UNIVERSITY OF SOUTHAMPTON

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MANAGEMENT SCHOOL

DENTAL WORKFORCE PLANNING FOR SRI LANKA

By

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Thesis for the degree of Doctor of Philosophy

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ABSTRACT

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Sri Lanka is a developing South Asian country which provides free education and healthcare for all its citizens. This thesis presents a policy-oriented study, partly empirical and partly modelling, whose aim was to understand dental care provision and workforce planning, at a time where Sri Lanka's dental health policies appear to have failed to achieve their intended results, leading to a mismatch between supply and demand, i.e. "underemployment and unemployment" of trained dental surgeons, despite an increasing need for dental care within the population.

The first section of this thesis describes a novel method of collecting primary data on Sri Lanka's dental health professionals, in a challenging setting where there was no existing database. The thesis also presents a methodology to convert need for dental care to demand for care, adapting an existing model developed by the World Health Organization and the Federation Dentaire Internationale to suit the Sri Lankan setting. Finally, this section of the thesis describes a survey to identify the "timings" taken for various dental treatment modalities in Sri Lanka.

The second section of the thesis presents a System Dynamics model, which uses the data obtained from these empirical surveys, to address dental workforce planning issues in Sri Lanka. The model is then used to simulate various different scenarios, generating realistic, practical and insightful lessons for policy making. Based on the results of this model, in 2011 the Government of Sri Lanka took steps to deal with the "employment mismatch" issue by restricting the annual intake of dental students and by creating 400 new Government-funded posts over the following two years.

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DECLARATION OF AUTHORSHIP

I, Maduwage Dileep Kumarasinghe De Silva, declare that the thesis entitled "Dental Workforce Planning for Sri Lanka" and the work presented in it are my own. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has been previously submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- Part of this work has been presented at conferences and in Governmental documents.

Recognition and Prizes awarded for this research

- Finalist in the World Prize for Application of Operational Research in Developing Countries. 19th Triennial Conference of the International Federation of Operations Research Societies (IFORS) 2011; Melbourne Australia.
- Recognized by the Department of Health, Government of Sri Lanka as the Working Paper on which the Master Plan (2011-2021) for providing employment for Dental surgeons was based.
- A Presentation by the author based on this research was selected for the 79th Annual Oration of the Sri Lanka Dental Association 2011 and was awarded the Orator's Gold Medal in recognition for the services rendered to the field of Dentistry in Sri Lanka.
- A Presentation by the author based on this research was selected for the 24th Annual Prof Britto Muthunayanam Oration of the College of the General Dental Practitioners of Sri Lanka 2011 and was awarded the Orator's Gold Medal for the contribution to General Dental Practice in Sri Lanka.

Parts of this study have been published in the following academic papers:

De Silva, D., Brailsford, S.C., 2009. Dental Workforce Planning; Sri Lankan Experience. The 35th International Conference on Operational Research Applied to Health Services (ORAHS 35), Leuven, Belgium 12-17th July 2009. www.econ.kuleuven.be/eng/tew/academic/prodbel/ORAHS2009/10.pdf

De Silva. D., Brailsford, S.C., Ekanayake, A.N.I., 2010. *The distribution of private sector dental practitioners and clinics in Sri Lanka*. Sri Lanka Dental Journal. Vol 40 (01) ISSN:1391-07280

De Silva D, Perera I.R, 2011. Origin of a Nationwide Institution for Oral Health: an innovative model for capacity building of oral health personnel in public & private sectors in Sri Lanka. The Journal of the College of General Dental Practitioners of Sri Lanka. Vol. 28. ISSN 1391-0981

De Silva D., 2012. *Dentists Where are we?* 24th Britto Muthunayagam Oration. The Journal of the College of General Dental Practitioners of Sri Lanka. Vol.29. ISSN 1391-0981.

De Silva D. and Gamage N.T., 2012. *Unqualified dental practitioners or Quacks in Sri Lanka.* Sri Lanka Dental Journal. Vol 41 (03).

Oral Presentations

- LASS Graduate School Conference, University of Southampton. June 2008.
- The ORAHS 34 PhD Workshop, 24th- 25th July 2008. Toronto, Canada
- The 34th International Conference on Operational Research Applied to Health Services (ORAHS 34), 28th July - 1st Aug 2008. Toronto, Canada
- The 35th International Conference on Operational Research Applied to Health Services (ORAHS 35), 12-17th July 2009, Leuven, Belgium
- 32nd Asia Pacific Dental Congress (APDC). May 2010 Colombo, Sri Lanka
- 24th Annual Prof Britto Muthunayanam Oration of the College of the General Dental Practitioners of Sri Lanka. February 2011. Colombo, Sri Lanka
- 79th Annual Oration of the Sri Lanka Dental Association, June 2011. Colombo, Sri Lanka
- 19th Triennial Conference of the International Federation of Operations Research Societies (IFORS); July 10-15 2011. Melbourne, Australia
- 4th International Dental Congress & Annual Scientific Sessions of the College of General Dental Practitioners of Sri Lanka. Feb 8-12 2012. Colombo, Sri Lanka.

Signed: ……..

Date: …….

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With the oversight of my main supervisor, editorial advice has been sought. No changes of intellectual content were made as a result of this advice.

Chapter 1: Introduction

This research is concerned with dental care provision and dental workforce planning in Sri Lanka, a developing island nation in the Indian Ocean. It attempts to describe the present status of dental care provision in the country, with the application of system dynamics to analyse future dental workforce issues.

This chapter introduces the subject of modern dentistry, and in particular of dental care provision in Sri Lanka. It then summarizes the emerging issues pertaining to the dental workforce, and gives a short account of the motivation behind this study, its importance, research methodology and the research contribution. Finally the layout of the thesis is described.

1.1 Modern dentistry

Modern dentistry is much greater in scope, more complex and has a greater scientific base than ever before. Today's dentistry concentrates on minimal tooth drilling, adhesive aesthetic fillings, periodontal care, orthodontics, root canal therapy, minor surgery, crowns and bridges, and implants. Modern dental care is provided by well-trained highly skilled teams of dental professionals. The global dental industry market is relatively small in relation to that of health care in general, but it is a lucrative and competitive market. The dental industry's manufacturing base is relatively small in global terms. It is however multi-national, consisting of a few very large companies and a larger number of small companies. Dental products are generally of high added value, so that the market, although small, is lucrative. In contrast, the market for oral care products, such as tooth brushes, tooth paste and mouth washes, used by the general public, is very large (Brocair Partners, 2010).

1.2 Dental care in Sri Lanka

'Modern' dentistry has been practised in Sri Lanka since the earliest colonial days. It dates back to the mid-19th Century, with British doctors in charge of the medical care of the British troops. Before this era, dental care givers in Sri Lanka were traditional healers and unqualified practitioners. The practice of dentistry in Ceylon (as Sri Lanka was known until

1972), was regulated by the Dental Registration Ordinance, which came into existence in 1915. The first qualified dentist was registered in Ceylon on 15th May, 1915, and was qualified in both medicine and dentistry. It was not until 1916 that the first dentist without a medical qualification was registered in Ceylon (Cooray, 2008). In 1927 the Dental Registration Ordinance was amended, making it a punishable offence for unregistered personnel to practise dentistry, and provision was made for the granting of licences to persons with an apprenticeship, following an examination conducted by the Ceylon Medical Council. The Dental Registration Ordinance was further amended in 1933, enabling the title of 'dental surgeon' to be used by those holding a recognized qualification granted by a university. Thus the situation was created whereby there were dentists and dental surgeons in general dental practice.

Formal training of dental surgeons in Ceylon began in 1938 at the Dental Hospital affiliated to the Ceylon Medical College in Colombo. The first batch of students taken in that year was medical graduates, who were to do dentistry as a specialty. They were awarded the L.D.S (Licentiate in Dental Surgery) as a postgraduate qualification after a two year course. However after the first batch of six graduated, the training programme was abandoned, mainly on account of the outbreak of World War II. Subsequently, in 1942, a Dental School was incorporated in the University of Ceylon. In 1947 the first batch, of four dental surgeons, graduated after following a full-time dental course (Tillekaratne, 1992). Up until now, Sri Lanka has had only one dental school in the country. It is known as the Faculty of Dental Sciences of the University of Peradeniya, and produces around 80 graduates annually.

In Sri Lanka, medical and dental care are both funded through taxation, and are provided free of charge in the state sector. The Sri Lankan Government provides health services for all its citizens via a network of around 1,000 health institutions scattered throughout the island nation. Dental health care is integrated with general health care. Dental services are available in about 750 state hospitals/institutions, and are provided free of charge at the point of delivery by government-employed dental surgeons. In addition, there is relatively small, but growing private dentistry sector, which is delivered both by full-time general dental practitioners and state sector-employed dental surgeons who do part-time private practice.

1.3 The problem of unemployed dental surgeons

The Sri Lankan Government also provides free education for all children, from the first year of school right through to Bachelors and Masters level at university. There are no private medical universities or dental schools in the country at present. Over the last half-century, government employment was guaranteed to all Sri Lankan trained dental surgeons as soon as they graduated. Although the Government still continues to train all dental surgeons at the taxpayer's expense, it has failed to employ them on a regular basis since 1995. At present there are around 250 dental surgeons awaiting government employment.

With economic liberalization in 1977, considerable relaxation of fiscal policy occurred in Sri Lanka during the 1980s. This inevitably resulted in a major structural budget deficit, involving problems of increased debt and balance of payments. There was another reason for curtailing public spending on health. This was the implementation of the structural adjustment programmes (SAPS) introduced by the World Bank and the International Monetary Fund in the 1980s. These fiscal constraints have made it more difficult for policy-makers to increase public spending on health in Sri Lanka in recent years. Sri Lankan dental services have also suffered due to these policy changes, which led to a lack of public sector investment and hence lower rates of employment for the new generation of dental graduates.

1.4 Motivation for this research

According to the National Oral Health Survey conducted by the Sri Lankan Ministry of Health, with assistance from the World Health Organization (WHO), there is widespread dental disease in Sri Lanka that obviously needs to be treated. However the Government is unable to create new vacancies on a regular basis, because of the financial and infrastructure constraints arising from the above-mentioned fiscal policies. The Government has to rely mainly on vacancies arising from 'natural attrition' in order to employ new dental graduates. The dental surgeons who are currently retiring or nearing retirement age are those graduates who were recruited to the service in the mid-1970s. In the 1960s and '70s, only about ten dental surgeons per annum were trained, graduated and hence recruited to the service. Therefore the 'natural attrition' of dental surgeons has been around ten per annum over the past decade. On the other hand, since 1997, about 80 new dental surgeons have graduated every year from the country's sole dental school.

Although there is a need for more dental surgeons, and there are plenty of dental surgeons available, the Government cannot employ them, due to the financial constraints described above. This creates a mismatch between supply and demand for dental surgeons in the state sector. This mismatch has led to ever-increasing unemployment among dental surgeons in Sri Lanka. Because of the lack of government employment, newly qualified dental surgeons are forced to enter the relatively small private dental care sector. This issue of dental surgeons, educated at the state's expense being either unemployed or under-employed has become a burning issue for health policy-makers, higher education authorities, practising dental surgeons and future dental surgeons in Sri Lanka.

This research has been motivated primarily by the paucity of government employment for dental surgeons in Sri Lanka, which has resulted in a rapid escalation in the number of dental surgeons looking for state employment for considerable periods of time. Furthermore, published research on Sri Lankan dental workforce issues is scare. There were two short papers entitled, "History of general dental practice in Sri Lanka" and "Government dental service- chronicle of some events", both published in the Sri Lanka Dental Journal Volume 13, 1982. In addition the author of this thesis undertook two surveys entitled, "A survey of dental surgeons awaiting government employment" in 1999, and "Supply and demand dynamics and operational characteristics of the private sector dental care provision in Sri Lanka" in 2007. The comparative lack of research on dental care provision and dental workforce issues in the country was another stimulus for this research.

1.5 Research questions and objectives

Stated very simply, the research question underpinning this study is, "How many dental surgeons does Sri Lanka need?" The broader, general objective of this research is to describe the present status of dental care provision and the future dental workforce dynamics in Sri Lanka, with the following specific objectives:-

1. To describe the basic demographic features of dental care providers (dental surgeons) in terms of the number of practitioners, the age and gender distributions, the district where they work, training, qualifications and experience, and the type of practice (public or private, and full-time or part-time).
2. To undertake a similar survey of the current cohort of dental students.

3. To develop a methodology to analyze the demand for dental care in Sri Lanka.
4. To develop a system dynamics model to address dental workforce issues. To use the results of the above study components to advise the higher education authorities and health policy-makers on the training and employment of dental surgeons.

This research primarily attempts to identify ways to limit the mismatch between the supply and demand for dental surgeons, and to plan for the future dental workforce in Sri Lanka. This may not have been such a daunting task in a country where updated dental databases were available, e.g. the NHS Dental Practice Database (DPDB) in the UK. One of the challenges of the present study was the fact that all data, even the simplest information, such as the number of active dental surgeons in the country, had to be collected from the study itself as primary data. Hence a multi-method approach was required in order to meet the aims and objectives of the study.

This study will be useful for the Sri Lankan Department of Health in developing its dental health manpower policy, and for the higher education authorities in deciding the intake of dental students. In addition, it will useful for any dental surgeon, especially newly qualified graduates, and other stakeholders in the dental care market, such as patients, insurance companies, investors, and dental material and equipment vendors, to ascertain the characteristics and scope of the dental care provision in the country.

In this research a system dynamics model was developed to address the country's dental workforce issues. Most of the data applied in the supply and demand functions of the model were generated during the study itself. This is in contrast to many similar studies, performed in Europe and America using data obtained from existing, well-managed and updated databases. This study will hence be a role model for countries which lack well-maintained and updated databases on dental care provision and dental manpower.

1.6 Research contribution

There are two aspects of this research: the empirical study and the system dynamics (SD) model. The results of the empirical study helped to develop a database of the dentists in Sri Lanka, fulfilling a long felt need for the entire dental profession. Moreover the methodologies used to develop this database were generic in nature, so that the same approach could be used

to develop databases for similar health professional categories such as doctors and nurses. The results of the empirical study served as the input data for the SD model.

Before this research was undertaken, dental workforce planning methods used in Sri Lanka were highly simplistic and narrow in focus, and considered only specific aspects of the problem without considering the whole system with a long term perspective. Therefore this study itself is novel in the history of dental health workforce planning in Sri Lanka, as it has used the operational research methodology of system dynamics, which analyses and gives an insight to how complex systems change over time. However as it was the first time such a model been introduced to the country's dental health planners, initially it was a challenge to convince them. Nevertheless the Sri Lankan Department of Health accepted the suggestions highlighted in this thesis which was based on the SD model, and has already taken steps to address the issue of impending unemployment of dentists in Sri Lanka.

The SD model developed in this thesis is simple to understand and comprehend by the medical fraternity, thereby enhancing its acceptability and usefulness. Another unique feature of this SD model is that, it was developed by a dentist for the benefit of the dentists and he was not only the modeller, but also a product of the system being modelled. This study has brought together various pieces of incomplete information, which have been defined, refined, supported and augmented by current knowledge practices and beliefs in order to allow systematic extrapolations. The study while highlighting the gaps in our knowledge, has integrated the fragmented knowledge we had, to give a holistic view on the dental workforce of Sri Lanka.

1.7 Layout of the thesis

This thesis is organized as follows. Following this brief introductory chapter, Chapter 2 presents a background to the issue of supply and demand in health and dental care. Chapter 3 is a brief introduction to Sri Lanka and its health care and educational systems. Chapter 4 presents a review of the literature on healthcare workforce planning. Chapter 5 focuses on applications of OR modelling in healthcare, in particular on workforce modelling. Chapter 6 describes the methodology used to carry out the empirical surveys, and Chapter 7 presents the results of these studies. In Chapter 8, we present the system dynamics model, and the results of the simulation experiments. Finally, in Chapters 9 and 10 we discuss our results and the limitations of this research, and suggest topics for further work.

Chapter 2: Background: supply and demand in health and dental care

This chapter describes the general context of this research, namely the provision of healthcare services, and dental services in particular, to meet demands made on those services. After an introduction to supply and demand in general terms, the spotlight turns to worldwide healthcare and dental services and their public and private funding.

2.1 Introduction

The subject of supply and demand in health and dental care is introduced with discussions of both need and demand for health. Healthcare supply and demand are considered in economic terms by market characteristics and independence. The focus then turns to supply and demand for dental services in particular.

2.1.1 Health need

The term 'health need' has been described as a state of being which is altered by the application of well-defined health (Green, 1999). The World Health Organization has further elaborated on heath need (WHO, 1971) and subdivided it into three categories:

a) Perceived need - the need for health services as experienced by the individual and which he/she is prepared to acknowledge. However under certain conditions perceived need may exceed or fall short of the professionally defined need.
b) Professionally-defined need - the need for health services as recognized by a health professional, considering the benefit obtainable from advice, preventive measures, management or specific therapy. However under certain conditions, professionally defined need may exceed the perceived need of the care seeker.
c) Scientifically-confirmed need - the need confirmed by objective measures. The objective measures could be biological, anthropometric or psychological factors, expert opinion, or the passage of time. It is generally considered to correspond to those conditions that can be classified in accordance with the International Classification of Diseases.

2.1.2 Demand for health

Demand for health could be described as an attempt by an individual in need to seek services from the health system. However, health demand is usually only measured in terms of the actual utilization of health services. The WHO described the demand for health according to two perspectives (WHO, 1971):

a) *Potential* demand, where demand for health services is described considering the perceived and professionally-defined needs. The greater of either perceived need or professionally defined need is described as the potential demand. This is applicable both at individual and population levels;
b) *Expressed* demand, i.e. the demand actually made on the health services, either at individual or population level. However the expressed demand may be greater than the actual utilization, because of the existence of waiting lists, limited resources, or differences between patients' perception of their needs and professionals' definition of those needs.

To measure the amount of health care demanded, different methods have been used, such as in-patient days, outpatient visits, or prescriptions. In addition, it could also be measured by the total cost of services, allowing for the combination of services measured in different quantity units (Vujicic et al., 2009).

2.1.3 Health service market characteristics

From an economic perspective, the health service market is a market wherein buyers and sellers interact through the market mechanism, resulting in the possible exchange of health care (Folland et al., 1993). The demand is associated with the patients, and the supply with the doctors. The benchmark paper on demand for health services published by Grossman (1972) suggests that what is actually demanded by the individuals is health, although what they actually purchase is healthcare services, and thus the demand for health services should be derived from the demand for health. Therefore it could be argued that health care it is not a 'good'. A 'good' is defined as a physical object or service that has value to people and could be sold for a non-negative price in the market place. Rather, the demand for health care is derived from a demand for health improvement or health maintenance. In contributing to a consumer's utility, health improvement and health maintenance have value in use (Feldstein, 1999).

Regarding supply dynamics, supply of human resources in health care is determined by many factors, such as training capacity, income and the perceived status of health professionals, and composition of the skill mix team. Health care is a labour-intensive service industry. In any country, health human resources (HR) is the key input in healthcare provision as well as being the most dominant component of the recurrent health budget. Payment of salaries and other benefits to healthcare workers are also significant components of total government health expenditure. A typical country devotes just over 42% of the total general government health expenditure to paying its health workforce. However, in some countries, staff salaries alone account for 60-80% of the government's recurrent health budget (Kolehmainen-Aitken, 1993). Although the health workforce is the key input in healthcare provision, and payment for health human resources is a key budgetary constraint, the market for HR in health care has been relatively under-researched and under-managed in many countries (Bloor, 2003).

In a typical textbook labour market, wages adjust to create equilibrium between supply and demand. However, in general, the price mechanism does not create equilibrium in the market for health HR (Folland, 1993). The main reasons for the above phenomenon may be:

a) Government regulation of the healthcare market to a greater degree than other labour markets
b) Entry to the healthcare labour market is highly constrained by licensing and professional regulation
c) Wages for different health staff are often negotiated at national level, e.g. in the UK NHS.

Therefore it could be stated that the health service market is characterized by market failure, i.e. the assumptions for having perfect competition are violated. In the presence of market failure, market mechanisms from a societal perspective lead to a non-optimal demand and/or supply in health services. Most markets are characterized by market failure, but what is unique to the health service market is the extent of these market failures (Hsiao, 1995).

According to Zurn et al. (2002), the health service market is affected by positive externalities, imperfect knowledge and uncertainty. 'Positive externalities' in health care means the benefit a person obtains by the consumption of health services administered by another person or persons. A good example is the benefit an individual person, or society as a whole, receives from another person having been vaccinated against a communicable disease. Stemming from the notion of asymmetry of information between the service provider and the recipient is the

ideology of 'imperfect knowledge'. The service recipient patients are not always fully aware of their health status; neither are they aware of alternative options available to either maintain or improve their health status. The phenomenon of 'uncertainty' in health services arises as we cannot plan our use of health services, simply because we do not know when we will fall sick, and often deterioration in health is sudden and unexpected. This especially applies to acute health problems, such as heart attacks and road traffic accidents.

2.1.4 Independence of supply and demand in the healthcare market

The relationship between supply and demand for health care is one of the most scrutinized topics in health service management. Most of the focus has been on whether suppliers – particularly doctors - act totally in their patients' interests, or if they succeed in convincing their patients to act in a way that also benefits them, as suppliers. In the literature, this has been couched in terms of whether doctors act as perfect agents for their patients, or, more commonly, in terms of whether they can induce demand among patients for their services. If the health care provided is of little or no value to patients in terms of health gains, then such demand inducement constitutes an inefficient use of healthcare resources. One reason that demand inducement has engendered so much interest among health economists is that its existence is totally at odds with the competitive model. Normally, increase in supply would lower price, but that is not necessarily the case if doctors induce demand. Furthermore, doctors would be expected to supply fewer services if they are paid less per service, but, again, this would not necessarily be true if demand inducement was present (Mooney, 2003).

In a survey of almost 300 USA and Canadian health economists (Rice, 1989), it was reported that 81% of the respondents believed that physicians generate some demand for their own services. But many economists seem to have considerable doubt concerning a doctor's ability to go so far as to hoodwink patients into demanding more services than they really want. One of the earliest methods of testing whether physicians induce demand was to determine how a particular market measure, such as utilization or price, changes in response to a change in the number of doctors. The idea behind the test is that, if there is an increase in competition among doctors, and doctors induce demand, they will do so to maintain their revenues. Many such studies have been conducted, some of which find evidence of demand inducement and others which do not (Rice, 1989).

