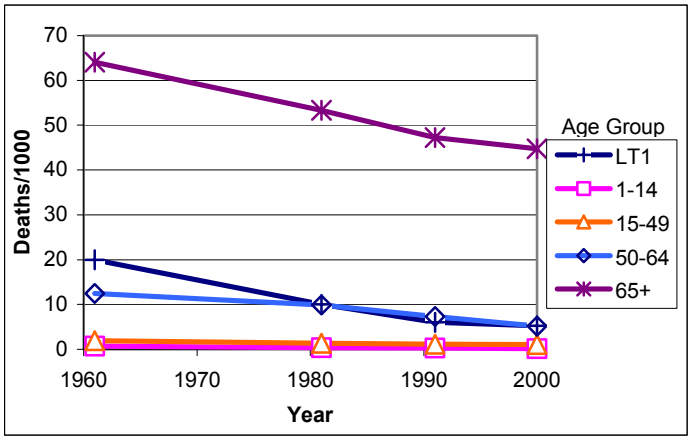

Figure 4. Age-specific mortality: Australia 1960-2000 [3].

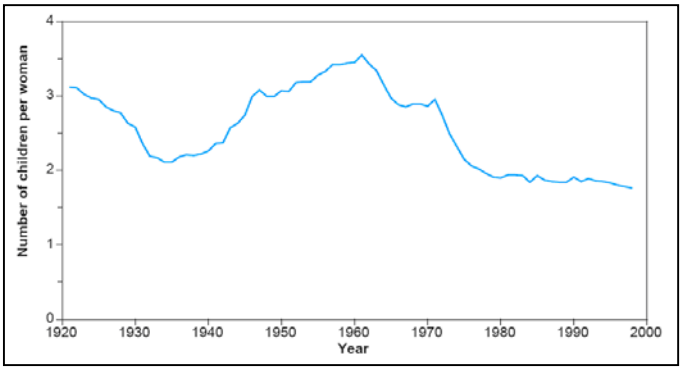

Figure 5. Birth rates: Australia 1920-2000 [3].

The model includes:

- A *population ageing chain* (Fig. 6), with births (based on number of women of child-bearing age and total fertility rate), net migration and age-specific mortality, including infant mortality. Because of the irregular fertility rate, and based on previous work, the ageing chain needs to segregate the 50-64 year age group to reflect the current "bulge" due to the 1946 to 1973 baby boom. Also to explicitly model infant mortality, a separate 0-1 age group stock is included. The model is calibrated using the data trends shown in Figures 4 and 5 along with an initial age-specific population taken at 1960.
- *Financing Sector* (Fig. 7), including Growth in GDP, Total Health Expenditure (THE) and Non-health Infrastructure Spend related to GDP.
- Doctors as *Resources* (Fig. 8), including time required for training, training non-completions, the effect of retirement and changes in working hours and work distribution.
- *Services* (Fig. 8), with Doctor visits per capita per year and subsequent doctor driven medical services.
- *Health Status* (Fig. 9), using Potential Years of Life Lost before the age of 70 (PYLL) as the main

outcome measure since long time trends for mortality and PYLL are available.

- *Feedback Effect* (Fig. 10) of the Combination of Service and Infrastructure Effects on Age Specific Mortality. This is calibrated against the current world's best practice and adjusted for geographical coverage of infrastructure (in Australia the largest difference is between urban infrastructure and rural infrastructure). For instance, in 1960, Iceland had the lowest infant mortality of 1.3% (vs. Australia 2.0%) and again in 2000 at 0.3% (vs. Australia 0.5%). Services impact is adjusted according to access related to insurance coverage. Prior to the introduction of universal health coverage in 1975, around 80% of the population had private insurance coverage.
- *Distributional Effects* (Fig. 11), represented by Income Quintiles and Household Disposable Income and the known recent differences in Average Life Expectancy of around 3 years between the Highest and Lowest Quintile.

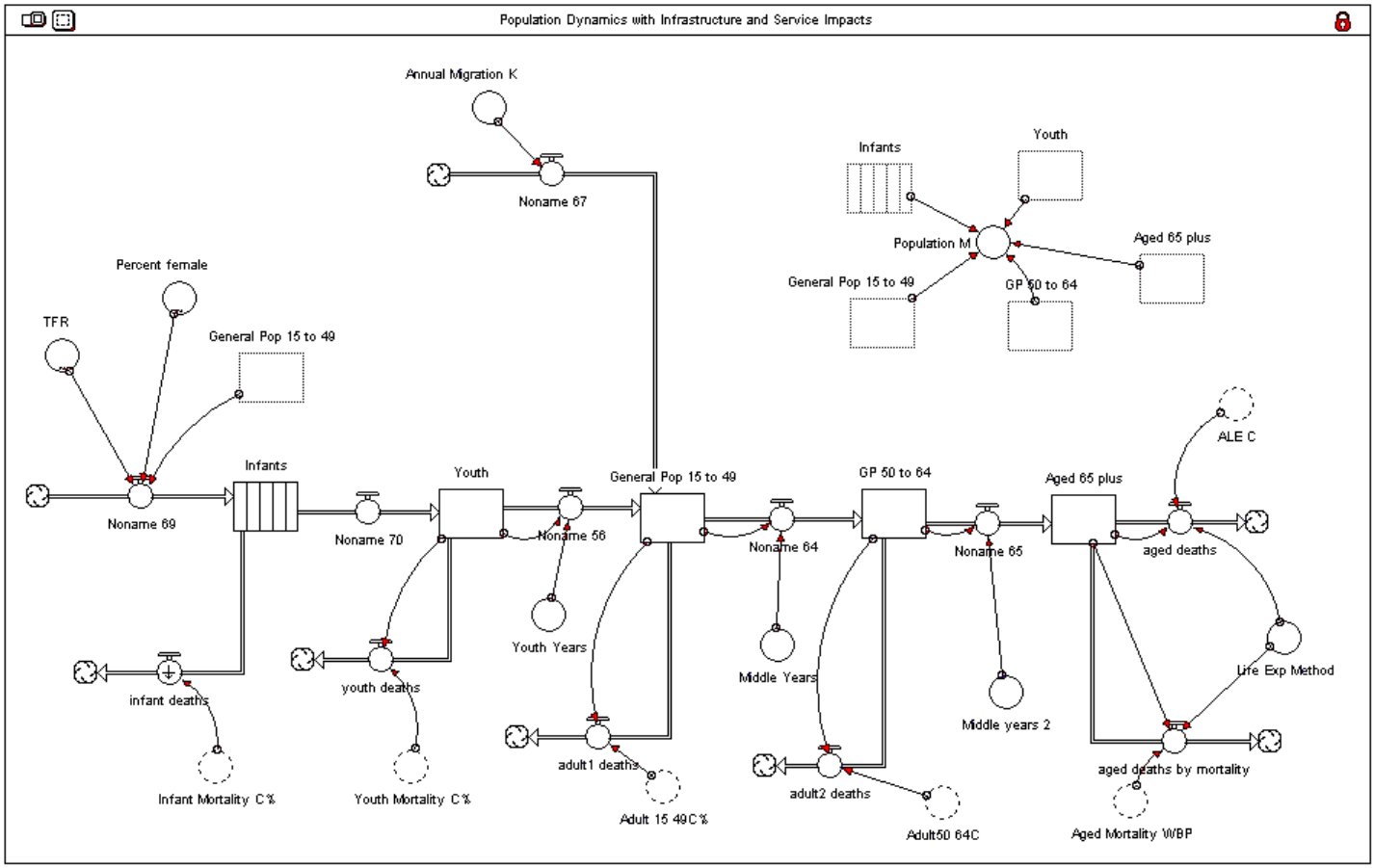

Figure 6. Population ageing chain.