2.1.5 Dental care supply and demand

A dental service could be considered as a sub-component within the broader parameters of health services. The dental sector is that sector of the economy in which persons wanting dental care interact with persons who are trained and empowered to provide it. Processes within the dental sector determine how much care is provided, to whom, and at what prices. The primary participants in this process are the patients seeking care and the dental surgeons who provide it. Consequently, it is appropriate to divide the dental sector into demand dynamics, concerning the decisions of the general population to seek care, and supply dynamics, concerning the availability of dental manpower and the decisions of dental surgeons to supply care. These two sub-sectors then interact to determine the prices of dental care (in the case of the private sector), utilization of care, income of dental surgeons and other variables.

2.1.6 Demand for dental care in comparison with general health services

Dental professionals accept that the need for dental care services ranges from minor in some individuals to extreme in others. The demand that people make to have their dental needs treated, however is dependent on a number of factors. Age, sex, race, income, education and place of residence are all important, as well as the attitudes of individuals regarding health and how they perceive their own susceptibility to dental disease. Other factors influencing the demand are the type of 'delivery system', accessibility and acceptability. Considering the features of uncertain demand associated with health care, and the asymmetry of information possessed by patients and providers, it has long been recognized by economists that health care is a unique service commodity. Consequently the research interest of many economists has been focused on health and medical care issues for more than 50 years, resulting in the emergence of a separate economic discipline named 'health economics'.

Based on the definition of health and its determinants, the discipline of health economics addresses healthcare market issues, where the demand for and supply of health care interact. It also offers a cost analysis (effectiveness, benefits, utility), evaluates the system as a whole and provides policy implications. Within this context, many researchers believed that dental services were just like general health services, and hence there was no necessity to consider the economics of dental care as a separate subject (Folland, 1993). However to justify the necessity of studying dental care separately from general health care, Sintonnen (2000) pointed out that two specific features of health care that distinguish it from other goods and

services may not necessarily apply to dental care. These two features were the unpredictability of the individual's demand for health care, and the lack of complete information about the quality of healthcare services. Sintonnen (2000) also offered a list of some characteristics of dental care that distinguish it from general health services. These are:

1. Smaller number of dental diseases;
2. Relatively more predictable occurrence and diagnosis of the dental diseases;
3. Dental diseases are rarely complicated and less invasive;
4. Ability to diagnose many dental diseases by using plain X rays;
5. Availability of several alternative treatment options for the same problem;
6. Individuals experience the same dental treatment (e.g. dental extraction) several times during a lifetime. Therefore the service recipient is able to judge the quality of treatment or service;
7. Preventive procedures (e.g. brushing of teeth) are much easier to practise;
8. The existing preventive procedures may be more effective as disease control;
9. Dental disease in general (excluding dental caries) is non-communicable;
10. The consequences of untreated dental diseases are less serious;
11. A dental disease will rarely become life threatening;
12. As the majority of dental diseases are not usually 'emergencies', the service recipient has the freedom to select the service provider, as well as to decide when to seek treatment.

The effects of dental disease on quality of life are less profound than general disease. Therefore, for many people, dental care does not have the same intuitive quality of life dimension as health care in general. Beyond purely economic considerations, there are philosophical and ethical aspects of health care that may apply with less force in the case of dental care. Due to the above reasons, market mechanisms can be expected to perform more efficiently in the case of dental care than in the case of health care in general (McDermott, 1986).

2.1.7 Dental Care Delivery

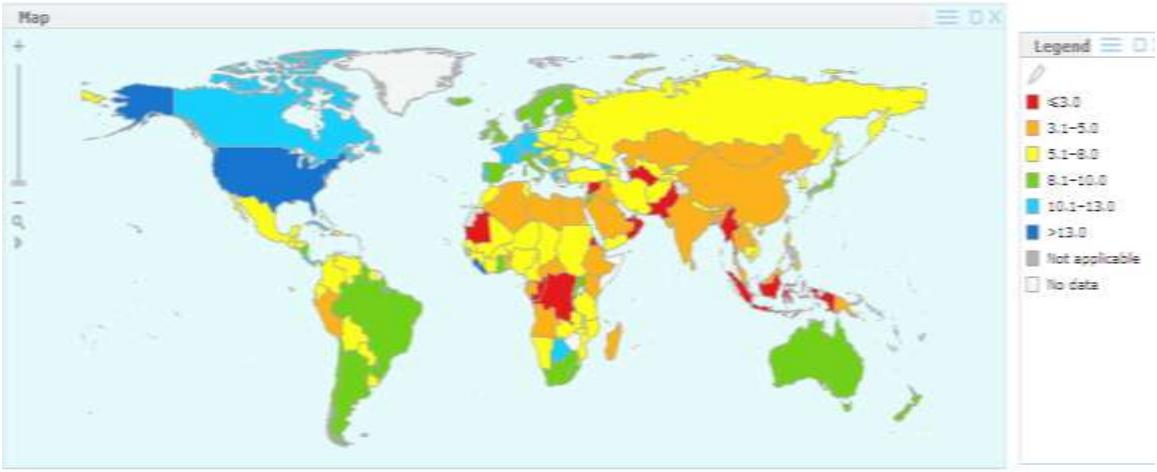
A service delivery system in dental healthcare is a complex entity, involving numerous inter-dependent elements. The most important of these are the supply of provider personnel of various types, the structure of the system, i.e. the organizational arrangements by which patients and providers get together for the provision of healthcare services, and the financing arrangements by which the care services are paid.

2.2 Healthcare systems worldwide

Health services anywhere in the world could be considered as large scale, complex systems, whose existence, development and contribution are critical to a country. For example, the UK National Health Service (NHS) is the third largest employer in the world, with an annual budget of approximately £70 billion (Department of Health, 2006). In the USA, health care is considered as the main domestic industry (Carter, 2002). Demand on healthcare services worldwide is changing due to many factors, such as quality, safety, increased expectations, technological advances, demographic changes and government health policies. The final output of the health sector – ensuring a healthy population – has an impact on the productive capacity of a country's workforce and the prosperity of the population in general. Trends in productivity and efficiency of health care will thus impact on the economy as a whole.

2.2.1 Health expenditure worldwide

Figure 2.1 illustrates how healthcare spending varies widely between continents and countries. In 2009 expenditure on health globally was lowest in South-East Asia, at around 3.4% of GDP, the highest being in the Americas, at around 13% of GDP, with a global average of 8.7%. Furthermore, the share of government in health spending varied from 76% in Europe, to 34% in South-East Asia. In low income countries where government expenditure on health was low, the shortfall was made up by private spending. In these countries, about 85% of private expenses on health care were out-of-pocket spending (WHO, 2009a).



Source: WHO (2009a)

Figure 2.1. Global health financing

The healthcare sector represents one of the largest service industries in the developed countries. For example, in 2008, European Union countries devoted 8.3% of their GDP on health care, which was more than the financial services or retail sectors (OCED, 2010).

However, spending a higher percentage of GDP on health does not necessarily mean that a country has achieved better health status. Therefore the question arises as to what percentage of a government budget should be allocated to health? Indeed, what percentage of the GDP should be spent on health? However there are no definite answers to these questions (McGuire, 1993). Table 2.1 illustrates health expenditure as related to national level of income.

Income Group	Govt. contribution to total health expenditure (%)	Total expenditure on health as a percentage of GDP
High Income	60.7	11.2
Upper Middle Income	55.1	6.3
Lower Middle Income	43.2	4.5
Low Income	36.2	4.3
Global	**57.6**	**8.7**

(*source: WHO, 2009).*

Table 2.1 Health care financing trends by country income level

Healthcare spending and national income levels are shown in Table 2.1 above. Here the countries are broadly divided into four groups depending on income. From the above figures, a strong positive correlation between national expenditure on health and national income can be observed. This positive correlation has been used to suggest that health care is a luxury

good. However, it could be argued that the application of microeconomic analysis to macroeconomic data may have led to this hypothesis. As this application is not considered to be appropriate, there is some doubt as to whether health care should be considered as a luxury good. It is further argued that factors such as the type of healthcare delivery systems in a country should be considered when determining expenditure levels. Therefore health care could still be considered a necessity rather than a luxury good (Parkin, 1987).

2.2.2 Examples of country-specific health care spending

Australia

All Australian citizens and permanent residents are covered by Australia's national health insurance programme, called 'Medicare'. The Medicare programme provides comprehensive coverage, including primary care, hospital care, and pharmaceuticals. Approximately 30% of the population were enrolled in private insurance in 2009 (AIHW, 2009). In 2009, Australia spent 3,382 international dollars per person on health, healthcare expenditure being 8.5% of GDP. Further, approximately two thirds and one third of health expenditure was financed by the public and private sectors respectively. Individual out-of–pocket expenditure as a percentage of total private sector expenses was high, at around 70% during first decade of the 21st Century (WHO, 2009).

United Kingdom

All residents of the United Kingdom receive care through the National Health Service (NHS). The NHS is comprised of organizations at a national, regional, district and local level (Bevan, 2006). The Department of Health is responsible for public health and health policy, and for overseeing the NHS. In 2009, the UK spent 9.3% of its GDP on health care. Per capita health expenditure at the international dollar rate was 3,399 in the same year. The Government was responsible for nearly 85% of the total heath expenditure, while the balance was privately funded. Individual out-of-pocket health expenses stood at around 75% of total private expenditure at the beginning of the 21st Century (WHO, 2009).

United States of America

The USA spent 16.2 % of its GDP on health services in 2009. This amounted to 7,410 international dollars per person, an amount that far exceeded most of the countries in the world. Out–of-pocket expenses stood at a relative low percentage, of around 25% of total private health expenditure (WHO, 2009). The USA did not provide universal health service

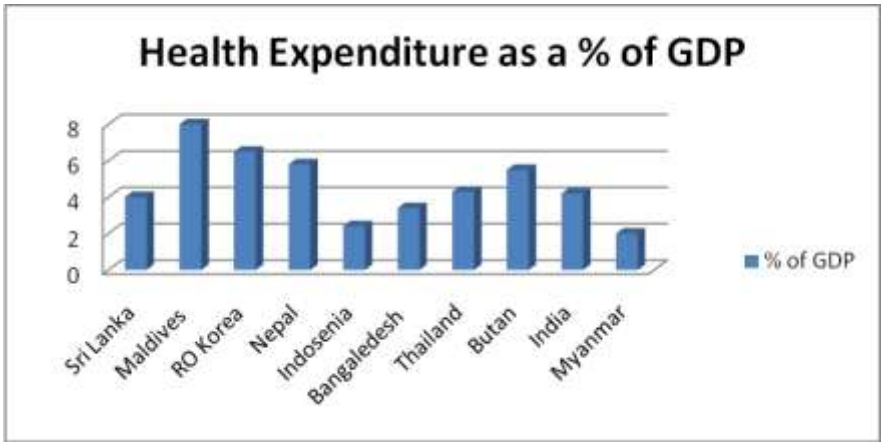
coverage. The Government had, however an important role as insurer of the elderly, disabled and poor (Department of Health and Human Resources-USA, 1999).

African countries

Since the beginning of the 21st Century, in most African countries the expenditure on health as a percentage of GDP stood at around 4-6%, with a per capita health spending in the range of 50-150 international dollars. For instance, Kenya spent 4.3% of GDP with per capita expenditure of 68 international dollars; and Senegal spent 5.7% of GDP with per capita expenditure of 102 international dollars. In the majority of African countries the Government contributed around 40% of the total health expenses, while the private sector was responsible for the larger share of about 60%. Within the private sector expenditure, out-of-pocket spending stood very high, in the range of 80-100% (WHO, 2009).

South East Asian countries

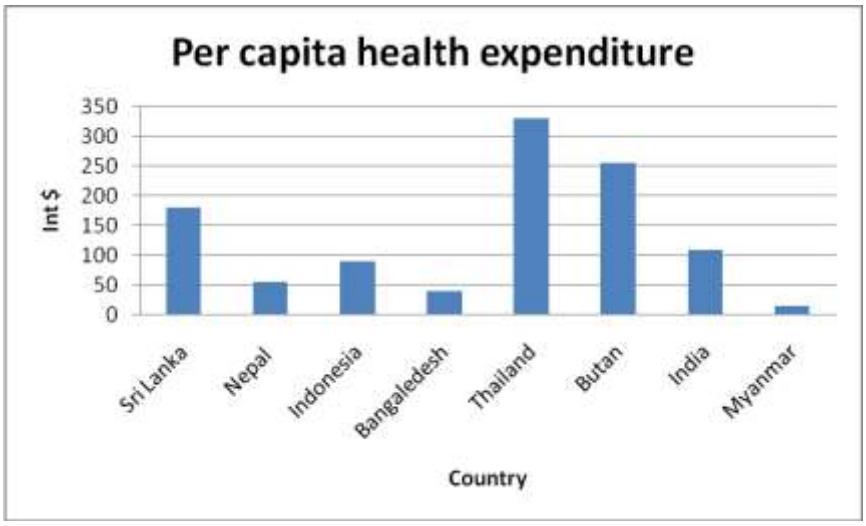
In the majority of South East Asian countries health expenditure was about 3-5% of GDP, in 2009, with a per capita health spending in the approximate range of 50-300 international dollars. For example, Bangladesh spent 3.4% of GDP, with per capita expenditure of 48 international dollars; and India spent 4.2% of GDP with per capita expenditure of 132 international dollars. In most countries, the Government contributed a smaller portion of the health budget, in the range of 35-45%, while the private sector contributed the larger portion. From the total private health expenditure, out-of-pocket expenses were relatively high, in the range of 75-100% (WHO, 2009).



Source-WHO (2009)

Figure 2.2. Health expenditure as a percentage of GDP in South East Asia, 2009

Total health expenditure is the sum of public health expenditure and private health expenditure. Taking into account the population of various countries together with health expenditure as a percentage of GDP, it could be observed that the higher the GDP: population ratio, the higher the per capita government expenditure on health. Figure 2.3 shows the total health expenditure per capita, i.e. the per capita amount of the sum of public and private expenditure on health. For comparison purposes, the international dollar (a common currency unit that takes into account differences in the relative purchasing power of various currencies) was used.



Source-WHO (2009)

Figure 2.3. Per capita health expenditure - WHO South East Asia Region in 2009

2.3 Dental care systems worldwide

Dentistry is a part of general health, and as such dental care provision is a part of the general healthcare service. Although the organization and funding of healthcare systems varies widely between different countries, many are facing similar challenges, and striving to achieve similar goals, ensuring accessible, high quality healthcare that is responsive, affordable and, finally, sustainable (Hobdell et al, 2003).

2.3.1 Overview of global dental health services

To gain an insight into global dental care delivery systems, we provide an overview of how dentistry and dental markets operate in selected countries. Despite major differences between

social health insurance and tax-based systems, there is a striking convergence in the way that dental services are organized and financed throughout the world. In the modern world, many countries seek to shift financial responsibility for dental services to the end-users. Therefore the dependence on private sector dentistry and increased dependence on user charges is a world-wide phenomenon (Buse, 2000).

The key producers of dental services everywhere in the world are the dental surgeons, supported by other professionals complementary to dentistry (PCD)**.** Health service provision depends on the availability of service providers, which in turn depends on the training capacity of healthcare providers. The training capacity of health personnel of a country primarily depends on the number of training facilities available. Table 2.2 below shows the health professional training institutions from a global perspective.

WHO region	**Medical**	**Dental**	**Nursing& Midwifery**	**Public Health**	**Pharmacy**
Africa	66	34	288	50	57
Americas	441	252	947	112	272
South East Asia	295	133	1145	12	118
Europe	412	247	1338	81	219
Eastern Mediterranean	137	35	225	8	46
Western Pacific	340	72	1549	112	202
Total	**1691**	**773**	**5492**	**375**	**914**

(Source: Mercer H , Dal Poz MR, Global health professional training capacity 2006)

Table 2.2. Health professional training institutes by WHO region

It should be noted that the above figures will have increased during the past four to five years, as is evidenced by the fact that, in India, at least, by 2009 the number of dental schools had grown to 290. (Indian Institutions, 2010).

The main product of dental schools or dental faculties is the dental surgeons. Dental surgeons provide the backbone of dental services in all countries. The number of dental surgeons in different WHO regions is illustrated in Table 2.3 below to highlight the distribution of dental surgeons from a global perspective.

WHO Region	Number of dental surgeons
Africa	23,744
Americas	880,636
East Mediteranean	75,405
Europe	450,624
South East Asia	92,748
Western Pacific	279,779
Total	1,802,936

(Source-:Malmö University 2009)

Table 2.3. Number of dentists by WHO region

When considering the availability of dental surgeons in a particular country or region, it is more logical to present the number of dental surgeons per 100,000 population, which enables a certain degree of comparison. Table 2.4 shows the number of dental surgeons in a few randomly selected countries, representing different WHO regions of the world.

WHO Region	Country	No. of dental surgeons per 100,000 population
Africa	Kenya	2
Europe	U.K	46
East Mediterranean	Egypt	14
East Mediterranean	Saudi Arabia	17
Americas	U.S.A	58
Americas	Canada	56
Western Pacific	Australia	45
Western Pacific	Japan	73
South East Asia	Thailand	17
South East Asia	India	6
South East Asia	Sri Lanka	7

(Source:Malmö University 2009)

Table 2.4 Number of dental surgeons per 100,000 population

Table 2.4 illustrates the large differences in the number of dental surgeons in the selected countries representing all regions of the world. All countries in the above list had a population above 20 million, and the dental surgeon to population ratio varied from 2 (Kenya) to 73 (Japan) per 100,000 population.

2.3.2 Dental/oral healthcare systems and services in selected countries

Most countries, especially developing countries, have no separate budget for dental care, and, as such, dental care expenditure is included in general health budgets. Given this limitation, it

is logical to assume that higher spending on health care would be associated with higher spending on oral health care.

United States

The dental market in the United States is mainly private, with a small percentage of public funded dentistry. The prices for private treatment are not set by a particular body, as this could constitute price fixing, which is against state and federal law. The overwhelming majority of dental surgeons own solo dental practices, where only one dental surgeon operates. According to the American Dental Association (ADA), in 2006, 79% of the nation's private dental surgeons were working alone. In 2003, there were 58 dental surgeons for every 100,000 population. 20% of all dental surgeons practise in one of the eight specialty areas recognized by the ADA. A 'fee for service' delivery model operates as the predominant dental care delivery system. Personal dental services are provided largely through private arrangements between dental surgeon and patient. Denturists receive extensive formal training, and are the only Professionals Complementary to Dentistry PCD to be legally recognized. Denturists can work independently from dental surgeons, and charge directly for their services.

The USA spends nearly 16% of its GDP on health care. Oral health care accounts for 4.7% of the country's health expenditure (Malmö University, 2009).

United Kingdom

The UK National Health Service (NHS) has been in existence since 1948. It is funded mainly through general taxation. There are basically three types of oral health care within the NHS, namely the General Dental Service (GDS), Community Dental Service (CDS) and Hospital Dental Service (HDS). The general dental service is provided by dental surgeons, who are non-salaried practitioners, working in privately owned premises. The community dental service is provided by salaried dental surgeons, catering for children with special needs and, occasionally, adults and communities where there are few GDPs. The hospital dental service is to be found in dental teaching hospitals and most large general hospitals. The majority of specialist dental treatment is done within the hospital dental service, usually via referrals from the GDS or CDS. All dental services provided by NHS hospitals are free to the patient. Furthermore, within the NHS all oral and dental health care is free for under 18 year olds,

students under 19 years, pregnant and nursing mothers and individuals on welfare benefits (Council of European Dentists, 2008).

The dental care sector has a low degree of market concentration. Historically, high street dental practices have been fragmented, small-scale, one-man-band businesses.. However, between 1992 and 2002 the percentage of surgeries with three or more partners rose from just under 30% to 36%. Moreover, there has been an increasing tendency for dental surgeons to work with teams of supporting professionals, including dental nurses, dental hygienists, dental technicians and dental therapists. However despite these trends, the dental sector is still dominated by small–scale activity, with approximately 24,000 General Dental Practitioners (GDPs) working as independent contractors for the NHS, in approximately 11,000 high street practices across the UK (Downer,2006). In addition to traditional practitioner–owned dental practices, there are currently 27 corporate dental groups which own chains of practices. Dental surgeons may work for these groups as salaried employees, or on a self–employed basis. Most dental surgeons are engaged in mixed practices, in which they treat both NHS and private patients, the proportion varying depending on the patient base, locality and practice owner's discretion. There are only approximately 200 practices that are totally private, but there has been a marked growth in the private component of NHS work in recent years (NHS Dental Services, 2009).

In 2009, total expenditure on health as a percentage of GNP was 8.3%. Furthermore, the UK devoted 0.6% of its GNP to oral and dental health care, with one dental surgeon for 1,976 population (Malmö University, 2009).

Africa

Total expenditure on health care as a percentage of GDP is in the region of 3-5% in most African countries, financial allocation for dental care being insignificant (McIntyre, 2007). There are less than four dental surgeons per every 100,000 population in most African countries. The governments provide limited free of charge dental services through their general healthcare institutions. Furthermore, in most African countries, due to the shortage of dental surgeons, dental auxiliaries provide a wide range of services in the public sector. The private dental sector is small and concentrated in bigger cites, the mode of provision of private dental care being through solo practices, where dental surgeons work on a 'fee for service' basis (Malmö University, 2009).

South East Asia

Most of these countries had less than eight dental surgeons per 100,000 population in 2007. As with the African region, the governments provide a limited free of charge dental service through the general healthcare network. The mode of provision of private dental care is similar to that of Africa (Malmö University, 2009).

2.4 Public and private funded dental care

2.4.1 Global trends in health system financing

Countries' health financing profiles change as they move to different stages of the income spectrum. In low income countries almost half of health spending is private. These are mainly direct out-of-pocket payments. Formal sector employment here is limited and therefore social insurance is scarce. Further, private health insurance is also extremely limited because of people's inability to bear the cost of the premium and other institutional constraints (Rannan-Eliya, 1990). In less developed or developing countries, the governments provide basic public health and clinical services to the entire population through their Ministries of Health, including tertiary-level hospital care. However government health budgets are extremely limited. Therefore long waiting times in hospital clinics to obtain medical services is the norm in these countries.

The economic prosperity of a country leads to the development of a formal taxable sector, thus enhancing the Government's ability to generate more revenue. Economic development also allows other institutions, such as financial markets, legal systems, and regulatory capabilities to become formalized and to develop. However private spending still accounts for around 40% of all health spending in middle income countries, while the out-of-pocket share declines as private health insurance markets develop. Ministries of Health generally continue to provide basic public health services and to serve as the insurer of last resort for the poor.

With improved institutions, more efficient governance, and greater revenue raising capacity, countries tend to move into the high-income group. It is noticeable that governments tend to spend a relatively small share on health services in high-income countries, where publicly financed universal coverage, or publicly mandated private coverage becomes the mode of

health service financing. In these countries, Ministries of Health do not directly get involved in service provision, but maintain responsibility for public health and surveillance (Gottret, 2006).