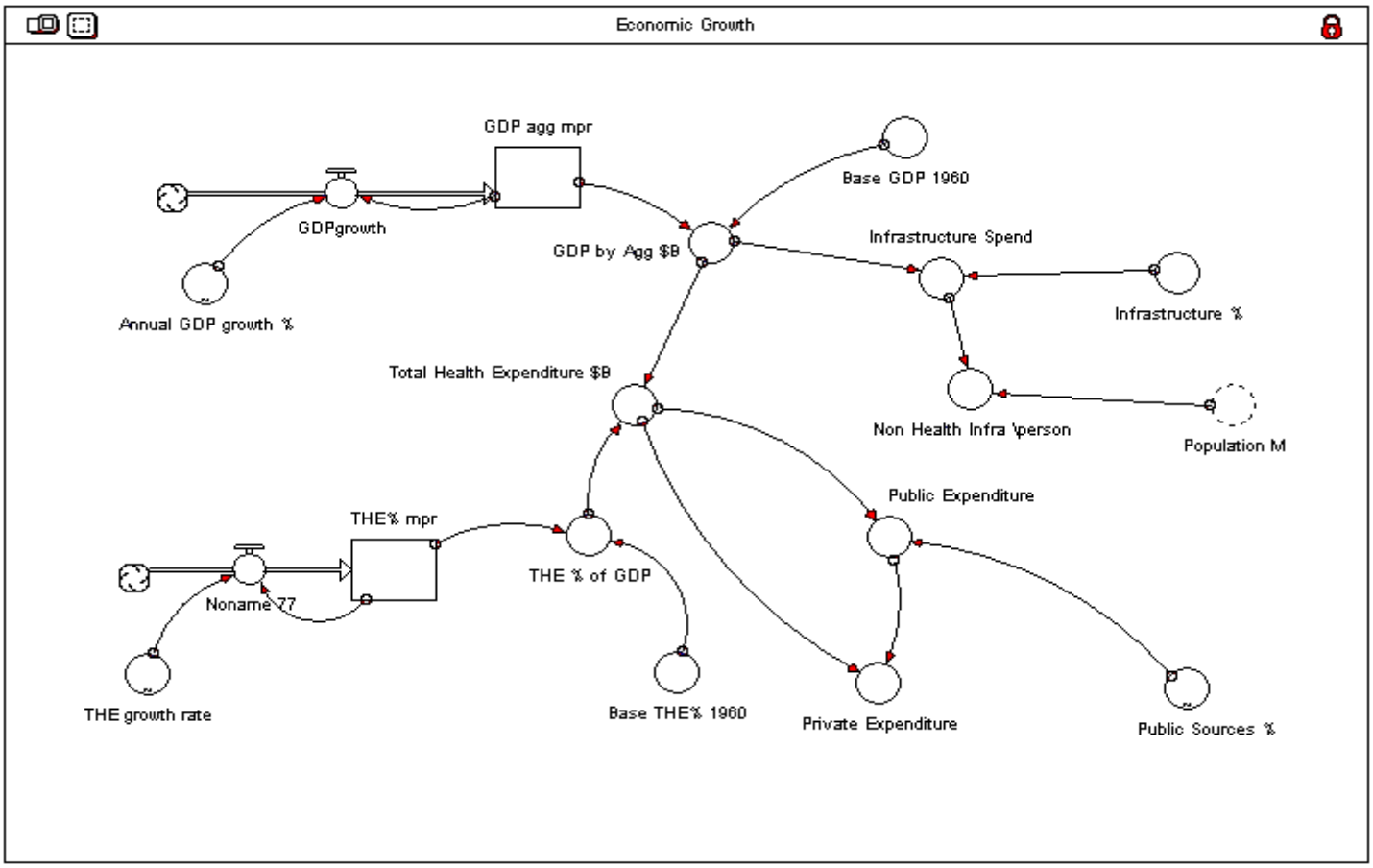

Figure 7. Financing Sector.

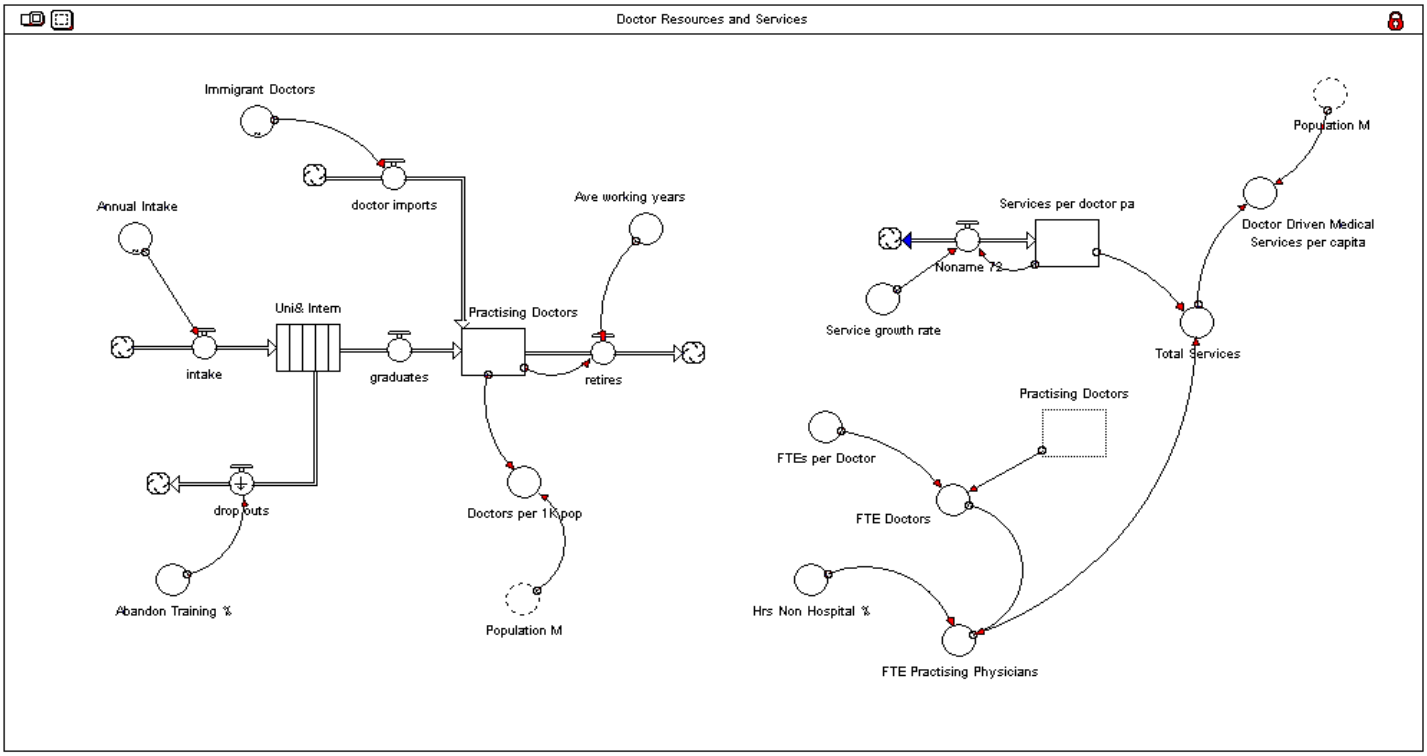

Figure 8. Doctor Resources and Services Sector.