The factors influencing health outcomes include economic and environmental influences, as well as direct health sector interventions. The disease burden and pattern experienced today, by the people of under-developed countries are strikingly similar to those of 19th Century Europe, i.e. they are primarily diseases of under-development and poverty. Moreover industrialized and urbanized sections of under-developed countries experience disease patterns more akin to those dominant in the industrialized countries. Sustained economic growth over the long run can lead to improved health and nutritional status of a country. Historical and contemporary experience has shown that there is a definite but complex relationship between economic growth and health status. However as discussed earlier, there is no direct correlation between health and nutrition indicators, and GDP per capita levels. This is because even at low income levels, improved income distribution and government-sponsored socially oriented programmes can accelerate improvements in health (Miler et al, 2003).

2.4.2 Private dental care provision

The governments of developing countries tactically encourage individuals to pay for their own health care where they are able to do so, and for the private health sector to meet these needs. However, government has an overall responsibility for ensuring that patients are protected and get value for money in both state and private sectors. It needs to consider how to regulate the private health sector without stifling initiative and innovation. Consideration also needs to be given as how best to encourage partnerships between state and private sectors to deliver quality services and contribute to national health goals. Strengthening of the capacity of the private health sector to provide quality care is also important (Oxfam, 2009).

With the present globalization of the economy, private dentistry is a delivery mechanism which has become increasingly important. According to the British Dental Association, what began 60 years ago as part of a world-famous publicly funded comprehensive National Health Service (NHS), is now fast moving towards private care provision in the United Kingdom (Office of Fair Trading, 2003).

Worldwide, private dental practice has existed since the beginning of dentistry. Private dental

care, or the provision of it, has a number of inherently desirable features. The flexibility and ability to choose the service provider are two of the main advantages. As a service provider, the dental surgeon can decide on the quantum of services provided. He or she can influence the quantity of services by adjusting the number of hours of work per day, or the number of working days per week. Private practitioners can respond to increasing demand in several ways: working longer hours, increasing productivity, increasing the fees, some combination thereof, or by doing nothing different. There is a built-in economic incentive to be as efficient as possible in private practice. A big investment of private capital in facilities and equipment is needed, the return on which forms the practitioner's profit. Choice of equipment, materials and employees is therefore made carefully, and all are chosen to suit the practice characteristics, such as locality and clientele (Chestnutt, 2009). It is accepted by most dental surgeons that private practice allows the provision of high quality dental care, as well as providing a personal and pleasing environment and convenience for the service recipient. However beliefs of this nature may be difficult either to substantiate or to refute in any objective manner (Hobdell, 2003).

Private practice allows free choice of dental surgeon by the prospective patient, and conversely, the dental surgeon is free to treat or not to treat anyone seeking care. The ability to choose one's own dental surgeon is valued among patients, especially in the higher socio-economic groups. These patients are more accustomed to regular dental visits and for the most part come from the same socio-economic strata as their dental surgeons. Patients in higher socio-economic groups also live and work in localities where dental surgeons tend to be more available, so that changing one's dental surgeon when desired is not usually difficult.

For lower socio-economic groups, there is little choice of dental surgeon, because few practitioners choose to practise in lower income localities. There is a clear relation between the availability of dental surgeons and per capita income of an area. Rural areas and poorer areas of cities are less attractive sites for private dental practice, because private practitioners are attracted to areas of high demand in order to show a return on their investment of capital. As a consequence, mal-distribution of dental surgeons is a standard feature of the private practice system. It is unlikely that there will be private practitioners available to serve the needs of many communities that are either geographically remote, economically depressed, or both (Hiroko, 1997).

Poorer groups often have a double problem where private dentistry is concerned. Care is less

available to them, and when it can be found, it is relatively expensive. The difficulties arising from the above issues have given impetus to the notion that persons in low socio-economic areas often do not value dental care. This belief is unlikely to be true; rather the circumstances of their lives do not always permit the disadvantaged the luxury of 'valuing dental care' the way that dental surgeons like their patients to value it (Pourat, 2011).

From the community viewpoint, the principal advantages and disadvantages of private practice as a delivery system relate to economics. Private funds are used to build the facilities, buy equipment and materials and hire supporting staff. Dental surgeons set their own prices and many also traditionally practise 'price discrimination', meaning that they charge well-to-do patients higher fees than they charge poorer ones for the same treatment. The complaint among some of the public that dental surgeons' fees are too high may be unfair, as such complaints often fail to take into consideration the characteristics embedded in private dental care provision. The solo dental practitioner is a self-employed businessperson, and thus has certain fixed overhead costs to meet, such as utilities, rent, equipment, supplies, staff payroll, insurance etc. Insurance for malpractice, although not yet the massive expense it has become in many medical specialties, is rising steadily for dental surgeons. Therefore dental fees may remain too high for many people, but this cost barrier is not necessarily a sign of the insensitivity of dental surgeons to public need: rather it is an inherent feature of private dental practice (Pourat, 2007).

The public sector finds it difficult to compete with the private sector, due to its inherent features of slow reaction to a fast changing world, slow and bureaucratic decision-making processes, lengthy and complicated procurement procedures, lack of a marketing orientation and excessive benefit costs. There has been a drastic shift in recent years from the principle of government responsibility for providing health care for all. At present, the global trend is focused as never before on more private sector participation in providing health care (Brennan et al., 2008).

Both supply and demand influence the ability of the dental work force to provide dental care adequately and efficiently. Major changes are occurring on both sides of the dental care market. Among factors shaping the demand for dental care are changing disease patterns, shifting population demographics, the extent and features of third-party payment, and growth of the economy and the population. The capacity of the dental workforce to provide care is influenced by enhancement of productivity and numbers of dental health personnel or skill

mix, as well as their demographic and practice characteristics.

Chapter 3: Sri Lanka and its Health and Dental Care System

This chapter continues the background to the research, with a description of the island of Sri Lanka, its healthcare system, its dental services and the education of dental professionals. A map of Sri Lanka is shown in Figure 3.1 below.

Figure 3.1. Sri Lanka

3.1 Sri Lanka: country profile, history, and economy

Sri Lanka is a tropical island located to the south of the Indian subcontinent in the Indian Ocean. It has a proud history which stretches back 2,500 years. The island's land surface is 65,610 square kilometres, which is approximately one fourth of the size of the United Kingdom. In the centre there is a mountainous region with peaks as high as 2,524 meters, surrounded by a coastal plain. For administrative purposes, Sri Lanka is divided into nine provinces, which are further subdivided into 25 districts. In 2009, the total population was approximately 20 million.

Throughout history Sri Lanka has been known by various names. The ancient Sinhalese (the majority population of the country) called it "Lanka", the Greeks called it "Taprobane", the Arabs named it "Serendib". The Portuguese and the Dutch called it "Ceilao" and "Ceylan" respectively. The British named it "Ceylon", and this was the name used until 1972, 24 years after independence from the United Kingdom. With the country becoming a republic in 1972, the name was changed to the present name, of "Sri Lanka".

3.1.1 History: foreign invasion

By the end of the 15th Century, Sri Lanka was divided into three kingdoms, namely the Kingdom of Kotte in the south-west of the island, the Kandyan Kingdom in the central highland of the country and the Tamil Kingdom in the northern part of the country. The Kingdom of Kotte was the most dominant kingdom, with influence on the affairs of the entire island. The Portuguese landed in Sri Lanka in 1505. It was the islanders' first exposure to Western civilization. While the Portuguese were able to establish themselves in the Maritime Provinces, the rest of country was governed by Sri Lankan rulers. The Maritime Provinces were captured by the Dutch from the Portuguese in 1658. However the central part of the country was still under the local rulers, namely the Kandyan kings.

The British captured the Maritime Provinces from the Dutch in 1796. For first time in the long history of this island nation, they were also the first colonial masters who were able to capture the Kandyan Kingdom, in 1815. Britain ruled the entire country until 1948, when independence was granted. 'Ceylon' as the British called it, soon became a very prosperous colony, to which many British nationals came in search of better prospects. Land was given to the British for starting coffee plantations at concessionary rates. This created the need for a labour force to work in the newly established plantations. With the rapid growth of the plantation industry, which spread its wings to tea and rubber cultivation, considerable numbers of British expatriates arrived to take up senior posts in the industry.

3.1.2 Country profile

Sri Lanka's population was 20 million in 2009, with an average population density of 319 per square kilometre. The capital district of Colombo has the highest population density of 3,410 per square kilometre. Sri Lanka was one of the first developing countries to experience a 'population explosion', but the population growth fell to 1.1% in 2007. The country remains predominantly rural; only 22% of the population lives in urban areas. Sri Lanka has a multi-

ethnic community, consisting of 82% Sinhalese, 4.3% Sri Lankan Tamils, 5.1% Indian Tamils, 8% Moors and 0.7% other ethnic groups. (Department of Census and Statistics, 2009).

Sri Lanka is a republic headed by an executive president. The president, together with the single-chamber legislature, is elected by the people. In 1987, extensive powers were devolved to nine provincial councils in the country. Sri Lanka's democracy is notable for many reasons, one being its origins. It is one of the few developing countries with a competitive multi-party political system, which has existed since independence in 1948. Sri Lankan democracy has shown unique resilience. It was able to survive and overcome two attempts to overthrow the elected government by Maoist insurgencies (1971 and 1987-1990), and a civil war with Tamil Tiger separatists (1983-2009). Sri Lanka's modern healthcare system is not only a product of this democracy, but it has itself contributed to the survival of that same democratic system (Rannan-Eliya, 2001).

Historically, Sri Lanka depended on agricultural cultivation, predominantly of rice. However with the British colonization, coffee, and then tea and rubber cultivation was introduced, thereby establishing a classic dualistic export economy by the end of the 19th Century. Most people continued to subsist on the basis of rice cultivation, while indentured labour from South India was brought to work in the new plantations. At Independence in 1948, the economy was highly dependent on trade. Tea, rubber and coconut accounted for more than 95% of the total exports. Sri Lanka has been a typical example of a developing economy facing declining terms of trade. Although she responded with policies of import-substitution and increasing government intervention in the economy, these fiscal measures failed and the country's income levels stagnated from the 1950s to the mid-1970s, leading to deterioration in living standards. Furthermore, the rapid population growth led to increasing levels of unemployment, and by the early 1970s, Sri Lanka was experiencing one of the highest levels of visible unemployment in Asia (Balasuriya, 1994).

With economic liberalization in 1977, performance growth substantially improved, mainly due to the rapid growth in an export-oriented labour-intensive manufacturing industry. Manufactured exports, principally garments, now account for more than three-quarters of export earnings. Industry has been the most dynamic part of the economy in recent years, and now contributes more to Gross Domestic Product (GDP) than agriculture. In 2009, the country's per capita GDP was USD 2053 with a real GDP growth rate of 3.5. Sri Lanka's

social indicators are impressive for a low-income country, as indicated by its infant mortality rate of 11.2 per 1,000 live births, expectation of life at birth of 73 years, and adult literacy of 90% (Central Bank of Sri Lanka, 2009).

The introduction of social welfare policies since the early 1940s, as well as the expansion of health and education services throughout the country during the early post-Independence era, could be attributed to the above achievements. However, since the 1970s, successive governments have found it increasingly difficult to maintain these services at an optimum level, due to the adverse economic conditions faced by the country. Furthermore, the structural adjustment programmes in the 1980s led to a reduction in social expenditure (Balasuriya, 1994).

However, Sri Lanka holds a unique position in South Asia as one of the first of the less developed nations to provide universal health, free education, strong gender equality and better opportunity for social mobility. As stated above, since its independence, successive governments have implemented welfare-oriented policies and programmes, which have allowed Sri Lanka to achieve relatively high standards of social and health development in comparison with countries of similar levels of economic development (World Bank, 1998). These developments are best reflected in the attainment by Sri Lanka of a high Human Development Index value of 0.691 in 2011, placing the country at 97 out of 187 countries and territories, notwithstanding being a less developed country (UNDP, 2011).

3.2 Sri Lanka's healthcare system

3.2.1 Development of the health system

In ancient Sri Lanka, 'ayurveda' (an ancient system of medicine that flourished in the Asian subcontinent) was the system of medicine practised by the local physicians. In the Sanskrit language, 'Ayu' means life, and 'Veda' were the books containing knowledge or science. (Cooray, 2008). Portuguese medicine was largely nurtured and developed by Arabic medicine, practised by the Moors in Spain. This system of medicine, brought over by the Portuguese, was predominantly practised amongst their soldiers and sailors, and did not make much of an impact on the civilian population (Tambiah, 1968). However during their rule, the Portuguese established several hospitals in the areas which were under their jurisdiction.

These were managed by Catholic priests, chiefly the Jesuits, who came along with the missionaries. The hospitals were called 'espirital' in Portuguese, and were financed by the Government. They catered mainly for Portuguese soldiers and their families who had settled in the coastal areas of the country. The country's premier hospital today, namely the National Hospital of Sri Lanka, Colombo, had its origin in the Portuguese period when it was established in 1553 (Perera, 1962).

The Dutch built a new hospital at a different site in Colombo, since the Portuguese hospital was destroyed during the siege by the Dutch army. The Dutch also built hospitals in other towns under their control. It is recorded that one such hospital, built in the southern coastal town of Galle, was staffed by one surgeon, two interns and ancillary staff (Samy, 1967). The Dutch-built Colombo Hospital was later used for the purpose of establishing a military hospital by the British. This hospital was staffed by army doctors and initially medical services were available only to the soldiers of the British Army and British civilians in the administrative services. The early phase of British medicine in Ceylon thus belonged to the military, who controlled both the military and civil health institutions (Cooray, 2008).

With the growth of coffee plantations, the British Government became committed to offer sound healthcare facilities for the British expatriates who were in the country. Moreover, in order to get the best from the plantations, the health of the workforce became a crucial issue. This led to the creation of a healthcare system, mainly to look after the health of the plantation workers. A new Civil Medical Department was established in 1858, separate from the military. This heralded a new era in the health services of Ceylon. To start with, there were three civil hospitals, a leprosy hospital, a lunatic asylum, a smallpox hospital and two prison hospitals. By the time Ceylon obtained its independence from Britain in 1948, there were 183 hospitals, including a general hospital, 45 rural medical units and 240 central dispensaries (Uragoda, 1987).

3.2.2 The current healthcare system

The country's healthcare system consists today of both public and private care services and is dominated by Allopathic medicine. Ayurvedic, Unani and several other systems of medicine are also practised in Sri Lanka. In the public sector, health care is free of charge to the patient, while in the private sector the patients pay out of their pocket.

The Ministry of Health, through the Department of Health, runs an extensive network of

facilities throughout the island. These are organized into a multi-tiered referral system of facilities, ranging from maternity homes and central dispensaries upwards, through rural, district, base and provincial hospitals to teaching hospitals and a national hospital. These provide mostly modern western-type care. According to the Department of Health, there are 1,000 institutions with around 64,000 beds in the government-managed healthcare system. Outpatient care is mostly provided through outpatient departments attached to the in-patient facilities, although some freestanding outpatient facilities also exist. Dental care is provided mainly as an outpatient service within the hospital set-up mentioned above. The majority of hospitals, except for central dispensaries and rural hospitals, provided dental services. In 2010, Government health-care facilities treated over 4 million in-patients and 44 million outpatients in general health-care and a total of 1.8 million patients in dental care, with a workforce of approximately 13,000 doctors and 1,000 dental surgeons, employed by the Ministry of Health (MOH, 2010).

At present all locally qualified medical graduates are recruited to the Department of Health within a few months after graduation. They work as full-time employees, although most of them do private practice during their non-working hours. As mentioned in the introductory chapter, in the past, dental surgeons were also provided with government employment immediately on graduation. However at the present time, dental surgeons are not guaranteed government employment, and the Ministry of Health does not employ dental surgeons on a regular basis. The Government contributes to around 45%-50% of the country's health expenditure. In 2009 government (public) health-care expenditure, as a percentage of Gross Domestic Product (GDP), was 1.48, out of which 82% was on recurrent expenditure, while only 18% was spent on capital expenditure. As dental services are an integrated part of government health services, they have no separate budgetary allocation, and therefore dental care expenses are included in the above figures (WHO, 2009).

Private healthcare services are largely ambulatory. Approximately 1,000 full-time private general practitioners (GPs) provide outpatient care from private clinics on a fee-for-service basis. This is supplemented by the part-time private practice of the government-employed doctors. There are approximately 19,000 traditional practitioners, mostly ayurvedic doctors, and around 200 homeopathic practitioners. However it is estimated that they treat fewer patients in total than the Western-qualified doctors (Rannan-Eliya, 2003). Many Western-trained private GPs dispense their own medicines, but a large number of private pharmacies

also exist. These private sector pharmacies are unregulated and mostly staffed by unqualified personnel.

In-patient care by the private sector was originally limited, and restricted to a small number of hospitals in urban areas. These hospitals are staffed by both full-time private doctors and government doctors working part-time in their off-duty hours. However, in recent years the private sector health-care industry has grown in volume as well as in the level of sophistication. For example, in 2001 there were approximately 65 private hospitals, accounting for approximately 2,200 beds. By 2007/8 this figure exceeded 100 institutions (MOH, 2009). Private expenditure on health was estimated to be about 1.92% of the GDP in 2003. This was approximately 55% of the total health expenditure in the country. 89% of private expenditure on healthcare was out-of-pocket spending, and private pre-paid plans accounted only for a very small percentage (WHO, 2009).

3.2.3 Spending on health care in Sri Lanka

It is estimated that, in 2009, Sri Lankans as private individuals spent slightly more than the Government in the realm of total health expenditure. This private expenditure was mainly for outpatient care. Only a small percentage of the population could afford in-patient care in the private sector, and only a few had medical insurance. Total expenditure on health was 4% of GDP in 2009, and total expenditure on health per capita was 193 international dollars (WHO, 2009).

Expenditure indicator	Value
General government expenditure on health as percentage of total expenditure on health	**45.2**
Private expenditure on health as percentage of total expenditure on health	**54.8**
General government expenditure on health as percentage of total government expenditure	**7.3**
Out-of-pocket expenditure as percentage of private expenditure on health	**86.7**
Private insurance as percentage of private expenditure on health	**9.1**

(Source:-WHO 2009)

Table 3.1. Health expenditure indicators in Sri Lanka-2009

Direct spending by households for medical treatment has been a feature of Sri Lanka's healthcare system from its early inception, as exemplified by the traditional practice of Ayurvedic practitioners treating patients by visiting their homes and being paid for their services. Out-of-pocket household spending has generated a stable 1.1-1.8% of GDP since 1950. ; Household spending on health in the 1950s-60s went mostly to traditional healers, though with little health gain or impact. However, free education and, more importantly, government-sponsored free medical services created greater awareness among the public about Western medicine. This caused a switch in demand from traditional healers to modern private providers. Thus tax funding (a source of government income) in effect changed the market for private care, by reducing lack of information and causing a paradigm shift on the part of consumers (Gooneratne, 1988). As shown in Table 3.1 above, out-of-pocket spending contributed approximately 86% of total resources for private healthcare services in 2009.

3.3 Sri Lankan dental services, public and private

3.3.1 Origin and development of 'modern' dentistry in Sri Lanka

The practice of dentistry in the early British period (1815-1875) was restricted to the extraction of teeth, mainly for the relief of pain, by doctors serving in the British Army. During this time, dentistry as a separate profession was developing in the United Kingdom. This 'fast developing dental environment' led to a higher level of expectation of better dental treatment. Therefore the British citizens who came to Ceylon also began to seek improved dental services in their adopted country. The rising demand for dental care here encouraged dental surgeons from the UK to come to Ceylon and start practising in the Island nation. Furthermore, during this era, dental diseases became widespread, due to the worldwide phenomenon of consumption of more and more sugar-containing food. Increasing levels of dental disease augmented the need for dental surgeons in the Island colony. Therefore a number of dental surgeons, trained in the UK, came to Ceylon and started to practise the profession of dentistry, firstly on British citizens, and then on the 'elitist group' of the local population. With the passage of time, more and more of the local population living in the cities began to emulate the lifestyle and health standards of the British population. Hence their eating habits, and the pattern of dental disease began to change, creating more demand for dental services. The need for dental treatment, and the expansion of services, prompted the organization of the dental profession in the country.

The development of dental services in Ceylon, a British colony, followed the organization and administration principles which were in force in Britain. The dental profession was legally established in Ceylon, with the enactment of the Dental Registration Ordinance, passed by the State Council in 1915. Mr Sperling Christoffelsz was the first to be registered under the Dental Ordinance, in 1915. He was soon followed by two more dentists, obtaining registration in the same year. It is worth mentioning that all three of them had both medical and dental qualifications, gained in the UK. It was only in 1916 that a dentist without a medical qualification was registered in Ceylon. He was Sydney William Garne, LDS(Edin), and was considered the first dentist in Ceylon (Cooray, 2008). Mr Garne established a practice in partnership with Mr Christoffelsz in the capital city of Colombo and later became the founding president of the Ceylon Dental Association, which was established in 1932 (Cooray, 1992)

To satisfy the growing need for dental services, the Government started a dental clinic in 1925 in the General Hospital of Colombo, then the country's main hospital. Over the past 85 years, this clinic has provided uninterrupted service to the public and it has grown to become the country's premier specialized dental hospital, namely the Dental Institute, Colombo, which employs around 50 dental surgeons and dental specialists. As there was no formal training programme for dental surgeons in the country, the practice was that qualified medical practitioners from Ceylon proceeded to the UK to obtain a postgraduate qualification in dentistry. On their return, they were appointed to the government dental clinics as dental surgeons. The second government dental clinic was started in Galle, in 1937, and this was followed by a clinic in Kandy Hospital. Most of these clinics were manned by practitioners who were qualified both in medicine and dentistry.

In 1933 the Ceylon Dental Association lobbied the Government to start a dental school. However it took five years to meet this request. In 1938 the first Dental School in Ceylon was started in the Ceylon Medical College in Colombo, which had been in existence since 1870. The principal and the entire staff of the Dental School had qualifications obtained in the United Kingdom. The first batch of students consisted of six medical graduates who were to be given two years' training in order to be granted a licence to practise dental surgery. This batch completed their course in 1940. However the programme had to be abandoned after the first course, due to the onset of the Second World War. By this time, from a global perspective, university-level training programmes for dental undergraduates were well-

established in Europe, in particular in the United Kingdom. From a local perspective, reforms were taking place in the country's tertiary education system. Furthermore, there was lot of lobbying by the Ceylon Dental Association of the Government to start formal dental education. These facts led to realisation of the need for an independent dental school in the country. As a result a Dental School was opened as part of the Ceylon Medical College of the University of Ceylon in 1943. It was located in the dental wing of the General Hospital of Colombo. The course of study, leading to either Bachelor of Dental Surgery (BDS) or Licentiate in Dental Surgery (LDS) was a four-year university study programme. Students who performed exceptionally well in the university examinations were awarded a Bachelor's Degree (BDS), and those who did not achieve such high academic standards were awarded the Licentiate (LDS). Five students were enrolled in 1943, with the first batch graduating in 1947. Out of the first two batches of students, the first person to obtain the Bachelor of Dental Surgery degree (BDS) was S.B Dissanayake. The LDS was abolished in 1962, and the BDS has continued to be the only qualification awarded at undergraduate level to date (Tillekaratne, 1992).

In 1949, Dr R.H. McKeag from Bristol Dental School was appointed as the first Professor of Dental Surgery. He is credited for organizing the teaching programme along the lines of British Universities. The Dental School, which was now functioning at its optimum in Colombo, needed to be expanded. However limitations of space at the existing location restricted any further expansion. Attempts to find a suitable location in Colombo for the expansion of the Dental School was not successful. During this time, a campus of the University of Ceylon was being built at Peradeniya, about 70 miles from Colombo, in the beautiful central hills of the country. After much deliberation, a decision was taken to shift the Dental School to Peradeniya. The move took place in 1953 with a batch of ten final year students. However the pre-clinical studies (for the first two years) continued to be carried out in Colombo. In 1955, Dr S.B Dissanayake (the first student to obtain a BDS degree from Ceylon Dental School) became the Professor of Dental Surgery, a post which he held until 1982. Prof. Dissanayake is credited for nurturing the present generation of senior academics of the Dental School who were all his students (Personal communiqué, 2009).

The Dental School, although sited in Peradeniya, remained under the Medical College, Colombo until 1964. When the Medical School of the Peradeniya campus was established in 1964, the Dental School came under its administrative control. Subsequently the Peradeniya

campus became an independent university in 1978. The Dental School continued to remain a single department, namely the Department of Dental Surgery of the Faculty of Medicine, University of Peradeniya. However, in 1980 the University Grant Commission sanctioned the creation of five departments for the Dental School, within the Faculty of Medicine. This arrangement led to many problematic administrative and management issues, so the Dental School was given its own faculty status in 1987. Elevation to faculty status gave much needed independence to plan for the development and expansion of services rendered by the Dental School. By this time, the Government had increased the annual intake of dental students from ten in the 1950s, to around 75 (Dental School, 1987).

Assistance from the Japanese International Co-operation Agency (JICA) was solicited to build a new complex for the Dental Faculty and Dental Hospital adjacent to the Peradeniya Teaching Hospital. The new complex, with all modern facilities was opened in 1998. Since 1953 until then, the Dental School and its successor, the Faculty of Dental Sciences, continued to be located in Augusta Hill in Peradeniya.

In the early days, the government hospital dental clinics in Colombo and outstations treated most patients by 'extractions'. The dental surgeons' work was confined mainly to the relief of pain by extracting the offending tooth or teeth. Dental surgeons hardly practised any form of preventive or restorative dentistry.

3.3.2 Expansion of public dental services in Sri Lanka

By 2009, during the 84 years of its existence, the public sector dental service had grown to provide service to the entire country, with about 1,000 dental surgeons on its payroll. At the start of public sector employment for dental surgeons in the 1920s, all dental surgeons appointed to the government service had medical qualifications in addition to their dental qualifications. The terms and conditions of employment of these 'dental surgeons' was not an issue, as they were employed first as medical officers, and their dental qualification (namely LDS) was considered a specialist qualification. Therefore they were placed on a specialist salary scale. With the passage of time, as the first batch of dental surgeons qualified from the new Dental School in 1947, they were recruited to the Department of Health as Grade II dental officers. Initially there were some 'teething problems' regarding terms and conditions of employment, especially in regard to the salary scale for the dental surgeons who had only the dental qualifications.

By the early 1950s, more than 30 dental surgeons had graduated from the Dental School in Ceylon and were employed by the Department of Health. They were faced with many problems, including anomalies in salaries and disparities in service when compared to their medical counterparts. In order to address these issues, the dental surgeons employed by the Government formed a trade union, by the name of the Government Dental Surgeons Association in 1951. This trade union, commonly known as the GDSA, had a membership of over 900 dental surgeons working in the Ministry of Health by 2009.

The Fellowship known as FDSRCS (Fellow of Dental Surgeons of the UK Royal College of Surgeons) from any UK based Royal College of Surgeons was recognized as a specialist qualification by the Ministry of Health in 1957. However it was implemented only for the dental practitioners who had medical qualifications. After much agitation and trade union action, in 1967 it was also recognized as a specialist qualification for those who had only the BDS or LDS. In 1959 the Higher Dental Diploma (HDD) examination was conducted by the Dental School. This was the first recorded local postgraduate dental qualification to be conducted in the country. It was accepted as a qualification for promotion of officers in the Ministry of Health from Grade II to Grade I. (Cooray, 1988).

Since the 1950s, the General Dental Practitioners (GDPs) have been growing in number to form the second largest group of dental surgeons in Sri Lanka. These GDPs are self-employed professionals, who practise in the community in which they live. They provide a comprehensive service, with continuity of care. Whilst they practise the full breadth of dentistry, they do not usually offer any specialty in depth. Their services have to be paid by the service recipients. The General Dental Practitioners Association (GDPA) was formed in 1971 to cater for the specific needs and interests of this group of dental surgeons. Even today, general dental practitioners are the second largest group of dental surgeons in the country (De Silva, 2007).

The beginnings of preventive dental health in Sri Lanka came with the Ministry of Health's 'Colombo Plan': a School Dental Service commenced in 1951, on the lines of the New Zealand model (School for Dental Therapists, 2009). To start with, six females were sent to New Zealand for a two-year training programme to qualify as dental nurses. They were to provide basic dental care for children under the age of 13 years. These nurses were to work under the supervision of a dental surgeon appointed to the School Dental Service. In order to continue to expand this preventive work, it was necessary to train more dental nurses in

Ceylon. Therefore a dental nurse training school was established in the early 1950s to train fifteen dental nurses per year. Training of dental nurses, who subsequently became known as 'dental therapists', continues to-date. The School for Dental Therapists, based on the New Zealand model, has been in existence for nearly 60 years, with an average annual intake of 25 students for a two-year programme. Dental therapists provide preventative care for children between 3-13 years of age, based in school dental clinics. There are approximately 370 school dental therapists employed by the Ministry of Health and working in school dental clinics, mainly in rural parts of the country (MOH, 2010).

The field of postgraduate dental education in Sri Lanka, as stated earlier, commenced with the introduction of the Higher Dental Diploma in 1959. The impetus for formally organized and broad-based local postgraduate dental education dates back to the 1970s, with the establishment of the Postgraduate Institute of Medicine (PGIM). The PGIM was established in 1979, and affiliated to the University of Colombo. A Board of Study in Dental Surgery to overlook dental postgraduate education came into operation in 1982. At present the PGIM is the only institution in the country which offers postgraduate degrees in Medicine and Dentistry. It offers several postgraduate courses in the field of dentistry, namely, the Diploma in General Dental Practice, Diploma in Hospital Dental Practice, MSc and MD in Community Dentistry, MD in Oral Surgery, Restorative Dentistry, Oral Pathology and Orthodontics. On completion of all parts of the MD degree, which includes mandatory overseas training, the dental surgeon is certified by the Board of Study as a consultant in their respective field. Board certification is a prerequisite to being appointed as a consultant in the Department of Health.

Until 2006, PGIM study programmes were restricted to government sector-employed dental surgeons/doctors. As the PGIM was the only institution in the country which provided postgraduate study programmes in Dentistry and Medicine, no dental surgeon or doctor employed full-time in the private sector could become a consultant/specialist in Sri Lanka. However, since 2006, a limited number of opportunities have become available for full-time private sector-employed dental surgeons/doctors to embark on postgraduate studies at the PGIM. All PGIM study courses are extremely competitive, with only a few candidates selected at the entrance examination for the various MD programmes, mainly according to the availability of vacancies in the Department of Health for MD qualified consultants.

3.3.3 Publicly funded dental/oral healthcare systems and services

Public sector dental services are provided through the health infrastructure by the Ministry of Health. The Chief Dental Officer, who holds the rank of Deputy Director General of Health Services, is in charge of dental services provided by the Department of Health. He is supported by 23 regional dental surgeons at district level. Dental services in Sri Lanka are broadly divided into curative and preventive services.

The Department of Health operates around 1,000 health delivery institutions, which comprise a network of 17 teaching hospitals, 5 specialist hospitals, 8 provincial and general hospitals, 37 base hospitals, 156 district hospitals and over 275 peripheral units and rural hospitals. Dental services are available in all teaching, provincial, general and base hospitals. Most district hospitals and rural hospitals, as well as some peripheral units and central dispensaries also have dental clinics. Approximately 1,000 dental surgeons serve in these government-owned hospital dental clinics across the country (Directorate of Dental Services, 2009).

The Department of Health recognizes four specialities in dentistry, namely Oral & Maxillo-Facial Surgery, Orthodontics, Restorative Dentistry and Community Dentistry. Dental specialist services are provided through three specialized institutions/hospitals and all teaching, general and some base hospitals in the country. The three specialized dental institutions/hospitals are located in Colombo and Kandy. By 2009, there were 49 dental specialists in the Department of Health (Directorate of Dental Services, 2010).

A need-based preventive dental care service is provided mainly through school dental services. School dental clinics are managed by school dental therapists, who provide services for children from 3-13 years of age. They are a group of dental auxiliaries who are trained for two years in very basic dentistry at the School of Dental Therapists. A school dental therapist has to work under the supervision of a dental surgeon, although the dental surgeon may not be present at the premises. School dental therapists are not entitled to engage in private practice (School of Dental Therapists, 2009). The distribution of school dental clinics is shown in Table 3.2.

District	Number of SDTs	District	Number of SDTs
Colombo	59	Anuradhapura	11
Gampaha	35	Polonnaruwa	08
Kalutara	22	Puttlam	08
(NIHS Kalutara)	07	Kurunagal	32
Galle	31	Trincomlee	02
Hambantota	10	Batticoloa	02
Matara	22	Ampara	03
Ratnapura	18	Kalmunai	02
Kegalle	16	Jaffna	06
Badulla	18	Kilinochchi	00
Monaragala	07	Mannar	00
Kandy	32	Mullitivu	00
Matale	11	Vavuniya	02
Nuwareliya	06		
		Total	**376**

(Source: Directorate of Dental Services 2009)

Table 3.2. Distribution of school dental therapists (SDTs)

The preventive care services are further strengthened by the dental surgeons working in adolescent and community dental clinics, of which there are only around 20 in the country. In addition to dental surgeons and school dental therapists, dental laboratory technicians are the only other recognized category of professionals in the field of dentistry in Sri Lanka. Dental laboratory technicians, too, have to work under the supervision of a dental surgeon and are not permitted to practise independently. They have to follow a two-year certificate level study programme at the Faculty of Dental Sciences, University of Peradeniya to qualify as dental laboratory technicians. In the government sector there are 26 dental laboratory technicians, based in hospitals where specialist dental surgeons are available.

Both curative and preventive services in the public sector are free of charge to any Sri Lankan. According to the latest available data, during 2007, there were 1.82 million patient visits to government dental care services (Ministry of Health, 2010).

3.3.4 Private sector dental care in Sri Lanka

While Sri Lanka prides itself on well-established public sector healthcare provision, the private sector plays a significant role in the health sector. From its inception in the early twentieth century, for 80 years private sector dentistry had a slow development. Only a few private clinics were established, and were limited to the main towns. General dental practitioners were well-to-do in terms of income and professional status. As there was government employment, few dental surgeons ventured voluntarily into the private sector to become full-time general dental practitioners with much zeal. In the past, there were enough employment opportunities both in the public sector and the private sector for dental surgeons (De Silva, 1999).

At present it is estimated that there are approximately 1300-1700 active dental surgeons in Sri Lanka, belonging to different age cohorts. Younger age bands are greater in number, compared to their older counterparts. It is estimated that there are around 100-175 established full-time private dental clinics and around 200-250 newly qualified young dental surgeons engaged in full-time private practice until they secure government employment. Approximately 500-700 dental surgeons are employed in the private sector on a part-time basis. This is a sub-set of the state sector-employed dental surgeons, who engage in private practice after their hospital working hours (De Silva, 2007).

Sri Lanka's private sector dentistry remains largely unregulated. Any person who is registered with the Sri Lanka Medical Council as a dental surgeon is eligible to enter the private sector anywhere in the country. As stated earlier, public sector dental surgeons are also allowed to do private practice after their official duty hours. All private practitioners work on a 'fee for service' basis in Sri Lanka. Fees for private dental treatment are not regulated and are determined by market forces. Almost all the payments for the private dental care are 'out of pocket' payments. As a result, no records of payment outflows could be obtained at a central level.

The Sri Lanka Medical Council has the authority to investigate any complaint regarding the misconduct of a practitioner. Apart from this, there is no supervisory role of private dental practitioners by either a professional dental body, or by the Ministry of Health. There is no minimum standard for a private practice, either in qualitative or quantitative perspectives.

There is no flow of information from the private practitioners to a central database. Therefore there are no records of the number of practitioners, number of patients, or diseases treated in the private sector. Furthermore, unlike in the UK National Health Service, there is no registered set of patients per practitioner.

The Association of General Dental Practitioners is a professional body consisting of general dental practitioners. The College of General Dental Practitioners is the academic arm of the Association. Membership of the Association is not compulsory for private practitioners, and less than a quarter of private practitioners are members (De Silva, 1999). The scope of the Association is limited to annual scientific sessions and a few guest lectures. The College collaborates with the Postgraduate Institute of Medicine, University of Colombo, in conducting a Diploma in General Dental Practice.

Given the above description, it is clear that there is little in the realms of management information pertaining to private dentistry. No authority knows how many service providers there are in the country, what they do and where they are located. A recent study by De Silva (2007) highlighted the similar importance of private sector dentistry in Sri Lanka.

The global demand for cosmetic dentistry and dental implants is increasing rapidly. The Sri Lankan private dental services are also challenged with adapting to the changing demand patterns. Dentistry is a service commodity with a high income elasticity of demand. Therefore the demand for dentistry in the private sector will depend on the income and the purchasing power of the service recipients, which will, in turn, depend on the economic growth of the country. Dental surgeons, who will, of necessity, have spent a long time over their undergraduate training and the subsequent need to maintain professional standards as well as status, expect a relatively high monthly income to sustain them in the profession.

3.3.5 The Sri Lankan dental care product industry

In 1999, there were 16 business establishments engaged in dental products trade in Sri Lanka. All were private limited companies but one, which was a partnership. In addition to these business entities, there were about 5-10 freelance individuals who brought over dental materials and dental hand instruments from India and Pakistan. Almost all the dental product vendors were concentrated within the city limits of the capital city of Colombo (De Silva, 1999). The Cosmetics Drugs and Device Authority (CDDA), a state-controlled agency which comes under the Ministry of Health, is the statutory licensing authority for medical and dental

products and devices in Sri Lanka. A Cosmetic Drug and Device Certificate (CDDC) is required to import dental products into the country.

China and the European Union are major suppliers of dental equipment and disposable and dental materials to the Sri Lankan market. The Government of Sri Lanka, through the Department of Health, deals directly with licensed and registered dental suppliers when purchasing for government dental services, while the private dental practitioners buy the quantities needed for their private practices on an individual basis.

There are many taxes with complex calculations applicable on various dental products. However the final percentage works out at 27% of CIF (cost, insurance and freight) value. According to the disclosed value of sales of dental products, the total annual dental product market in 2007 was estimated to be about Rs.300 million (approximately US $ 2.7 million) (De Silva, 2007).

3.4 Dental disease patterns in Sri Lanka

The quantity of services needed and demanded by a population depends partly on the disease pattern and disease level of a country. Dental indices are designed to measure the status of various dental conditions quantitatively. A ‘dental index’ could be defined as a quantitative method for measuring, scoring and analysing dental conditions, either in individuals or in groups. Therefore an index describes the status of individuals or groups with respect to the dental condition being measured (Burke, 1995).

There are number of dental indices which have been used over the years. Gingival Index (GI), Periodontal Index (PI), Plaque Index, Oral Hygiene Index, Calculus Index, Dean’s Dental Fluorosis Index (DFI) and DMFT Index are a few examples of frequently used dental indices. Of these various indices, the DMFT index is one of the most commonly used index in the field of dentistry. DMFT stands for **D**ecayed, **M**issing, **F**illed **T**eeth. It is a composite index which gives an indication of caries prevalence, or the level of disease, as well as that of the treatment level. The DMFT index is usually measured for specific identified age groups and is used by the WHO to compare the dental health of different countries (Benzian, 2011). Similarly “dmft” refers to deciduous (milk) dentition, where the letters d, m, f and t stand for the same definition as D, M, F and T. The National Oral Health surveys conducted by the

Ministry of Health in collaboration with the World Health Organization (MOH, 1984; 1993; 2003) indicate oral disease trends in Sri Lanka, summarized in Table 3.3.

Age Group	Disease level	1984	1993	2003
6 years	Caries prevalence	78%	76.4%	65.5%
	dmft	4.4	4.1	3.6
12 Years	Caries prevalence	67%	53.1%	40%
	DMFT	1.9	1.4	0.9
	Population with Healthy Gums	12%	13.3%	27.2%
35-44 years	Caries prevalence	92%	91.1%	91.5%
	DMFT	9.2	10.1	8.4
	Population with Healthy Gums	6%	2.1%	10.1%

(Source:- MOH National Oral health surveys 1984; 1993; 2003)

Table 3.3. Dental disease trends in Sri Lanka, 1984-2003

As illustrated in Table 3.3, over the years the DMFT index and the level of healthy gums has shown an improvement. However when the above results were compared with some developing countries (Malmo University, 2009) it showed the need to further improve the dental health status of the Sri Lankans.

3.5 Dental education in Sri Lanka

University education is free of charge for all citizens of the country. University selection is done by the University Grants Commission (UGC), based on GCE Advanced level examination results, and is conducted by the Ministry of Education. Selection is based both on examination marks obtained (merit basis) and the district in which the student had his/her school education (district quota basis) (UGC, 2010).

The Faculty of Dental Sciences, University of Peradeniya is the only institution which produces dental surgeons in Sri Lanka. Therefore it is almost the sole supplier of dental surgeons to the country. As shown in Table 3.4, since its inception in 1944, over a period of more than 65 years, the Dental School had produced 2,396 dental surgeons by 2009 (Faculty of Dental Sciences, 2010).

Year	Number of Graduates	Year	Number of Graduates	Year	Number of Graduates
1947	4	1969	27	1991	42
1948	7	1970	25	1992	65
1949	9	1971	27	1993	69
1950	3	1972	23	1994	64
1951	6	1973	23	1995	125
1952	6	1974	44	1996	50
1953	6	1975	50	1997	71
1954	12	1976	33	1998	80
1955	9	1977	17	1999	70
1956	8	1978	43	2000	93
1957	15	1979	45	2001	85
1958	7	1980	36	2002	92
1959	7	1981	56	2003	73
1960	9	1982	47	2004	125
1961	5	1983	6	2005	80
1962	8	1984	42	2006	123
1963	6	1985	38	2007	*65*
1964	6	1986	48	2008	78
1965	7	1987	14	2009	73
1966	17	1988	0		
1967	21	1989	0		
1968	21	1990	30	**TOTAL**	**2396**

(Source: Faculty of Dental Sciences 2010. Student Admission Register)

Table 3.4. Number of dental surgeons graduating from the University of Peradeniya

This highlights the ever-increasing number of dental surgeons graduating from the country's sole dental school. It is important to note that nearly 50% of its output was during the period between 1995 and 2009. During the last three years of the 1980s, the entire university system of the country was closed, due to the Southern insurgency upheaval. This resulted in no dental students graduating during the period 1988-1989. Upon reopening of the universities in 1990, in order to clear the backlog, double batches of students were trained in certain years. As seen from Table 3.4, the training of double batches was one of the contributory factors to the high output of graduates appearing after 1995.

Around five foreign-qualified Sri Lankan dental surgeons return to the country annually. They have to pass the statutory examination (Act 16 Examination) in order to practise in Sri Lanka. Approximately 60 foreign-qualified Sri Lankan dental surgeons have succeeded in passing the above statutory examination since 1995 (SLMC, 2010).

The training rate is a measure of the number of dental degree awards relative to total employment in the occupation. This is a measure of the rate at which supply can potentially grow through training. The training rate for dental surgeons in New Zealand was estimated to be around 3.4% in the first decade of the new millennium, while in Australia it was around

1.6% (AIHW, 2003). The training rate for dental surgeons in Sri Lanka, as shown in Table 3.4, has been above 8% since 2000.

In addition to the emerging importance of private sector dentistry both globally and locally, Sri Lanka is faced with the situation of non-availability of government employment for new dental graduates. Training of dental surgeons has, however, continued. The Dental School at the University of Peradeniya normally admits around 80 students per year for the four- year Bachelor of Dental Surgery programme. However from 1995 until 2009 more than 1,200 dental surgeons have graduated. Dentistry is a highly specialized profession, so dental surgeons cannot be employed in any other field. The Ministry of Health, the main employer for dental surgeons in Sri Lanka, has been unable to provide government employment on a regular basis. When opportunities in the public sector are scarce, newly qualified graduates have no other option than to work in the private sector as dental surgeons. Therefore the global trend of more private sector participation in dental health-care provision is augmented, due to the lack of government employment opportunities for newly qualified dental surgeons.

Chapter 4: Literature Review

In this chapter we briefly review the literature on workforce planning in general, but then focus at greater length on healthcare workforce planning. Upon deciding the broader research domain, the following literature review method was used. Firstly, appropriate sources and bibliographic databases were identified. These were: Web of Knowledge, the Cochrane Library, PubMed Central, GoPubMed, MedlinePlus, Academic Publication eJournal, CINAHL (Cumulative Index for Nursing and Allied Health), HAL, RePEc (Research Papers in Economics) Science Direct, Global Health, CORE, Book Review Index online, Academic Reference and Research Index, Google, and FreeFullPDF.

The literature review was mainly focused on the following key words: "Health services", "Health service planning", "Dental service planning" and "Health human resources". Using these key words, initially around 600 published articles were identified and scanned. Subsequently 275-300 publications with more relevant subject matter were selected and read thoroughly. Further around 140 publications which formed the core of the subject matter of this thesis was analysed and studied in depth.

In addition to the above sources, around 60 published documents in relation to health human resources, health service planning and dental health planning by the WHO, World Bank and Ministries of Health from several different countries were scrutinized.