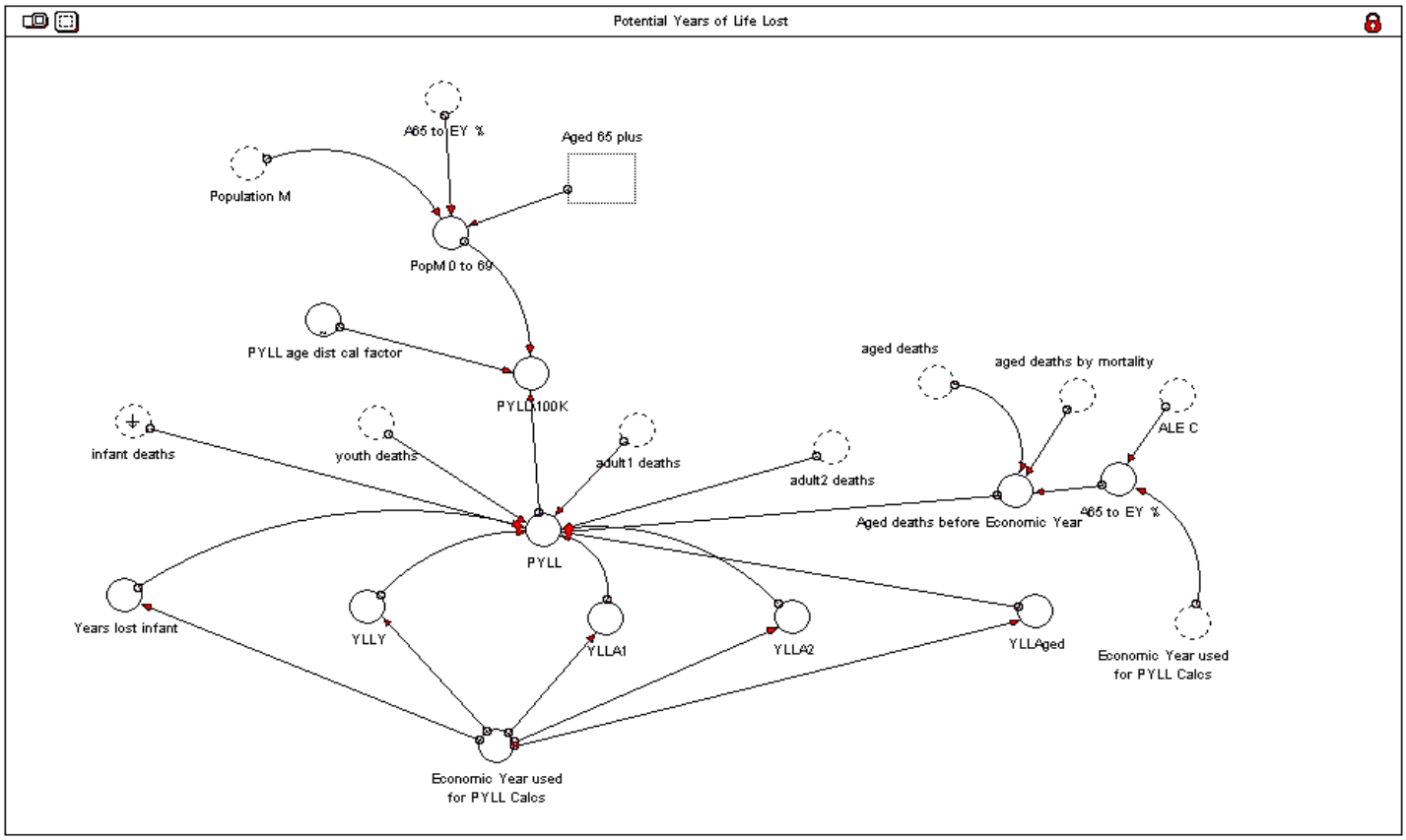

Figure 9. Health Status Sector.