4.1 Workforce planning

In modern day organizations, driven by the knowledge economy, irrespective of industry sector or company size, human capital is the key asset for success. Employees represent the most important and flexible resource available to an organization. Deploying people in the right numbers, with the right skills and in the right place is fundamental to success and achievement of organizational goals (Cole 2001). In this context "manpower planning" and "workforce planning" could be used synonymously as both denote the same human resource (HR) practice. One well-respected definition of manpower planning is "a strategy for the acquisition, utilisation, improvement and retention of an enterprise's human resources" (Department of Employment 1974).

Workforce planning is an important activity as it is a vital aspect of managerial functions, motivation, better human relations, and higher productivity. Workforce planning is necessary to identify shortages and surpluses and take remedial action. Further it will help to reduce labour costs as overstaffing could be avoided, and can also identify training needs and develop training programmes for the benefit of the staff (Bratton 2003). However workforce planning in any industry could address the obstacles of underutilization of manpower, absenteeism, lack of education and skilled labour. Further workforce planning in many large organizations would become less effective if a homogenous method or a model of workforce planning is applied to heterogeneous groups of employees. This is because the behavioural patterns on which workforce planning is based, such as acquiring new skills, getting promoted or leaving varies from employee category to category (De Feyter 2006).

As stated before workforce planning is an important activity in any organization from an industry like commercial airline service, which is high technology depended, extremely competitive and safety-sensitive (Laszlo 1999) via manufacturing industry where the impact of worker differences on the production system could lead to a substantial loss in throughput (Buzacott 2002), to the Military where workforces are characterised by their closed nature and strict hierarchy (Wang 2005).

In general workforce planning requires a systems approach and should consist of sequential steps: analysing the current manpower profile, forecasting future requirements, developing employment programmes and designing training activities. Expert forecasts, trend analysis, workload analysis, workforce analysis were the main traditional methods used for workforce planning though operational research methods are now frequently used (Brandeau et al 2004).

Workforce planning should stem from the vision, mission and strategic objectives of an organization. Strategic planning, budget, and human resources are key ingredients in workforce planning, which also needs the commitment and blessings of the top management. Moreover workforce planning should be geared to address, systematically, issues that are driving workforce change ((Bratton 2003).

4.2 Workforce planning in healthcare

The health worker is defined as a "person primarily engaged in actions with the primary intent of enhancing health". The global workforce is huge, amounting to 59.2 million full-time workers, of whom two thirds and one third are health service providers and health management support staff respectively. In health care systems the health worker is an integral part of a team where each member contributes different skills and performs different functions (WHO 2006).

Health care planning and organizing involves strategic decisions about the economics of health care systems, the structure of the health care systems and other aspects of public policy regarding health care**.** The workforce is connected to the system of health care. Therefore health care systems depend not only upon infrastructure and resources, but also on the availability of skilled human resources (Parkash 2006). Thus workforce planning for health services is complex, complicated and challenging. Furthermore due to the rapidly changing social and technological frontiers, demand for certain skills in health care delivery will decline while demand for certain other skills will increase (Brandeau et al 2004)

Further another main contributing factor for this challenge is the long duration of training required to produce a health professional such a doctor, dental surgeon or a nurse. Normally it takes 4-5 years for the basic training of these categories while it may even take 15-20 years to train a fully-fledged consultant. Hence decisions made today regarding training opportunities in universities and colleges, only have a noticeable impact five to ten years later. Therefore in the period of time between when the plans for training are made and come to fruition, the demand for health care professionals may have changed (The Health Committee 2007). Moreover according to Barer et al (1999) Canadian researchers have characterised health workforce planning as a "*classic policy soap opera-tune out for a few years*".

Nevertheless, health workforce planning is of paramount importance. It is the means for the health service to understand and comprehend the impact of socio demographic, technological and policy implications for future service requirements and workforce dynamics. Moreover in most countries, staff cost alone accounts for 60-80% of the government health budget. For example the in the NHS in the UK staff cost was approximately 70% (The Health Committee

2007) and in Peru in the 1990s it exceeded 90% (Kolehmainen-Aitken 1993).

In the United Kingdom health policy makers had emphasized the need for changes to the structure of the workforce and to the way in which staff work. It had been argued that in light of expected policy, demographic and technological developments, future workforce requirements are likely to change radically. Therefore it is imperative that simply planning for "more of the same" will be insufficient to meet the challenges of the next 10 years and beyond (The Health Committee 2007).

Effective health workforce planning must be an integrated process covering the whole workforce rather than considering each staff group in isolation and more importantly it should be strategic and long term oriented. Further workforce planning must become a priority of the health service in any country. This was exemplified by the fact that WHO dedicated its annual flagship report: Annual Health Report 2006 to health human resources (WHO 2006).

In this context, the WHO (2010) proposed several health workforce planning methods as follows:

i. The Workload Indicators of Staffing Needs (WISN) methodology;
ii. Trend analysis
iii. Regression analysis;
iv. Meta-analysis;
v. Econometric analysis
vi. Simple models for consideration of other health aspects, such as the impact of HIV on the workforce

Various authors have used the above methodologies in different health care settings. For example, the WISN (workload indicators of staffing needs) methodology, which incorporates a combination of work activity measurement and professional judgement, has been used to improve health workforce planning in some Asian and African nations (Kolehmainen- Aitken et al., 2009, Namaganda, 2004). Trend analysis uses observed trends to predict the future and has been used to analyse growth of the private sector health care service in Canada (Health Canada, 2001) while Queensland Health (2007) used regression analysis for workforce profile determination of different health manpower categories. Meta-analysis has been often used in health research to assess clinical effectiveness of health care interventions: Buchan and Calman (2005) argued the use of this methodology in manpower skill mix surveys.

Scheffler et al (2008) used econometric analysis to study the population demand for physicians on the basis of domestic product and national income.

The complexity and the nature of the health care systems and the diversity and interdependency of its human resources has forced health workforce planning to move beyond traditional approaches taken to it and embrace on more holistic and comprehensive techniques. In these context operational research techniques, tools and theories had been applied in different health care issues and settings. As stated by Brandeau (2004) OR (operational research) applications in health care could be broadly classified into health care operations management, public policy and economic analysis, and clinical applications. However the literature cited in this thesis concerns mainly public policy in health in general and dental health in particular.

4.3 Workforce Planning in Dental Care

Dental health planning is complex enough in its own right, making workforce planning for it even more difficult. Many factors and issues associated with the dental care market and its stakeholders make workforce planning a complex and challenging task (Parkash, 2006). The following key factors have been identified in dental workforce planning (Colombet, 1996; Try, 2000; Robinson, 2004):

- As with any other disease condition, morbidity patterns in dental diseases can vary due to many factors, such as time, population characteristics and geographical location. Therefore availability of accurate and timely morbidity data is vital for dental workforce planning.
- It is important to differentiate between the concepts of need, demand and utilization in dental workforce planning. Need is what the patient thinks he/she wants; it becomes a demand when it is complemented by purchasing power. Utilization is the amount of dental care consumed or purchased as a result of decisions arrived at jointly by the patient and the health service provider. From the policy perspective, what is needed may not always be translated into demand.
- The productivity of the dental workforce could vary due to a number of factors, such as age, gender, number of auxiliaries, practice patterns and technology used.
- Knowledge of both the number of dental surgeons and their geographical distribution is

vital for workforce planning**.**

- Increasing the capacity of dental training institutions will involve a considerable time frame. On the other hand, reducing the number of trainees will lead to under-utilization of the training capacity. Furthermore, training of a dental surgeon takes about five years, and therefore whatever the changes to the training capacity, it will take a minimum of five years to be practically effective as far as the workforce is concerned.
- Unique market characteristics in the field of dentistry, such as high cost of capital investment, long periods for return on investment, and professional settings are also important when planning for the dental workforce.

4.3.1 Dental workforce planning techniques

Having presented some of the key factors involved in dental workforce planning, we next consider the techniques that can be used. The literature differentiates between various approaches to forecasting and planning health personnel requirements. Personnel-to-population ratios, needs-based planning and service targets are just a few examples of methods of forecasting and planning health HR, as identified by De Friese and Barker (1982). These health manpower techniques are described below.

Projection from manpower-to-population ratios is a simple, straightforward and easy to understand technique. It attempts to estimate the supply of health manpower (in this case the dental surgeons) in some future year by examining factors such as the current stock of practitioners, projected retirement and death of dental surgeons, as well as projections of the number of dental students in the training institutions. Population estimates are taken for a country or given geographical region. Once the projected number of dental surgeons and population figures are available, manpower to population ratios are calculated for each year from the present to the target year. Manpower to population ratios will suggest either an oversupply or an undersupply of dental surgeons according to an arbitrary ratio which is considered as the benchmark standard. The main criticism of the so-called benchmark standard is whether it could be considered as a universally optimal ratio. In the calculation of this ratio, productivity of all dental surgeons is considered equal, and the demands of all population segments are taken as relatively equal. However, several writers have expressed their concerns about the validity, and hence the applicability, of population to dental surgeon ratios, citing many factors that could affect both the supply dynamics of the service provider

and the demand dynamics of the population. These factors include age, sex, race, occupation, level of education, income, cultural and social values on the demand side, and age, sex, number of auxiliary personnel employed, and number of hours worked on the supply side (Dawson, 2005).

The method is usually employed when no other data are available, and is considered to be rather a crude method, as it does not take into account factors such as productivity or geographical distribution. As stated earlier, dental surgeon to population ratio could be expressed for an entire country, or for a given geographical area, such as a county, district, or city.

Practitioner opinion surveys of practising dental surgeons may take place in a country or identified geographical region (Epelman, 2009). In these surveys, practitioners may be requested to comment briefly on the structure and size of their practices. They may also be asked for their opinion as to whether there is a shortage of dental manpower in the vicinity of their practices. The surveys may also contain questions pertaining to 'how busy you are', and the number of additional patients they can cater for in their clinics. On the basis of these qualitative responses, particular countries or geographical areas can be defined as dental manpower surplus or shortage areas.

Estimates of requisite demand to absorb current capacity is a more complex method than the methods stated above, involving quantitative analysis. This technique requires information on the practice structure, patient volume and estimates of demand for dental care services. Further, it takes into account the supply dynamics of dental manpower.

Econometric practice-productivity study is another approach which involves quantitative analysis. Through the use of regression equations, a large number of variables known to correlate with the output of dental practice are related to the demand and utilization of dental services. Output variables are usually measured in terms of visits, patients, procedures, or clinical time for a given period. This technique is somewhat more complicated conceptually and methodologically than the above methods.

The health needs method focuses on the incidence and prevalence data in the general population. These data are then translated into treatment needs generally according to expert opinion about people's health needs. In this methodology, total personnel hours required to meet the health needs of a projected population in a given target year is calculated. Further, the productive capacities of the dental practices are taken into account. Using these

parameters, manpower requirement is estimated. This method requires well maintained databases and surveillance capacity, combined with planning expertise.

4.3.2 Previous dental workforce studies of importance

The Department of Health and Social Security (1987) addressed workforce planning in dentistry in England. A series of national surveys in the UK, conducted between 1999 and 2002, dealt with the working patterns and career pathways of dental practitioners (Newton, et al. 2000). Furthermore Newton et al (2001) demonstrated the impact of increasing number of females entering the dental profession. The Scottish workforce planning model (Newton et al.2007), identified a potential shortfall in the supply of dentists and highlighted the fact that this may cause difficulties in recruiting and retaining dentists in certain parts of the country.

According to the Australian Dental Association (2001) many factors will affect the required number of dentists including aging and demographic changes in the dentist workforce, dentists' productivity and the availability of allied dental personnel. Moreover the demand for dental services also plays an important role in workforce requirements and the dental profession must develop a balanced workforce.

Lexomboon et al (2000) addressed the issue of supply of dentists in Thailand. Doughan et al (2005) have emphasized the need for planning dental manpower in Lebanon while Maupome (2001) has discussed the basis for deciding how many dentists should be trained in order to meet the dental needs in Canada. Parkash et al (2006) highlighted dental workforce issues in a global context. According to the Australian Dental Association (2011) "*a tidal wave of dentists is also heading to shore and that wave will be followed by another as numbers of graduates from allied oral health programs enter the workforce. The real problem in Australia is not one of workforce shortages, it is about funding and access*".

One of the key studies most frequently referred to in this thesis is the 1999 BDA Heathrow Timings inquiry (Bearne, 2000). This UK-based study provided information on the time required to carry out 21 key dental treatments. This study was conducted by a panel of eminent dentists representing various British Dental Association committees, and covered the entire country. This survey showed that a dentist in the General Dental Service in the UK, worked 43.5 hours per week while he/she had 4.5 weeks holiday a year. Accordingly, 1953 hours of working time was available for a year after allowing for sickness and bank holidays.

Moreover this survey formed a central part of the BDA's 1999 evidence to the Doctors and Dentists Review Body. The concept of "treatment timings", the time measurement methods and the criteria for selection of the investigators; highlighted in the Heathrow Timings inquiry, has been applied with modifications, to design Sri Lanka Timings inquiry, described in this thesis.

The primary care dental workforce review (England) was conducted by the Department of Health in England, and focused on the dental workforce in England. It included dental surgeons, together with professions complementary to dentistry. It offered a review of demand and supply in dental care provision (DOH, 2004). In this review, supply and demand models for dental care were developed and projected to understand future scenarios. Demand was measured in terms of 'clinical time'. The parameters considered in the analysis of demand were trends in demographic and oral health, dental visit patterns, and mix of treatment provided. The supply models were generally based on General Dental Council (GDC) registration data. Age, sex, qualifications, patterns of working hours, career breaks, numbers of new entrants and retirement were the input parameters for the supply model. The supply and demand analysis showed a 9% under-supply of dental capacity in 2001. This under-supply was projected to increase to 16-21% by 2011, and 20-27% by 2021.

The Victoria (Australia) oral health services workforce plan (AIHW, 2008) was a study carried out by the Australian Institute of Health and Welfare Dental Statistics and Research Unit on behalf of the Victorian Department of Human Services. The objective of the study was to project the supply and demand of the dental workforce in Victoria for a ten-year period. The theoretical basis of the projections was based on De Friese and Barker's (1982) model of supply and requirement for dental services. The supply of the oral health workforce was estimated using a Markov chain model, where supply was considered as a dynamic system of stocks and flows. On the demand side, past trends in utilization was extrapolated into different scenarios, based on various demand assumptions. Subsequently, projected supply and demand was matched to reconcile oral health workforce requirements.

The Wisconsin dental workforce study (Beazoglou, 2002) consisted of a market-based approach to analyse economic factors leading to choice of dental practice location as well as service utilization, and was carried out in 2000 by a research organization on behalf of the Wisconsin Dental Association. This review, which assessed the supply and demand for dental services in the state of Wisconsin, USA, considered in its analysis population size, average

income, availability of medical insurance, etc. The final result of the study showed a marked maldistribution of dental surgeons within the state.

The dental requirements model (Institute of Medicine and National Research Council, 2001) was a needs-based model developed to estimate the dental surgery requirement to meet the needs of the children in the state of Illinois, USA. Prevalence of dental caries and restorative needs were obtained from population-based estimates. These estimates were used to develop a spreadsheet tool to analyse the full-time equivalent (FTE) of dental surgeon requirement.

The Dutch dental workforce model (Bronkhorst, 1995) is a sophisticated system dynamics (SD) simulation model, which took four years to develop. It was produced by the Dutch Government to analyse supply and demand in the dental healthcare system in the Netherlands. This is a complex model, containing about 440 state variables, and is one of the most complete and comprehensive scenario-based workforce models for dentistry. The model consisted of five sub-models, each of which was a comprehensive model in its own right. On the demand side, the model included major demographical, pathological, sociological and economical processes. The availability of dental surgeons, dental hygienists and other factors influencing productivity was considered on the supply side (Bronkhorst, 1995). In this study, a wide range of future scenarios were explored and analysed, including different skill mix among dental staff, changes in the oral health-care needs of the population, and disease patterns.

A series of studies were undertaken by the NHS Education for Scotland and the NHS National Services for Scotland to analyse the demand dynamics for dental needs and service provision (NHS Education for Scotland, 2008). These analyses were based on the trends of past historical data, and consisted of a service utilization model and a supply model. The utilization model considered population, treatment needs, patient attendance and dental activity, while the supply model was focused on dental students and the number of available dental surgeons. These two models were used to make projections for future demand and supply scenarios.

Chapter 5: OR Modelling in Healthcare

In this chapter we briefly discuss the application of Operational Research (OR) modelling approaches in healthcare. We focus specifically on system dynamics, as this is the chosen modelling approach adopted in this thesis. The chapter concludes with a justification for the choice of system dynamics as a modelling tool for this research.

5.1 Introduction

Operational Research modelling and simulation are well-known techniques or scientific methods which have been applied in a wide range of fields, ranging from manufacturing to defence (Naseer, 2008). A model is a simplified representation of a real world system or process. Pidd (2010, p15) defined a model as "*an external and explicit representation of part of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality*". Models may be constructed to represent an entire sector, such as the health system, or a sub-sector of it, such as health human resources, or disease specific issues. Models permit us to ask 'what if' questions. These questions could be directed to discover what might happen under various assumptions or scenarios in the future. Models may be deterministic, with pre-determined inputs and outcomes, or stochastic, where an element of probability is involved. Moreover, the use of models as an investigational tool helps to reduce cost, risk and time, while enabling the trying out of different possible scenarios applicable to a given situation (Jun, 2009).

Healthcare delivery is a large, complex, socio-technical system, compounded with increasing complexities and growing uncertainties. Moreover, healthcare needs are ever changing and ever more demanding. Healthcare decision-making is even more complicated, as it involves different stakeholders in different strata with different perspectives. Therefore health planners need to use systemic and systematic approaches to address them. In this context, OR modelling techniques can be used to address many system problems encountered within the healthcare setting (Koelling, 2005).

The history of applying OR in health care dates back to the mid-1950s (Flagle, 2002). Ever

since then, the application of OR techniques in the field of health care – at least in terms of academic publications – has been growing (Lagergren, 1998). There is a vast academic literature in this field, with many thousands of published models (Brailsford et al., 2009). The importance of OR techniques in healthcare applications was highlighted by Taylor (2006), who argued that modelling and simulation in healthcare should be a research priority. Five dominant healthcare settings were identified by Mielczarek (2007), where simulation modelling had been used with great success. These were epidemiology, healthcare system operations, health and care system design, medical decision-making and crisis management.

A wide range of OR techniques, such as statistical analysis, queuing theory, linear programming, integer programming and modelling have been used in the broader field of healthcare. Of these, statistical analysis is the most commonly used, followed by simulation modelling (Brailsford et al., 2009). Philippatos (1973) defines simulation as "*an artificial setting within which to assess the behaviour of the real world system*". Furthermore, according to Shannon (1975), simulation is "*the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behaviour of the system, or of evaluating various strategies for the operation of the system*". Discrete-event simulation (DES) is particularly appropriate in healthcare as it can incorporate the variability and uncertainty inherent in health systems, as well as allowing stakeholder input and engagement via a graphical interface. System dynamics (SD) has many additional benefits, although it has the drawback of being a deterministic approach. The features and relative merits of DES and SD are discussed in section 5.4, where our choice of SD for this research is justified. A few examples of simulation models in healthcare are in waiting time management (Benneyan, 1997), outpatient appointment scheduling (Worthington, 1993), surgical bed management (Millard et al., 2000) and in capacity planning (Ridge et al., 1998).

SD modelling has been used in a wide range of health applications within the last 30 years. At one end of the spectrum is the use of SD modelling for a particular, specific disease, examples of which are screening for disease, developing emergency health and social care, and managing waiting times for treatment. At the other end of the spectrum is the application of SD in more complex and wider ranging issues in health care, such as assessing public health risks, or planning the healthcare workforce (Royston, 1999).

Unfortunately, despite the high flexibility and risk-free setting in which to experiment, the actual implementation of simulation models in healthcare has not been universally widespread (Fone et al., 2003) and the practical impact of OR simulation in healthcare settings has not been as high as expected (Proudlove et al., 2007). The following reasons were cited for the low impact by several authors, such as Harper and Pitt (2004), Brailsford (2005) and Eldabi (2009):

- The complexity and number of different stakeholders at different levels in healthcare settings;
- Lack of involvement of stakeholders in the modelling process;
- Lack of interest, commitment and reluctant to accept importance of OR simulation on the part of healthcare professionals;
- Lack of in-house OR capacity and the cost involved in hiring external consultants;
- Many OR applications and solutions were not configured individually for different customers.

Lowery et al. (1994) and Brailsford (2005) highlighted the barriers of utilizing OR simulation models in practice in healthcare settings. Moreover they have also suggested numerous approaches as how to increase the participation and acceptance of OR simulation among healthcare professionals.

5.2 System dynamics

System dynamics is an analytical modelling approach and a methodology for studying complex feedback systems (Forrester, 1961), the foundations of which were laid in the late 1950s at MIT by Forrester in his pioneering work on industrial dynamics. Essentially, it is an aid to understanding the behaviour of complex systems over time (Lane, 2000). The key features of SD, as stated by Williams (2005) are that it

- *models the problem issue, or evaluation questions;*
- *assumes endogenous causes of the problem;*
- *assumes events are part of patterns, which are generated by structures;*
- *places importance on problem boundary selection;*
- *places more importance on extent in time and space than on detail;*
- *involves hypothesis testing.*

SD describes how the behaviour and relationships of separate components of a system contribute to the behaviour of the system as a whole. In other words, the fundamental principle of SD is that *structure determines behaviour*. Such emergent behaviour can often be counter-intuitive. Therefore it is only by the studying and analysing of the component parts that the reasons for this "unexpected" behaviour can be understood (Brailsford, 2008).

SD has two aspects, one qualitative and one quantitative. The qualitative aspect is a diagramming approach which involves mapping the causal relationships between pairs of elements within a system and then identifying feedback loops which drive certain types of behaviour. These loops can explain unintended consequences and can be either balancing (maintaining the status quo) or reinforcing ("vicious circles") which can cause a system to spiral out of control.

The quantitative aspect involves the development of stock-flow models, which are essentially compartmental differential equation models which are solved numerically by discretization. Specialized computer software is required, and a number of commercial packages are available. The software tools are generally based on mathematical equations such as the Euler algorithm or Runge-Kutta algorithm (Houcque, 2005). The SD approach is useful in allowing relatively rapid modelling to be carried out in a generally intuitive manner, to clarify the complexities of a system. It answers questions that may have been overlooked by those using other modelling approaches. It enables various pieces of incomplete information to be put together so as to allow systematic extrapolations to be made on the basis of current knowledge and belief. Further, as stated by Forrester (1961), SD models are 'learning laboratories'. SD provides a natural learning environment, reflecting the dynamic nature of any system.

5.2.1 Qualitative aspects of SD

The process underpinning qualitative model development in SD is based on expert opinion, understanding, intuition and descriptive accounts of the behaviour of the elements of the system under consideration. In normal, plain language we can easily present the interactions between two or more elements or components in cause/effect chains. However it is difficult to express circular chains of cause and effect in verbal terms alone. Therefore diagrams can be used to express non-linear cause and effect more effectively.

When components or elements within a system indirectly influence it, the portion of the

system involved may be called a feedback loop or a causal loop. A feedback loop could be defined as a closed sequence of causes and effects, i.e. a closed path of action and information (Richardson, 1981). Qualitative SD is concerned with the construction of causal loop or influence diagrams. Causal loop diagrams illustrate graphically the way the system components are related to each other. Construction of causal loop diagrams will enhance stakeholder understanding of the relationships between various components of the structure and how the behaviour of these components affects the system as a whole. It will be possible to apprehend the system in a more comprehensive manner, thereby helping to analyse any problems which may occur due to the structure.

A causal link from one structural component X to another component Y is positive when a change in X leads to a change in Y in the same direction: if X increases, then so does Y, and if X decreases, so does Y. A causal link from X to Y is negative when a change in X leads to a change in Y in the opposite direction: if X increases, then Y decreases, and if X decreases, then Y increases. In causal loop diagrams, the identified components or elements are connected by arrows. As explained above, in causal loop diagrams the + and – signs are used. These signs do not denote the magnitude, but only illustrate the direction of the influence (Richardson, 1995). These links are of particular interest if they can be combined to form feedback loops (for example A affects B, B affects C, C affects D, and D affects A).

A feedback loop is identified as a *positive* feedback loop or *vicious circle* if it contains an even number of negative causal links, while a feedback loop which contains an odd number of negative causal links is called a *negative* feedback loop or *balancing* loop. In a positive feedback loop (also called a *reinforcing* loop) more change leads to the system spiralling out of control. A balancing loop retains the status quo, and, as such, helps to achieve a steady state of the system (Morecroft, 2007).

A causal loop diagram for the number of dental surgeons trained and its consequences is shown in Figure 5.1.

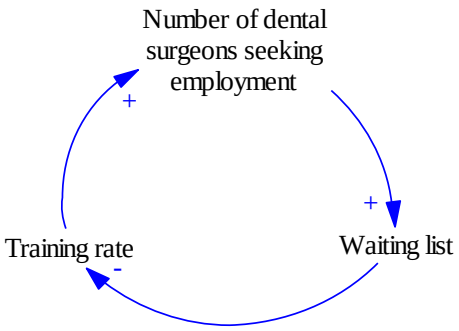


Figure 5.1 Causal loop diagram – Training of dental surgeons

As the number of graduating dental surgeons increases, the waiting list increases, which is shown by a +. However, as the waiting list increases, it puts pressure on the higher education authorities either to reduce the number of dental surgeons being trained, or to at least keep to the present level. This effect is denoted by a –. The training rate has a positive influence on the number of dental surgeons being trained and hence the number of dental surgeons seeking employment. The causal loop diagram above shows an odd number of negative signs, and therefore it is a balancing loop. Illustrations such as this simple causal loop diagram help to gain an insight into the system and clarify how various components within the system behave and interact with each other.

In many instances, the qualitative analysis comprising of causal loop links, is itself of value in order to understand how various components within a system work to give the final outcome of the system. Further qualitative analysis or qualitative modelling will be beneficial to highlight how unintended action/s of a system element or elements will affect the whole system. This is further illustrated by the scenario shown in Figure 5.2.

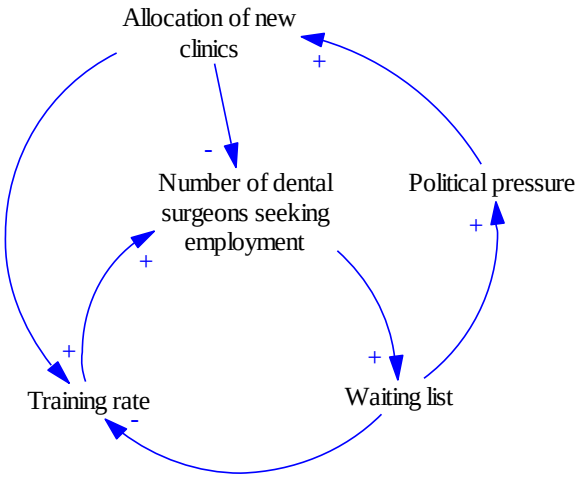


Figure 5.2 Causal loop diagram - training and employment for dental surgeons

As illustrated in the above causal loop diagram, when the waiting list for employment increases, there will be increased political pressure to provide employment. This will, in turn, lead to the allocation of funds to establish new government dental clinics in the country.

One possible solution to the problem would be to increase the number of vacancies, whereby more and more dental surgeons could be employed, thus reducing the waiting lists for employment. However, the allocation of funds for new clinics does not guarantee a proportional increase in the number of vacancies for dental surgeons in the state sector. On the other hand, an unintended effect of allocating funds for new clinics is that it will inevitably lead to a situation where the higher education authorities, together with the general public will ask for more training slots for dental surgeons. This will lead to an increase in the training rate, and more dental surgeons seeking employment, thus increasing the waiting list, followed by the vicious cycle shown in the top half of the causal loop diagram above. What will happen here is that the longer waiting list for employment will generate a greater political pressure. This will result in the establishment of more and more clinics, and hence more employment for dental surgeons. This, in turn, will lead to a further increase in the training rate and number of dental surgeons seeking employment, hence a longer and longer waiting list, etc.

Of course, in practice the vicious cycle illustrated in the top half of Figure 5.2 will be mitigated by the two balancing loops (the original balancing loop shown in Figure 5.1 and the new balancing loop shown in Figure 5.2). However the net effect of these three loops cannot

be fully determined by looking at the diagrams alone. Here we need to consider quantitative analysis, and develop a stock flow model. However, even without quantitative modelling, the insights that the qualitative approach gives by way of casual loop diagram/s, is very useful to understand how the system will be affected by change in its component elements. In fact, even the qualitative analysis alone, without the quantitative modelling, gives us a better picture as to how the system works.

5.2.2 Quantitative aspects of SD

Qualitative SD models are very useful in their own right for gaining insights, but as illustrated above, quantitative models are required when the relative effects of several different feedback loops interact. An initial model is developed using appropriate software, and the best available data (or expert opinion) are then used to quantify the model parameters so that the model can be simulated (Hirsch, 1979). Figure 5.3 depicts such a model, developed in the software Stella used for this research. The two "clouds" in the diagram indicate a source and a sink, which, in our example, denote dental surgeons outside the system. The source is the pool of newly qualified dental graduates, while the sink is the pool of employed, qualified dentists.

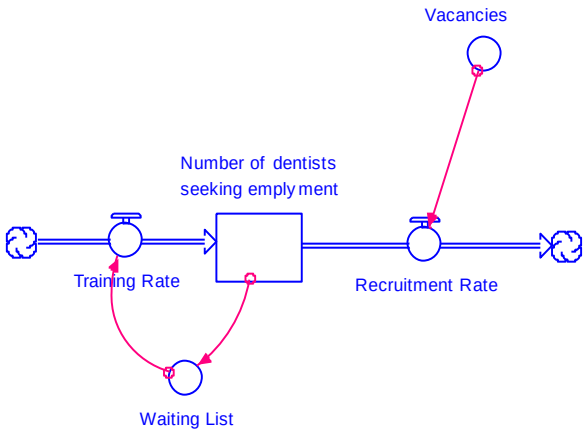


Figure 5.3 Stella diagram - training and employment for dental surgeons

A quantitative SD model can best be understood by analogy with a domestic water system, where water is stored in tanks (stocks) and flows around between them in pipes. The rate of inflow and outflow are controlled by valves (taps) which can be turned up or down (or right off). Water is a continuous, homogenous substance, and likewise an SD model does not represent distinct, individual items. This can cause a conceptual difficulty when the stocks

contain people, such as patients in a healthcare system, and means that SD is generally better suited to very large populations.

A quantitative SD model consists of three groups of variables (Bronkhorst, 1995):

- Input variables – these describe processes outside the boundaries of the model, but have an impact on the internal behaviour of the system (for example, the initial number of dentists awaiting employment);
- State variables – these represent the internal behaviour of the system and are considered as the 'memory' of the system (for example, the relationship between the length of the waiting list and the training rate);
- Output variables – these are processes which are influenced by, and represent, the part of the system that could be observed from outside (for example, the changing number of unemployed dentists over time).

Rectangles in stock flow models could denote the stocks, which may be material, personnel, equipment, orders, or money. In our model, rectangular boxes represent a stock or level (of accumulation) of dental surgeons. Further, the two arrows or pipes leading to and from the rectangle represent training and employment, or recruitment respectively, and the valves represent the rate of flow along these pipes.

Physical flows, as well as information flows, can be considered in stock flow diagrams. In physical flows, accumulations take place over time. Inflows and outflows add and reduce the levels stored in the accumulation respectively. Information flows connect the accumulations to the flow rates. This highlights the dependence of the flow rates on the accumulations.

In the basic stock flow diagram illustrated above, we have depicted the 'waiting list' as an *auxiliary variable* which is influenced by the stock, or amount of dental surgeons seeking employment, and it, in turn, influences the training rate. In the illustration, 'vacancies' for dental surgeons is considered as another auxiliary variable which has an influence or impact on the recruitment rate. Further, the 'training rate' is an inflow, while the 'recruitment rate' is an outflow to and from the accumulation of dental surgeons seeking employment respectively.

5.2.3 SD models in healthcare workforce planning

Workforce planning is a multi-dimensional concept which involves both internal and external

factors to an organization, while taking a strategic holistic approach (Bratton 2003). Similarly it is accepted by healthcare professionals that healthcare provision cannot be understood by looking at factors in isolation (Lane 1999). The role that SD can play in a wide range of healthcare issues, including workforce planning, is emphasized by Taylor (1998). Mutingi (2012) argues that SD is a useful tool in representing the dynamics of capacity building in healthcare manpower supply**.** As stated by Ghaffarzadegan et al. (2010), SD models have been developed to study a wide range of domains in public affairs. Examples are public health, national security, social welfare, sustainable development, education and many other related fields. However, despite its high applicability to public policy problems and wide spectrum of use in health care, SD has rarely been used in dental health workforce policy, although it has been used sparingly in dental health planning (Koelling, 2005). The model presented in this thesis is therefore a significant contribution to this field.

Of course general workforce supply SD models are a standard illustration in many key SD textbooks, for example those by Morecroft (2007), Sterman (2000), Coyle (2000) and Wolstenholme (1990). Typically, such models contain stocks of people at different career stages, with flows between them representing recruitment, career progression, attrition and retirement. Such models can include feedback between stages and can be highly complex. The model presented in this thesis is an example of this class of model. Dangerfield (1999) and Royston et al (1999) highlighted different applications of SD in healthcare including that of planning the health care workforce. Furthermore, Lane (2000) addressed the issues of staffing (among many other aspects) in a hospital Emergency Department by using SD modelling.

Burnett (2010) developed an SD model for the health management of the Townsville garrison. The model addresses issues pertaining to service demand, medical staffing, health dependency, health facilities, costing and budget amounts. Masnick and McDonell (2010) describe clinical workforce skill-mix planning by illustrating a broad endogenous systems model of health and health care. Kwon (2006) presents an application of SD modelling in nursing manpower planning. Further Chung et al. (2010) present a forecasting model for nursing manpower requirement in Korea, using system dynamics.

Smits et al (2010) performed a systematic review of the methods and models in use for medical manpower planning in Netherlands since 2000, and encourage the use of SD modelling for improved accuracy and relevance. Bronkhorst (1995) developed a

comprehensive SD model for dental health care in the Netherlands, explaining the importance of dental workforce dynamics, while Udompanich (1997) discusses the importance of application of SD in dental manpower planning in Thailand. Even more futuristically, Lin and Chen (2012) present a SD model to explore the use of healthcare robots to address the healthcare needs of elderly people.

5.3 Choice of SD as a modelling approach

SD models can contain different groups of dynamically interacting variables, and, as such, SD is well-suited for integrating knowledge and theories from different scientific fields into one model. This pragmatic character of SD is very important in a study such as dental health workforce planning, where knowledge from many different scientific disciplines has to be utilized. Moreover there is an explicit distinction between input variables, and state and output variables. This explicit distinction being an important part of the SD methodology, system dynamics have proven to be particularly successful for those fields where the control of a certain system is the key concern (Bronkhorst, 1995). It is clear, then, that SD provides a useful tool set for the discussion, policy analysis and recommendations involved in our research question, which deals with the problem of dental workforce planning at a national level.

SD models are most commonly associated with conceptual or strategic level decision-making. Strategic level decisions could be defined as the set of decisions and actions that result in the formation and implementation of plans designed to achieve an organization's long-term objectives. As stated by Koelling (2005), the policies that SD typically considers are higher-level, focusing more on the effect of the structure and possible changes to that structure. The conceptual differences between SD and discrete-event simulation (DES) as suggested by Lane (2000) cited in Koelling (2005), are illustrated in Table 5.1.

	DES	SD
Perspective	Analytic, emphasis on detail complexity	Holistic; emphasis on dynamic complexity
Resolution of models	Individual entities, attributes, decision and events	Homogenized entities, continuous policy pressures and emergent behaviour
Data sources	Primarily numerical with some judgemental elements	Broadly drawn
Problems studied	Operational	Strategic
Model elements	Physical, tangible and some informational	Physical, tangible, judgemental and information links
Human agents represented in model as	Decision-makers	Rational policy implementers
Clients find the model	Opaque/dark grey box, nevertheless convincing	Transparent/fuzzy glass box, nevertheless compelling
Model outputs	Point predictions and detailed performance measures across a range of parameters, decision rules and scenarios	Understanding of structural source of behaviour modes, location of key performance indicators and effective policy levers

Source:Lane (2000), cited in Koelling (2005).

Table 5.1. Conceptual differences between DES and SD

Considering our research aim of dental workforce planning in Sri Lanka, it is obvious from the above conceptual differences that SD is a more suitable technique to apply in our research than DES. In scenarios where key variables cannot often be quantified and there will be no single optimal solution, system dynamics is a valuable tool (Royston, 2009**).**This further highlights the applicability of SD as an OR tool to address dental workforce planning issues in Sri Lanka.

There are a number of further reasons why SD is particularly well suited to address healthcare problems or healthcare planning. According to Brailsford (2001), and also according to expert opinion, SD is a suitable methodology to address dental workforce planning issues pertaining to Sri Lanka, for the following reasons. To begin with, the data

requirements of SD are less than for many other OR techniques. In the Sri Lankan context we do not have properly maintained databases pertaining to the health workforce. Data requirements of SD are very much less, since SD models are usually higher level and more aggregated. Further the ability of SD models to be run on estimated data or expert opinion is of considerable help in the Sri Lankan scenario.

Sri Lanka is no different from anywhere else in that there are multiple stakeholders, often with conflicting objectives and different levels of ownership and power among those responsible for dental workforce planning. The qualitative aspects of SD are very useful when trying to understand such political issues. SD is generally applied at a strategic level, for policy level decisions. In the Sri Lankan context, dental workforce planning is done at a national level, and hence the strategic approach of SD is of importance to the Sri Lankan health policy-makers. SD is capable of modelling very large and complex systems. The healthcare system in Sri Lanka is relatively large and very complex, involving both government and private service providers, and including dual service providers (working both in the government and private sectors). Further, the interactions and relationship between the trainer and the main employer for dental surgeons are minimal, or tend to be complicated. Finally, SD is able to deliver both qualitative and quantitative output measures. This makes understanding SD models by the 'doctor community' much easier, and hence increases its acceptability. Parameter estimation and validation are less of an issue, which makes it relatively easy to develop and apprehend SD models.

As a field of policy, dental health care is very complex. To begin with, 'oral health' is a major variable. There is no standard level of oral health applicable to all situations or scenarios. It is embedded in an extensive system of factors: factors which oral health is dependent on, and factors which are partly determined by oral health. Therefore dental workforce policy becomes an even more complex issue, and, considering that it is directly related both to oral health and the training of the dental workforce, in particular dental surgeons, the key players in dental care provision, it takes a considerable period of time and resources. Further, closing a dental school leads to a large amount of capital destruction, as well as social problems of a different magnitude.

Policy decisions, whether to deal with a treatment option, transportation, workforce planning, or whatever the case scenario may be, lead to action. Such action can change the system states. This in turn may require a change in policy decision. Therefore policy decisions may

be involved in circular cause-effect relationships, which are captured in SD.

In this chapter, we have briefly discussed the application of OR modelling in healthcare, and given our rationale for the choice of SD as a modelling approach for this research. The model itself is presented in Chapter 8. The following two chapters describe the process of data collection to "feed" the model, and present the findings from the empirical study, which was a significant undertaking in its own right.

Chapter 6: Data Collection

A vast amount of information was required in order to provide the input data for the system dynamics model described in Chapter 8. However, the data collection process was itself very challenging and formed a substantial standalone component of the research in this thesis. These data have never been collected before in Sri Lanka. In this chapter, we describe the empirical data collection process. The results, which are of considerable interest in their own right, are presented in Chapter 7.

6.1 Supply side

In this section we describe the methodology for collecting data on the current (2008) dental workforce in Sri Lanka, which forms the baseline for the provider side of the system dynamics model.

6.1.1 National-level data collection

Descriptive cross-sectional studies were carried out to determine the basic socio-demographic and employment characteristics of the current dental workforce, and the socio-demographic characteristics of the current dental students, who would form the future workforce. These studies involved a questionnaire survey of the entire population of dental surgeons and dental students in Sri Lanka. Further historical information on the dental workforce (dental surgeons) who had been trained in the past, extending over half a century, was collected by studying existing records held at the Faculty of Dental Sciences, University of Peradeniya, and the Sri Lanka Medical Council.

It was necessary to make an inventory of all the dental surgeons in Sri Lanka, since the study concerns both government-employed dental surgeons and private practitioners. Lists of dental surgeons employed by the Department of Health were obtained and updated, with the help of the health authorities based at the departmental head office in Colombo. Details of dental surgeons attached to various government hospitals, available at the Department of Health and provincial health departments, were also scrutinized. Details of dental surgeons employed in the universities and Defence forces were obtained from the respective heads of these institutions.

However, no organization or professional body had a comprehensive list of private dental practitioners in the country (either full-time or part-time practitioners). Therefore, preparation of a list of dental surgeons working in the private sector in Sri Lanka was very challenging. The register of dental surgeons maintained by the Sri Lanka Medical Council gives the names of all registered dental surgeons in Sri Lanka. This register identifies individuals with residential addresses, but gives no indication of where, or, indeed, whether that individual is currently undertaking dental practice in Sri Lanka. Therefore, in addition to the Sri Lanka Medical Council Dental Registry, membership details of the Sri Lanka Dental Association, College of General Dental Practitioners of Sri Lanka and the Government Dental Surgeons' Association were obtained to provide the names and addresses of all dental surgeons in the country.

Data pertaining to the batches of newly graduated dental surgeons awaiting government employment were obtained from the Dean, Faculty of Dental Sciences, University of Peradeniya and the Deputy Director General of Dental Services, Ministry of Health. According to a previous study (De Silva, 1999), most of the dental surgeons belonging to this category were employed in the private sector until they received government employment.

By adopting the above methods, a comprehensive and updated list of dental surgeons actively engaged in dental practice was prepared. However, there was an overlap in the names of dental surgeons obtained from the above sources. There were also dental surgeons who, although their names appeared in the dental surgeons' registry and other membership records, were not engaged in active dental practice. Further, some dental surgeons, although in active dental practice and registered with the Sri Lanka Medical Council, did not belong to any of the above associations or to the Ministry of Health. Therefore these two lists of government and private sector practitioners had to be checked and verified for omissions and duplication of names. The location or addresses of the private dental clinics/offices also had to be identified. This was a lengthy and time-consuming process. Focus group discussions were used to enhance the accuracy of the list of active dental surgeons, and to finalize the list of private practitioner addresses.

6.1.2 Focus group discussions at district level

Focus group discussions were conducted at district level in order to 'map' or identify the locations or addresses of private dental clinics/offices. Five senior dental surgeons from each district (with the exception of the Northern and Eastern provinces, due to the civil war that

prevailed at the time of the research) were identified and invited to these focus group discussions which were held in the respective district capitals, and coordinated and chaired by the author of this thesis. As the Northern and Eastern provinces were inaccessible for outsiders, two senior dental surgeons from each province were invited for a meeting in the capital city of Colombo to identify locations of private dental clinics. This meeting was also chaired by the author of the thesis.

The invited dental surgeons from each district played the role of key informants. They were informed about the study and the task of mapping the private dental clinics in their respective districts. As stated above, they were invited to attend a meeting in the district capital, and were asked to come prepared with the names and the addresses of all practising dental surgeons in their respective district, as well as details of any unqualified dental practitioners working in their area. Accordingly the key informants collected information on all dental surgeons in their respective districts using a snowball sampling technique.

The focus groups were conducted as follows. After a brief introduction, the purpose and the scope of the discussion were explained by the researcher, who also thanked the participants for attending the meeting. The participants were then invited to give a short self-introduction, which should include their place of work and residence. The following discussion was structured around two key issues, namely the location of private dental practices and practices of unqualified dental practitioners within the relevant district. All participants were asked to identify the full-time and part-time dental practices in their locality. They were encouraged to speak and were given the opportunity to actively take part in the discussion. A variety of moderating tactics were used to facilitate the group, such as stimulating the participants to talk to each other and politely intervening if the discussion drifted away from the issues under consideration. It was important to strike a balance between keeping the conversation moving and allowing participants adequate time to share their thoughts. The discussion was limited to a maximum of one and a half hours. Notes of the discussion were written by the researcher, who finished by thanking all the participants for actively taking part in the discussion, acknowledging that their contribution was of immense value to the researcher.

This exercise enabled the researcher to obtain or confirm the addresses of dental surgeons and to locate or map the private practices/offices within the district. Thereby it was possible to verify the dental workforce situation at district level, and a complete and up-to-date list of dental surgeons practising in the government sector, the private sector, or in both sectors in Sri Lanka, as at September 2008, was finalized. The above process of identifying the

location of private dental clinics was termed the ‘mapping exercise’. All the active dental surgeons thus identified were then sent a postal questionnaire.