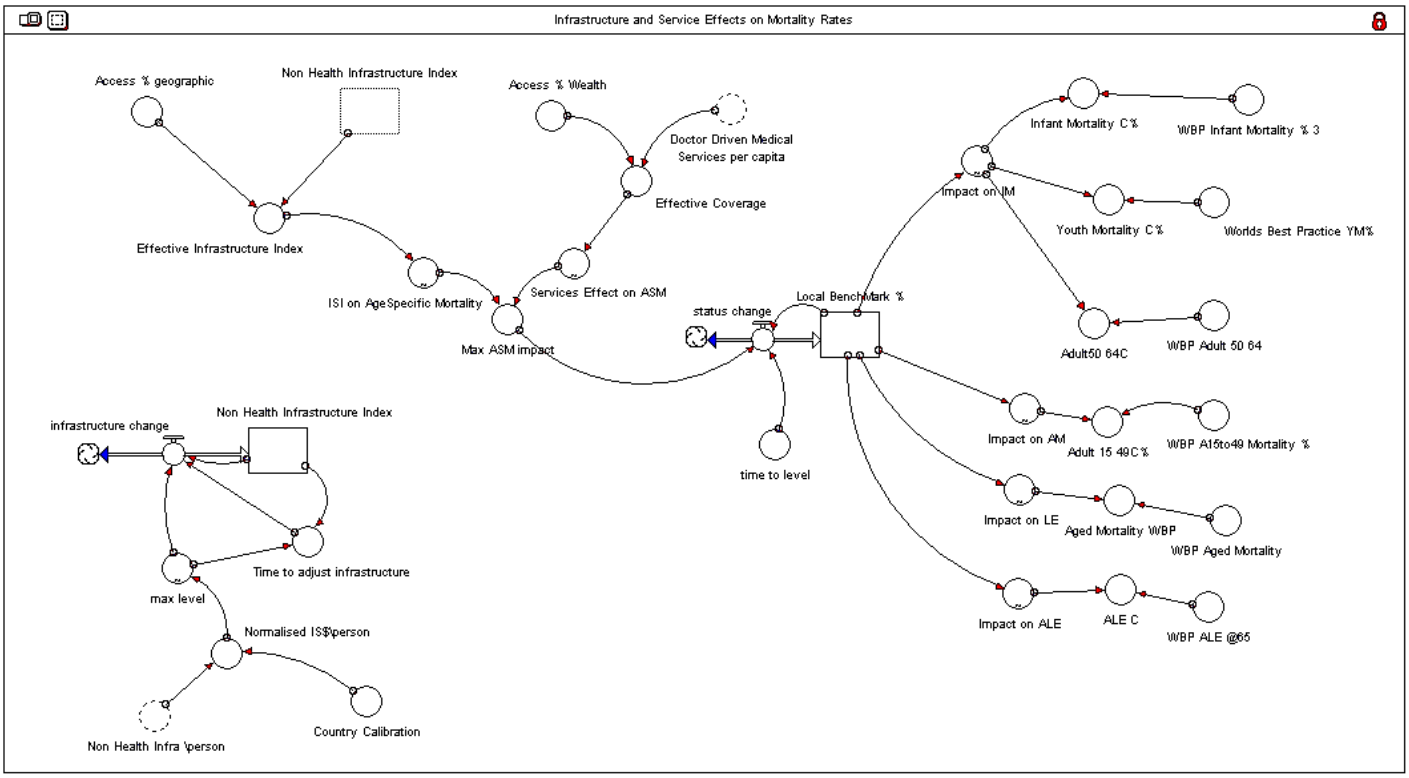

Figure 10. Feedback Sector.