6.1.3 Postal questionnaire

Even before commencing this research, the author was already aware that Sri Lanka, unlike the UK or other developed countries, did not maintain any formal record of its dental health workforce. Therefore one of the original and practical aims of this research was to create a comprehensive database of dental surgeons in Sri Lanka. Subsequently it was decided to develop a System Dynamics model to depict the entire system of dental service provision, covering both supply and demand, in Sri Lanka. Clearly, such a model would require baseline data about the current workforce. In practice, the development of the model and the creation of the database were conducted in parallel. However, the SD model development preceded completion of the finalized questionnaire, and therefore it was possible to modify the questionnaire and add extra questions to ensure that it would yield all the necessary information required as inputs by the SD model. Essentially, the questionnaire had a twofold function: its primary purpose was to compile a dental workforce database for Sri Lanka, which would be a useful resource in its own right, but in addition it also provided the baseline input data for the SD model.

The choice of a postal questionnaire to collect data from all practising (active) dental surgeons was based mainly on the fact that the principal investigator wished to collect data from the entire population of all active dental surgeons in the country, rather than take a representative sample. The decision to take the entire dental surgeon population into the survey was to increase the validity and acceptability of the study, as well as being practical, considering the total estimated number of dental surgeons in the country. Clearly such an approach would not be feasible in the UK. The facts that dental surgeons are scattered throughout the country, that Sri Lanka has a well-organized postal service, and the low cost involved, weighed in favour of the decision to use a postal questionnaire, as opposed to other data collection tools. The questionnaire was prepared in the English language, as it is the medium of instruction for dental surgeons in Sri Lanka.

The questionnaire was designed to collect information on personal demographic data, current working patterns, including district of employment, provision of private dental care and professional development. In order to make the questionnaire attractive, the following general guidelines were used:

- Generous use of white space;
- Headings and instructions were made clear;
- Code boxes were included;
- All questions were numbered;
- The questionnaire started with straightforward questions and included more complicated, specific or sensitive questions later;
- Questions were arranged in a logical manner;

Furthermore, the following recommendations, suggested in a meta-analysis by Edwards et al. (2002) were adhered to, in order to increase the response rate:

- Keep the questionnaire short;
- Use personalized letters introducing the research and the questionnaire thereof;
- Use stamped return envelopes;
- Contact participants before sending out questionnaires.

The questionnaire was tested for clarity and interpretation of the questions in a pilot survey, and modifications were made where appropriate. The final version of the questionnaire instrument can be found in Appendix A1.

Before the commencement of the study, publicity was given through the Sri Lanka Dental Association (SLDA) monthly newsletter. The secretary of the SLDA wrote to the membership endorsing the study and requested the fullest cooperation. All dental surgeons in Sri Lanka who were actively engaged in the provision of dental care were sent the postal questionnaire, accompanied by a personally signed covering letter from the researcher which explained the purpose of the research. The covering letter also contained an endorsement by the Sri Lanka Dental Association and the Ministry of Health, and assured confidentiality. A stamped addressed envelope was also enclosed along with the postal questionnaire. Three weeks after posting, all dental surgeons were sent a reminder asking them to respond, if they had not yet responded, while thanking those who had already responded and asking them to ignore the reminder. The reminder enclosed the same questionnaire and another stamped addressed envelope.

For the purposes of this study, a ‘part-time clinic’ was defined as a dental clinic which is open either for morning or evening sessions only, for five hours or less per day. A ‘full-time

clinic' was defined as a dental clinic which is open for two sessions (morning and evening) or for more than five hours per day.

6.1.4 Dental students survey

In order to access the future supply of dental surgeons, it was essential to study the dental student population of the country. As stated earlier, Sri Lanka has only one dental school, with an average annual intake of approximately 75-80 students for the four-year Bachelor of Dental Surgery (BDS) degree programme. Around five Sri Lankan students annually go abroad to study dentistry (SLMC, 2010). However it is difficult to trace in which countries or universities these students are studying at present. Therefore the future supply of foreign-qualified Sri Lankan dental graduates, which is quantitatively small, was not considered in the present investigation. For this part of the study, only dental students studying in Sri Lanka as at 1 September 2008 were considered.

Similarly to the survey of practising dentists, a self-administered questionnaire was used to obtain information from dental students. This was fairly straightforward since all Sri Lanka's dental students are located in a single institution. Therefore, the entire dental student population of the country, totalling approximately 350, could easily be contacted about the questionnaire. As there were five batches of students in the Dental School at the time of the survey, it was decided to take them in their year batches to explain about the research study. A self-administered questionnaire was prepared in the English language, as it is the medium of instruction in the Dental School. The questions covered personal demographic information, and career and working intentions. The same general guidelines described in the section above were followed for the questionnaire design, and it was pre-tested for clarity and interpretation of the questions.

Permission to conduct this survey was obtained from the Dean of the Faculty of Dental Sciences, University of Peradeniya. The principal investigator took one batch of students at a time belonging to a particular year to administer the questionnaire, which was done in a lecture hall at the Faculty of Dental Sciences. The principal investigator gave an introduction about the research and explained all the questions in the questionnaire. Students were requested to answer honestly as the questionnaire was anonymous, and were given 20 minutes to complete it. The survey instrument can be found in Appendix A2.

6.1.5 The Sri Lanka timings inquiry

A survey entitled 'Sri Lanka Timings Inquiry' was conducted, in order to obtain the time taken for various dental treatment modalities. The purpose was to identify how much time is needed for various treatment modalities under a hospital set-up in government dental clinics and in private clinics. This study was done with the direct participation of the Ministry of Health and private practitioners. It was conducted in a somewhat similar manner, although in a shorter form, to the 'Heathrow Timings Inquiry' conducted by the British Dental Association in 1999 (Bearne, 2000).

The main treatments offered to patients in the government hospital dental clinics and private dental clinics were identified by the author through his 15 years of experience as a dental surgeon, supplemented by expert opinion and reports from annual health bulletins (MOH, 2010).Through this process, it was established that treatment provided in dental clinics in Sri Lanka was limited, and belonged to three main categories of dental extractions, dental restoration and periodontal treatment. An information collection sheet was developed with the help of expert opinion to capture the time taken for these three main treatment modalities and their subdivisions.

The study was conducted in 30 government hospital dental clinics and 20 private dental clinics, covering the entire country. Dental surgeons working in different strata of government hospitals, representing district, base, general and teaching hospitals, as well as dental surgeons working in rural, semi-urban and urban private dental clinics, were chosen to conduct the Timings Study. The dental surgeons were chosen to reflect the profession in terms of gender, service seniority and geographical locations. They were given clear written instructions in order to minimize inter-examiner variability. This was further augmented by verbal advice over the telephone. Timings for the three main treatment modalities identified above, with further subdivisions, were recorded by the chosen dental surgeons. Each participant recorded a minimum of five readings for a single treatment option during the survey period of four weeks. This study facilitated the calculation of average time taken for the main treatment modalities in government hospital dental clinics and private dental clinics. The final result of this study component was used to determine the total treatment hours required to meet the treatment needs of the country. Subsequently, the number of total treatment hours thus calculated was used as input data for the system dynamics model described in Chapter 8. The data collection instrument can be found as Appendix A3.

6.2 Demand side

In this section we describe the methodology used to calculate the population need for dental care, and then to convert this into the demand for services, in Sri Lanka. As discussed in Chapter 2, there is a considerable difference between need, demand and service utilization. This translates into a complicated relationship between the clinical need for basic dental care, and the potential demand for future services. The WHO/FDI model described in section 6.2.2 is an attempt to map between need and demand as countries become increasingly developed. Clearly, in economically prosperous countries there is demand for, and a commercial market in, more complex and expensive treatments such as cosmetic dentistry, bridgework and orthodontics, whereas in poorer countries the issue is how to meet the basic need for simple fillings, prostheses and extractions. However, historical data just shows the recorded levels of service utilization, which clearly depends hugely on availability and access, and therefore represents neither the true need nor the hypothetical demand.

6.2.1 Secondary data from national oral health surveys

Calculating the need/demand for dental services in any country is a difficult task (Maupome, 2001), and Sri Lanka is no exception. The Annual Health Bulletin of the Ministry of Health is the only publication available indicating dental service utilization in Sri Lanka. It provides statistics pertaining to the dental services provided by most of the government dental clinics. However there is no source of data from private sector dentistry. The Annual Health Bulletin, however, is outdated, incomplete, and lacking in accuracy and clarity (De Silva, 1999). This is evidenced by the fact that the only three dental hospitals in the country, and around 40 specialist units had not sent any data to the centralized medical statistics unit of the Ministry of Health, which publishes the Annual Health Bulletin, and the publication is three years behind schedule. Therefore in this research we had to adopt another strategy to identify both the need and demand for dental services in Sri Lanka.

The Ministry of Health, in collaboration with the World Health Organization (WHO), conducts nationwide National Oral Health Surveys every ten years. These surveys are conducted according to WHO guidelines and are comprehensive and accurate. The first took place in 1984, while the latest was in 2003. The surveys were performed among 10,000 randomly selected members of the population, covering the entire country. They were supervised by dental surgeons who held Masters Degrees in Public Dental Health. All the

examiners were specially trained for the purpose, and calibrated in order to minimize intra and inter-examiner variability. There have been three National Oral Health Surveys in the country so far. The author was one of two principal organizers, as well as an examiner, in the 2003 survey.

A National Oral Health survey, conducted on a regular basis, is very important for a country to monitor the progress of oral disease levels, as well as the overall effectiveness of the dental service delivery system. It also provides a sound basis for the estimation of the present status and future needs for oral health care of a population. In the 2003 National Oral Health Survey, a multi-stage stratified random sampling technique was used to select the study sample, covering the entire country. A representative sample of 2,000 subjects from each age group of 5, 12, 15, 35-44 and 65-74 years, were surveyed, making a total sample size of 10,000. As stated earlier, the survey was carried out according to the methodology and methods recommended by the WHO. The survey subjects were exposed to both systematic clinical examination and a questionnaire (MOH, 2003).

The survey findings, among many other results, indicated the need in Sri Lanka for various dental treatments, such as periodontal treatment, restorative treatment, prosthetic treatment and dental extractions. It is clear that the surveys indicated only the *treatment needs* of the country, and not the demand. Therefore, in order to determine the demand for dental treatment in the country, using the results of the National Oral Health Survey, we require a mechanism to convert need into demand.

The four broad categories of treatment needs identified above (periodontal treatment, restorative treatment, prosthetic treatment and need for dental extractions) were converted to demand, by using a methodology proposed by the World Health Organization(WHO) and Federation Dentaire Internationale (FDI), which is fully described in section 6.2.2 below, combined with the Sri Lanka Timings Inquiry (see section 6.1.5) and the population characteristics.

6.2.2 Demand for dental health care in Sri Lanka – the WHO/FDI methodology

The WHO/FDI model for demand identification (WHO/FDI, 1989) is an internationally recognised approach for calculating the demand for dental healthcare in different settings. It takes into account substantial differences in economic development, in addition to the differing disease experience and progression at different ages, as well as attitudes to oral

health care in different countries, by utilizing suitable age cohorts. The age cohorts normally used in the WHO/FDI model were 0-14 years, 15-29 years, 30-64 years and 65-79 years (WHO/FDI, 1989, p. 23). However, the WHO/FDI approach states that different cohorts can be used where appropriate: "*The WHO proposed methodology could be applied using different, more or fewer cohorts as desired.*" (WHO/FDI, 1989, p. 23).

Firstly, the WHO/FDI model estimates the services needed per person, expressed in minutes, for all relevant aspects of oral healthcare over the whole period of each cohort. These are then divided by the number of years in each cohort to calculate minutes per person per year. The selection of age cohorts and the time allocated for various activities or treatment modalities in the original WHO/FDI model are based on the results of many international studies and expert opinion. For each age cohort, the model uses the following treatment categories (WHO/FDI, 1989, p.26):

a. Preventive care
b. Special Group care
c. Surgical care
d. Orthodontic care
e. Periodontal care
f. Restorative care
g. Prosthetic care.

The National Oral Health Surveys conducted in Sri Lanka assess dental health needs at 6 years of age, then at 12, 15, 35-44 and 65-74 years of age. These age groupings were utilized for calculation purposes. Furthermore, the time allocation for various treatment modalities was obtained from the results of the Sri Lanka Timings Inquiry. This approach, too, was recognized in the WHO/FDI methodology: "*It is recommended that those using this method, allot time for various services relevant to the practice conditions which prevail for their populations*" (WHO/FDI, 1989, p. 43).

The WHO/FDI methodology recommends the use of different percentage values to convert Need to Demand, in different age cohorts. Essentially, these values represent the fraction of people who have a dental care need who actively seek treatment for it. In an economically prosperous country such as the UK or US, a high proportion of people with a dental healthcare need will expect to be treated. However, in a developing country, a much lower proportion of people will seek treatment for anything other than acute pain. In the original

WHO/FDI model, these percentage values were selected following a series of consultations with relevant experts from different parts of the world, and using results of previous research work. In deciding these percentage values, many factors, including the health system, the health status, level of education and the level of development of the country, were considered. Accordingly, the following percentage values were recommended for developing countries with a moderate to high awareness of the need for dental health (WHO/FDI 1989):

Age cohort	Conversion factor (Need to Demand)
0-14 years	65-100%
15-29 years	65-85%
30-64 years	30-65%
65+ years	10-30%

Table 6.1. Need-demand conversion factors in the WHO/FDI model

According to expert opinion, taking into account the literacy rate, availability of a well-established network of health-care facilities, socio-economic status and the level of development in Sri Lanka, it was decided to consider the dental awareness among the Sri Lankan population as moderate to high. This decision was further justified by a similar finding in the National Oral Health Survey 2003 (MOH, 2003).Therefore we were able to apply the percentage values above to convert need to demand for the Sri Lankan population.

However, in order to further enhance the validity of this research, it was decided, with expert opinion, to consider the conversion of need to demand at three levels within the stated range, as shown below. The demand arising from the three levels of need to demand conversion was termed as Minimum, Intermediate and Maximum demand. This was the percentage of people with need, anticipated to become demand, dental care.

Age	Minimum Demand (%)	Intermediate Demand (%)	Maximum Demand (%)
0-14 Years	65	82.5	100
15-29 Years	65	75	85
30-64 Years	30	47.5	65
65+ Years	10	20	30

Table 6.2. The three demand scenarios tested in the system dynamics model

The results from the system dynamics model experiments using the three scenarios shown in Table 6.2 are presented in Chapter 8.

Chapter 7: Results of the Empirical Studies

7.1 Results of the postal questionnaire and the mapping exercise

The response rate for the postal questionnaire, which as described in section 6.1.1 was sent to all practising dental surgeons in the country, was 72% (after two reminders). This was a remarkable achievement. The reasons for such a high response rate could be attributed to the design of the questionnaire, the personalized letter which accompanied it, the integrity, recognition and popularity of the principal investigator among the targeted audience, and more critically, the importance of the broader research domain of the study to dental surgeons in Sri Lanka.

Nevertheless, there were still 28% non-respondents. However (non-respondent bias) has been mitigated to a greater extent, as this study was performed on the whole population without taking a sample. Moreover after receiving all the responses to the questionnaire, the researcher contacted a randomly selected sample of 50 dental surgeons. It was found that 44 of this sample had received the questionnaire and already responded, while 5 dental surgeons have not received the questionnaire or the reminder (which also contained the questionnaire). One has not responded due to personal reasons though he had received both the questionnaire and the reminder. Therefore the primary reason for non-response is more likely to be due to the inefficiency of the postal service rather than to any systematic, socioeconomic or professional differences between respondents and non-respondents.

The results presented in this chapter are all analysed with respect to the population density of the district or the province where appropriate. This is in order to indicate the demand for dental care, as population can be considered as a proxy for demand for a given geographical area. Therefore all the Tables and Figures (maps) in this chapter display the Dentist to Population Ratios (DPR) in different domains. In addition a map of Sri Lanka, showing population density by district, can be found in Appendix A11.

7.1.1 Government sector dental care provision

State sector (public) employed dental surgeons belonged to three broad categories, namely those employed by the Ministry/Department of Health, those employed by the university and those attached to the Defence establishment. The largest of these three categories of employers was the Ministry of Health (also called Department of Health), which is analogous to the National Health Service (NHS) in England and Wales. The Faculty of Dental Sciences, University of Peradeniya, employed almost all the dental surgeons who worked for the university system. The Defence establishment consists of the Army, Navy, Air Force and Police departments, of which the Sri Lankan Army was the key employment provider for dental surgeons. The data, by province, including the DPRs, are shown in Table 7.1.

Province	Ministry of Health	University	Defence Forces	Total	Population (000)	DPR*
Western	351	1	38	390	5,636	14,451
Central	181	57	2	240	2,556	10,650
North Central	62		3	65	1,167	17,954
North Western	96			96	2,259	23,531
Southern	97	1	2	100	2,394	23,940
Uva	78			78	1,247	15,987
Sabaragamuwa	86			86	1,877	21,826
North	39		5	44	1,145	26,023
East	48		4	52	1,571	30,212
Total	**1038**	**59**	**54**	**1151**	**19,853**	

DPR = dentist to population ratio

Table 7.1 Provincial distribution of state sector-employed dental surgeons in 2008

However the number of state sector employed dentists, mainly the Ministry of Health dentists, who cater for the general population, should be considered along with the population of the province or district. Therefore it could be noted (in Table 7.1) that the most and the second most populated provinces mainly the Western and Central provinces have the highest and second highest number of Ministry of Health dentists respectively.

Figure 7.1 presents the population densities and the number of Ministry of Health dentists, mapped geographically by district. The dentist to population ratio varies from 1: 9,296 in the Colombo district to 1: 147,000 in the Mullaitivu district.

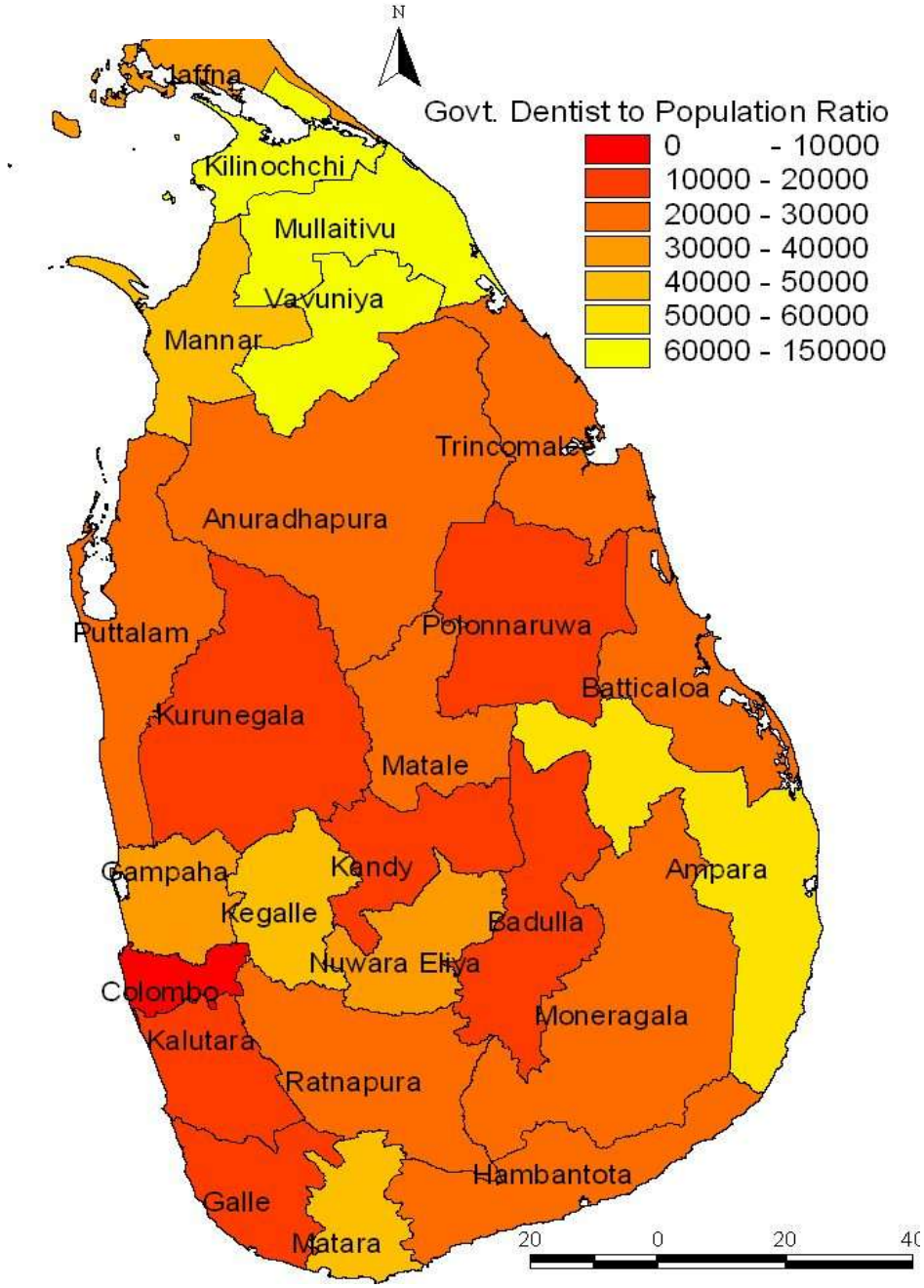


Figure 7.1 Map of Sri Lanka showing the Government (Department of Health) employed dentist to population ratios in each district

Obtaining employment in the Department of Health has been the pattern and accepted norm for the vast majority of newly graduating dental surgeons since the early 1950s. Furthermore, the Government has been enhancing free healthcare provision for the entire population by establishing hospitals throughout the country, enabling more and more dental surgeons to be

employed by the Ministry of Health. As a result, the Department of Health accounts for more than 90% of the state (public) sector-employed dental surgeons in the country. However, as shown in Table 7.1 above, there is a severe geographical mal-distribution of dental surgeons employed by the state sector. In 2008, nearly one third of all dental surgeons employed by the Department of Health were concentrated in the Western province of the country. The Central Province had the second highest concentration, which accounted for nearly one fifth of Department of Health dental surgeons.

As the Faculty of Dental Sciences, University of Peradeniya is situated in Kandy (the second largest city of the country) within the Central province, almost all dental surgeons employed by the university system were concentrated in the Central Province. Nearly 70% of the Defence establishment-employed dental surgeons were located in the Western province.

7.1.2 Private dental care provision by state sector-employed dental surgeons

Table 7.2 shows the percentage of Government-employed dental surgeons also engaged in part-time private practice from the different state sector organizations. Dental surgeons from all three categories of state employment were engaged in part-time private care provision. More than half of the public sector-employed dental surgeons worked as part-time private sector service providers. As mentioned in Chapter 6, for the purposes of this research a 'part-time' clinic was defined as a clinic which was open either in the morning or in the evening for five hours or less per day. A 'full-time' clinic was defined as a clinic which was opened for two sessions (morning and evening),or more than five hours per day.