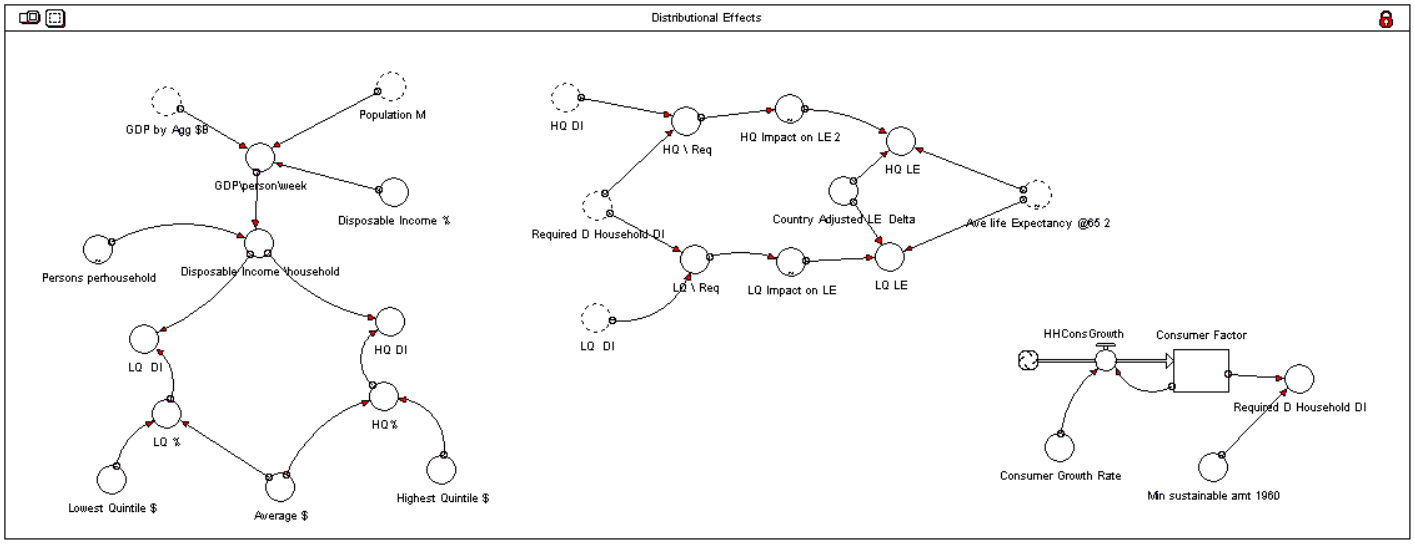

Figure 11. Distributional Effects Sector.

7 RESULTS OF MODEL RUNS

We have chosen three simple scenarios to demonstrate the behaviour of the model. The scenarios are generated by varying the Service Growth Rate, defined as the rate that the number of doctor service events per annum increases.

Figures 12, 13 and 14 present *Population*, *PYLL* and *Doctor Driven Medical Services per capita* for a Service Growth Rate of –2%, 0% and +2% pa respectively.

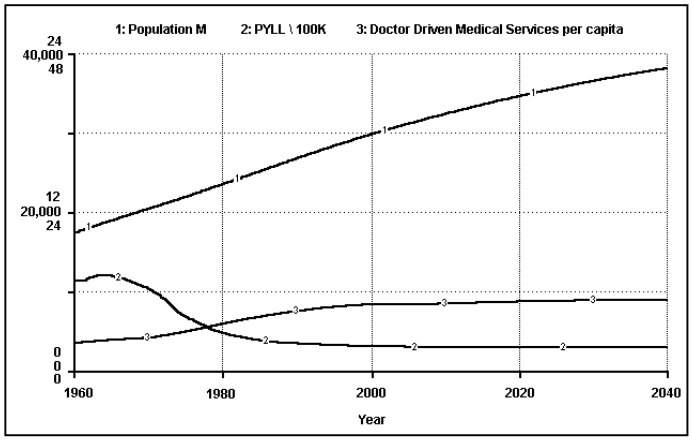

Figure 13. Population, PYLL and Doctor Driven Services for a 0 % Service Growth Rate.

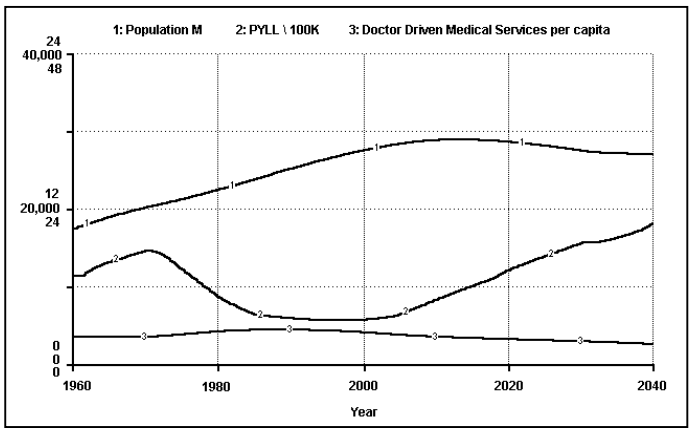

Figure 12. Population, PYLL and Doctor Driven Services for a –2 % Service Growth Rate.

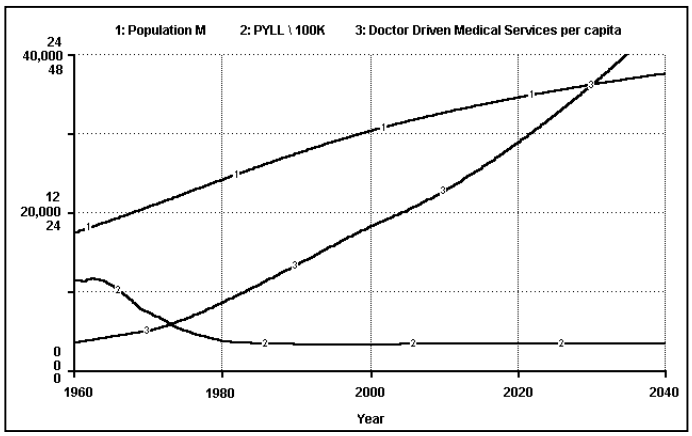

Figure 14. Population, PYLL and Doctor Driven Services for a +2 % Service Growth Rate.

8 DISCUSSION

Most health care applications of System Dynamics to date have addressed issue-specific problems, including the dynamics of human services delivery [13], diffusion of new medical technologies, management of acute or chronic diseases, patient flows, microworlds for managed care and public health interactions such as syndemics (contact author or Health Policy SIG for a list of health SD references).

This model is an initial simplified SD representation of elements of the health system consistent with the overall WHO HSP Framework. The skeletal model can be "fleshed out" by including other resources (other health workers, health infrastructure, medicines, knowledge and new technologies) and services (particularly hospital, primary health care and public health), more detailed private and public funding flows and condition-specific morbidity and disability as well as mortality measures. Rather than PYLL, the HALE (Health Adjusted Life Expectancy) is a better measure for countries where the life expectancy is considerably above the age of 70. HALE includes the average disability free life expectancy and then discounts the years of life with disability according to the level of disability. Past population measures of disability have been unstable though they should be more consistent and therefore useful in the future.

With more complete models it may be feasible to present regular national "state of health" reports as web based simulations, where future trends and possible policy interventions can be played out by a wide range of interested parties including "average citizens".

In time the SD Modelling approach has the capacity to compare countries' health system performance trajectories and capture the social and economic context relevant to health status. This may lead to more realistic comparisons of countries' health systems.

Another line of development would be to broaden the model to place the contribution of the health system to healthy living and wellbeing in the context of wider social, economic and environmental factors and policies. Some work to collect a range of healthy living and well-being indicators is occurring worldwide, including Australia [14]. This could provide a more balanced picture of the health services, living arrangements, environment, economic, work and leisure, family and community networks that contribute to the overall well-being captured in the WHO definition of health.

9 CONCLUSION

The results presented in this paper show promise for the application of SD within the WHO framework. Comparison of different countries' health system performance under this framework could provide real benefits when assessing the relative merits of various health policies.

"Various health care systems seem to have different strengths. Some health care systems deliver a large quantity of care overall. Some are far more costly than others. The issue of treatment mix remains open, as it can be subject to institutional and economic incentives.

Some healthcare systems…incur relatively high production costs or providers operating at less than full capacity." [2]

The Health Policy SIG may be able to enhance this analysis using SD within a widely accepted WHO HSP Framework.

A recent BMJ Editorial underlines the global relevance of this HSP Work [16]:

"…There is no point in throwing masses of funds at diseases such as HIV/AIDS, tuberculosis, and malaria without paying close attention to the health systems that will deliver the interventions that will impact on those diseases…moving the lens from specific diseases to supporting the health systems which will deliver the interventions."

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