State Organization	Percentage of employees engaged in part-time private service provision
Ministry of Health	54
Defence Forces	43
University	42

Table 7.2. Participation in part-time private dental care provision by state sector

In all provinces apart from the Western province, part-time private dental clinics outnumbered full-time private dental clinics. Furthermore, overall there were more part-time private dental clinics in the country than full-time private dental clinics, with a ratio of 1.7:1. The Western province accounted for 64% and 28% of private full-time and part-time dental

practices respectively, as shown in Tables 7.3 and 7.4. These data are depicted geographically by district, as in Figure 7.1, in Appendices A8 and A9.

Province	Full-time clinics	Part-time clinics	Total	Population (000)	PCPR*
Western	210	157	367	5,636	15,357
Central	25	91	116	2,556	22,034
North Central	8	36	44	1,167	26,523
North Western	23	71	94	2,259	24,032
Southern	38	61	99	2,394	24,182
Uva	5	23	28	1,247	44,536
Sabaragamuwa	13	51	64	1,877	29,328
North	3	19	22	1,145	52,045
East	4	38	42	1,571	37,405
Total	**329**	**547**	**876**	**19,853**	

*PCPR = private clinics/offices to population ratios

Table 7.3 The provincial distribution and private clinics/offices to population ratios, by province

Table 7.4 illustrates the distribution of private dental clinics according to district. The Colombo district, which is situated in the Western province of the country, accounted for nearly a quarter of all private dental clinics in Sri Lanka. The district of Colombo had the highest percentage of both full-time and part-time private dental practices. Although the Colombo district accounted for nearly 46% of the full-time private clinics, no district accounted for more than 15% of the part-time private practices. In all districts apart from Colombo, between 30-35% of private dental clinics were located within a 2-3 km radius from the main town centre of the district. However in the district of Colombo, private dental clinics were more widely distributed.

District Code No	Province	District	Full-Time Clinics	Part-Time Clinics	Total
1	Western	Colombo	151 (45.8%)	79 (14.4%)	230 (26%)
2	Western	Gampaha	36 (10.9%)	50 (9.1%)	86 (9.8%)
3	Western	Kaluthara	23 (6.9%)	28 (5.1%)	51 (5.8%)
4	Central	Kandy	18 (5.4%)	65 (11.8%)	83 (9.4%)
5	Central	Nuwara Eliya	4 (1.2%)	10 (1.8%)	14 (1.5%)
6	Central	Matale	3 (0.9%)	16 (2.9%)	19 (2.1%)
7	North Central	Anuradhapura	3 (0.9%)	27 (4.9%)	30 (3.4%)
8	North Central	Polonnaruwa	5 (1.5%)	9 (1.6%)	14 (1.5%)
9	North Western	Kurunegala	19 (5.7%)	44 (8.0%)	63 (7.1%)
10	North Western	Puttalum	4 (1.2%)	27 (4.9%)	31 (3.5%)
11	Southern	Galle	15 (4.5%)	26 (5.3%)	41 (4.6%)
12	Southern	Matara	19 (5.7%)	22 (4.0%)	41 (4.6%)
13	Southern	Hambantota	4 (1.2%)	13 (2.3%)	17 (1.9%)
14	Uva	Badulla	4 (1.2%)	13 (2.3%)	17 (1.9%)
15	Uva	Monaragala	1 (0.3%)	10 (1.8%)	11 (1.2%)
16	Sabaragamuwa	Ratnapura	7 (2.1%)	30 (5.4%)	37 (4.2%)
17	Sabaragamuwa	Kegalle	6 (1.8%)	21 (3.8%)	27 (3.0%)
18	Northern	Jaffna	2 (0.6%)	8 (1.4%)	10 (1.1%)
19	Northern	Kilinochchi	0 (0.0%)	2 (0.3%)	2 (0.2%)
20	Northern	Vauniya	1 (0.3%)	6 (1.0%)	7 (0.7%)
21	Northern	Mannar	0 (0.0%)	2 (0.3%)	2 (0.2%)
22	Northern	Mullatiuv	0 (0.0%)	1 (0.1%)	1 (0.1%)
23	Eastern	Tricomalee	1 (0.3%)	10 (1.8%)	11 (1.2%
24	Eastern	Ampara	1 (0.3%)	13 (2.3%)	14 (1.5%)
25	Eastern	Batticaloa	2 (0.6%)	15 (2.7%)	17 (1.9%)
		Total	**329 (100%)**	**547 (100%)**	**876 (100%)**

Table 7.4. The district distribution of private dental clinics/offices

As shown by this study, Sri Lanka had a national average of 4.5 private dental clinics per 100,000 population in 2009. The district of Colombo had around ten private dental clinics per 100,000 population, which was by far the highest in the country. Second was the Kandy district, with 6.1 clinics per 100,000 population, followed by the Matara district with 5.1. In thirteen districts, out of the 25 in the country, there were between three and five private dental clinics per 100,000 population. In the remaining nine districts, there were less than three clinics per 100,000 population. However out of these nine districts, six were in the war area of the Northern and Eastern Provinces.

When the dental surgeon or dental practice to population ratio is considered from a practical perspective, what it tells us is the number of practices there are in a given geographical area, or, in other words, the amount of competition. The number of private dental clinics/offices, and hence the active number of dental surgeons employed in the private sector and their district wise distribution, is one of the key issues discussed in this thesis. These important parameters are illustrated in Figures 7.2 to 7.4 and in the Sri Lanka maps in Appendices A8 and A9.

Figure 7.2 illustrates the distribution of private part-time and full-time dental clinics according to district. As graphically shown here, the number of part-time clinics was more than the number of full-time clinics in all districts except the Colombo district (#1). As seen from the above results, Colombo, the capital district of Sri Lanka, was a complete outlier as far as dental care provision was concerned. Therefore in the remaining analysis, the district of Colombo is considered separately, while all other districts are considered together. The District code number refers to the number assigned to each district in Table 7.4.

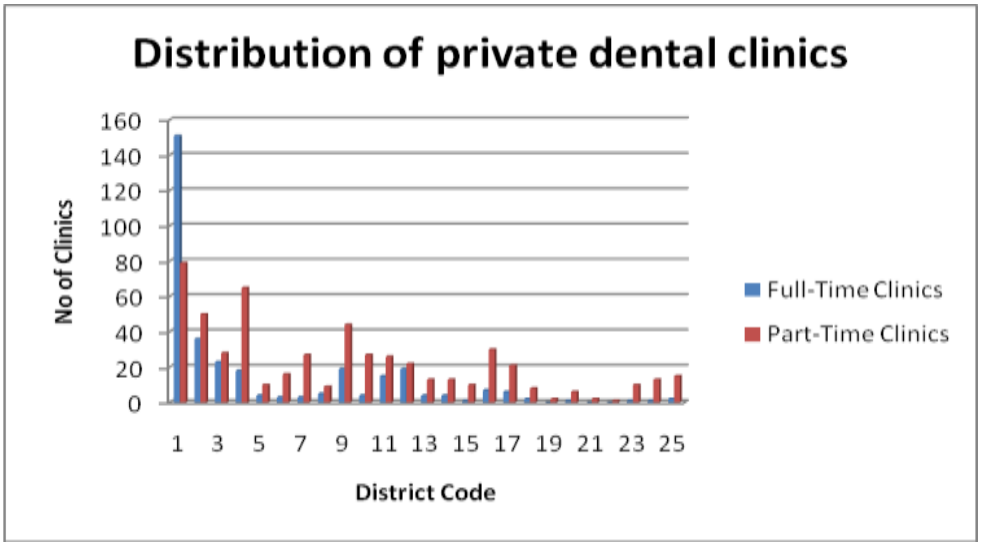


Figure 7.2. The distribution of private dental clinics/offices

The box and whisker plots shown in Figures 7.3 and 7.4 depict the median, upper & lower quartiles and 2nd and 98th percentiles for the numbers of full-time and part-time private dental clinics/offices respectively, distributed in different districts in the country. The box itself contains 50% of the data and the upper and lower edges of the box indicate the 75th and 25th percentiles of the data set respectively. The line in the box indicates the median value of the data. In both box-plot graphs, the median line within the box is not equidistant from the edges,

showing that the data are skewed. The points outside the ends of the whiskers, depicted by asterisks, can be regarded as outliers. These correspond to Colombo (a clear outlier) in Figure 7.3, and Colombo and Kandy in Figure 7.4.

Figure 7.3 Box-plot of the distribution of full-time private dental clinics/offices

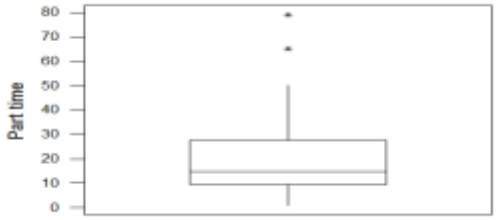


Figure 7.4 Box-plot of the distribution of part-time private dental clinics/offices

7.1.3 Workforce profile in private sector dental care provision

67% of all dental surgeons in Sri Lanka were engaged in either full-time or part-time private practice. Of the dental surgeons engaged in private dental care provision, 31**%** were full-time practitioners while 69**%** were part-time practitioners. There was more than twice the number of part-time practitioners than full-time practitioners. 63% of private practitioners were male, while 37% were female.

As far as principal occupation was considered, the government sector had almost three times more active dental surgeons than the private sector. As stated earlier, dental surgeons working in the public sector are allowed to do private practice after hospital working hours. More than half of the public sector-employed dental surgeons use this privilege and work as part-time private sector service providers in addition to their full-time employment in the state sector. Therefore, due to this dual employment, when the FTE (Full-Time Equivalent)

dental surgeons were calculated, the public and private sectors showed an almost equal percentage of dental surgeons, with 51% in the public sector and 49% in the private sector. Furthermore, it is interesting to note that almost all the part-time private practitioners were full- time public sector service providers. The inference is that private dental care provision in Sri Lanka, especially the part-time segment, is nourished by state sector-employed dental surgeons.

7.1.4 Characteristics of private dental care provision

93% of dental surgeons practised in one private clinic, while only 7% practised in more than one private clinic. The inference is that the large majority of private dental practitioners limit their service provision to a single location. 49% of dental surgeons had practised in their present clinic for less than five years, and 74% for less than ten years. The above figures could have been affected to a certain degree by the recent high influx of dental graduates. Fewer than 1% (0.6%) of private dental clinics in the country were limited to a specialty service provision, such as orthodontics, surgery, endodontics, etc. This means that almost all private dental clinics function as general dental practices. In the Colombo district, almost 70% of the patients arrived without a prior appointment. In other districts, nearly all (97%) had no prior appointment to meet the dental surgeon. Only 6% of the private dental clinics in the country (including the specialist clinics) worked strictly on a 'by appointment only' basis.

Medicinal drugs, mainly a few antibiotics and analgesics, were stored and issued to patients at most of the private dental clinics. 28% of the clinics in the Colombo district, and 50% of the clinics in other districts adhered to this practice. This is the norm for private medical practice in Sri Lanka, with almost all private General Practitioners (GPs) in the country issuing drugs from their dispensaries (Goonaratne, 1998). Normally the medicines issued by private dental clinics are generic products and are purchased in bulk by the dental surgeons, who obtain a discount from many chemists on bulk purchases, as well as the 10% discount given to doctors. It transpired during the discussions with senior private dental practitioners, that medicines were normally given for three days, and that there was no upfront charge made for medicine. However, the dental fee was generally inflated by Rs 150/-to Rs 200/- to accommodate the provision of drugs, although the actual cost of the drugs issued was around Rs 75- Rs 100/-. Therefore the issuing of medicine was another method to increase the profit margins. As seen from this study, the issue of medicines by private dental clinics was more prominent in districts outside Colombo.

Solo practices accounted for 97% of the private dental practices in Sri Lanka. There were only a few group and other kinds of practices in the country. These were mainly confined to the Colombo and Kandy city limits. Colombo is the commercial capital of the country, and Kandy is the capital of the Central province, the country's only dental school being located within 2-3 km from the outskirts of Kandy city.

7.1.5 Unqualified dental practitioners

As a part of the mapping exercise, identification of dental practices manned by Unqualified Dental Practitioners (UDPs) was carried out. In this context, a UDP was defined as a person who has not obtained a degree level qualification in dental surgery or dentistry, nor the mandatory registration from the licensing authority, namely the Sri Lanka Medical Council, to practise as a dental surgeon in Sri Lanka. According to the Medical Ordinance of Sri Lanka, it is illegal to practise dentistry without obtaining registration from the Sri Lanka Medical Council. Table 7.5 shows the distribution of UDPs and the ratios by population density, in Sri Lanka according to district. It is evident that UDPs were practising in all districts of the country. There were 89 dental practices manned by unqualified practitioners. All the clinics manned by UDPs were solo practices offering full-time clinics. These data are also presented geographically, mapped by district, in Appendix A10.

District code and name	**UDP clinics**	Population (000)	UDP CPR*
1.Colombo	17 (19.1%)	2,389	140,529
2.Gampaha	8 (8.9%)	2,141	267,625
3.Kaluthara	5 (5.6%)	1,106	221,200
4.Kandy	6 (6.7%)	1,351	225,167
5.Nuwara Eliya	2 (2.2%)	737	368,500
6.Matale	3 (3.3%)	468	156,000
7.Anuradhapura	2 (2.2%)	788	394,000
8.Polonnaruwa	2 (2.2%)	379	189,500
9.Kurunegala	9 (10.1%)	1516	168,444
10.Puttalum	3 (3.3%)	743	247,667
11.Galle	5 (5.6%)	1,041	208,200
12.Matara	4 (4.4%)	804	201,000
13.Hambantota	1 (1.1%)	549	549,000
14.Badulla	2 (2.2%)	829	414,500
15.Monaragala	1 (1.1%)	418	418,000
16.Ratnapura	4 (4.4%)	1,070	267,500
17.Kegalle	3 (3.3%)	807	269,000
18.Jaffna	2 (2.2%)	608	304,000
19.Kilinochchi	1 (1.1%)	146	146,000
20.Vauniya	1 (1.1%)	145	145,000
21.Mannar	2 (2.2%)	99	49,500
22.Mullatiuv	1 (1.1%)	147	147,000
23.Tricomalee	2 (2.2%)	391	195,500
24.Ampara	1 (1.1%)	625	625,000
25.Batticaloa	2 (2.2%)	555	277,500
Total	**89 (100%)**		

**UDP CPR = Unqualified Dental Practitioner clinic to population ratio*

Table 7.5 Distribution of Unqualified Dental Practitioner clinics and UDP clinics to population ratios

The 89 UDP clinics in the country gave a ratio of one UDP clinic to ten legitimate private dental clinics. A correlation analysis was performed to see if there was any relationship between the number of UDP clinics and the number of clinics run by qualified dentists. Computation of the Pearson Product Moment correlation was performed using the following formula:

$$Correlation = \{EXY- [(EX)(EY)/N]\}/\{ [EX^2 -(EX)^2/N][EY^2-(EY)^2/N]\}^{1/2} = +0.98$$

The number of UDP clinics in a province was found to be highly positively correlated to the number of legitimate private clinics run by qualified dental surgeons, as shown by the +0.98 Pearson Correlation Coefficient and presented in Table 7.6.

Province	No. of legitimate clinics (X)	No. of UDP clinics (Y)	X^2	Y^2	XY
Western	367	30	134,689	900	11,010
Central	116	11	13,456	121	1,276
N. Central	44	4	1,936	16	176
N.Western	94	12	8,836	144	1,128
Southern	99	10	9,801	100	990
Uva	28	3	784	9	84
Sabaragamu	64	7	4,096	49	448
Northern	22	7	484	49	154
Eastern	42	5	1,764	25	210
N=9	**EX=876**	**EY=89**	**$EX^{2=}$175,846**	**EY^2=1413**	**EXY=15476**

Table 7.6. Correlation between the distribution of 'legitimate' clinics and UDP clinics.

7.1.6 Dental care provision

Expressing the number of dental surgeons per 100,000 population is an accepted norm in any country when dealing with dental manpower. In addition to the above, we have calculated the private dental clinic density, taking into account the number of dental clinics per square kilometre of a particular district. The reason for calculating private dental clinic density was to take into account the influence of geographical size of the relevant district. The results are shown in Table 7.7.

The average private dental clinic density was 0.013 clinics per sq. km. The interpretation of this finding is that there was one private dental clinic for every 76 square kilometres. However, the outlying district of Colombo had a private clinic density of 0.329 per sq. km., meaning one private dental clinic for every three square kilometres. This is 25 times the national average. Gampaha and Kandy districts had the second and third highest clinic density, 0.062 and 0.043 clinics per sq. km. respectively. The lowest was the Mullatiuv district (in the Northern province) with a density of 0.0003 clinics per sq. km. All these districts showed a marked deviation from the national average of 0.013 per sq. km. Clearly, clinic density depends both on geographical size and the number of clinics in a district. The Colombo district is the smallest (699km^2) in size, but had the highest number of clinics. These two factors have contributed to a very high clinic density in the Colombo district.

District Code No	District	Area (km^2)*	Estimated Population (2006)** '000s.	Total # of private clinics	Clinic density (per km^2)	# of private clinics per 100k pop
1	Colombo	699	2389	230	0.329	9.63
2	Gampaha	1387	2141	86	0.062	4.02
3	Kaluthara	1598	1106	51	0.032	4.61
4	Kandy	1940	1351	83	0.043	6.14
5	Nuwara Eliya	1741	737	14	0.008	1.90
6	Matale	1993	468	19	0.009	4.06
7	Anuradhapura	7179	788	30	0.004	3.81
8	Polonnaruwa	3293	379	14	0.004	3.69
9	Kurunegala	4816	1516	63	0.013	4.16
10	Chilaw	3072	743	31	0.010	4.17
11	Galle	1652	1041	41	0.025	3.94
12	Matara	1283	804	41	0.032	5.10
13	Hambantota	2609	549	17	0.007	3.10
14	Badulla	2861	829	17	0.006	2.05
15	Monaragala	5639	418	11	0.002	2.63
16	Ratnapura	3275	1070	37	0.011	3.46
17	Kegalle	1693	807	27	0.016	3.35
18	Jaffna	1025	608	10	0.009	1.64
19	Kilinochchi	1279	146	2	0.002	1.37
20	Vauniya	1967	145	7	0.004	4.83
21	Mannar	1996	99	2	0.001	2.02
22	Mullatiuv	2617	147	1	0.0003	0.68
23	Tricomalee	2727	391	11	0.004	2.81
24	Ampara	4415	625	14	0.003	2.24
25	Batticaloa	2854	555	17	0.005	3.06
	TOTAL	**65,610**	**19,583**	**876**	**0.013**	**4.47**

Table 7.7 Private dental clinic density

** Area of Sri Lanka by district (1988)-Survey Department.*

*** Estimated 2006 population by district (based on 2004 figures - The Registrar General Department).*

Figure 7.5 depicts the numbers of private dental clinics per 100,000 population, as shown in the furthest right-hand column of Table 7.7, mapped geographically by district.

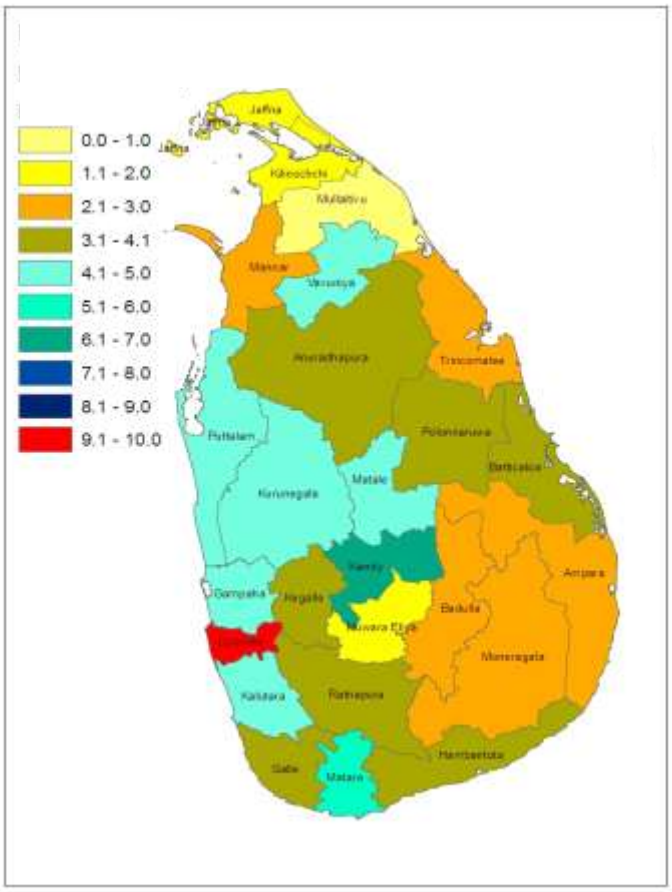


Figure 7.5 Numbers of private dental clinics per 100,000 population, by district

In the public sector there were 5.7 dental surgeons per 100,000 population, while in the private sector there were 4.5 dental surgeons per 100,000 population. When both public and private sectors are considered together, along with the phenomena of full-time equivalents and active participation, Sri Lanka had a dental surgeon to population ratio of 8.9 dental surgeons per 100,000 population, or, in other words, approximately one dental surgeon per 11,300 population.

7.1.7 Provider characteristics

The average age of a dental surgeon practising in Sri Lanka was 39.73 years. Table 7.8 shows that the age group between 31-40 years accounted for nearly half (48%) of all active dental surgeons in the country. Further, 571 dental surgeons out of the 1,038 (55%) employed by the Department of Health were in this age category. Moreover, the 31-40 year age group is the only age group which represented all main occupational categories of dental surgeons. However, a different age distribution was observed in the established full-time private practitioner segment, nearly one third of these practitioners being over 60 years of age.

Unestablished full-time practitioners were mainly the newly qualified dental surgeons awaiting government employment and engaged in full-time private practice until such time as they achieved government employment. They belonged to the younger age groups of 21-30 and 31-40. Therefore, when the private sector is considered as a whole, 84% of dental surgeons in active full private practice were under 50 years of age.

Age *Main Occupation*	***21 - 30***	***31 - 40***	***41 - 50***	***51 - 60***	***Over 60***	***Total***
Ministry of Health	11	571	363	93	-	1038
University	4	18	21	14	2	59
Defence Forces	7	34	7	6	-	54
Established full-time private general dental practitioners	-	32	37	27	45	141
Unestablished full-time private general dental practitioners	200	118	-	-	-	318
Others	1	3	1	1		6
Total	**223**	**776**	**429**	**141**	**47**	**1616**

Table 7.8. Age distribution of dental surgeons by main occupational category

There were more females than males in the dental profession in Sri Lanka: 52% female and 48% male. The male to female dental surgeon ratio was 1:1.1. Table 7.9 shows the ethnic distribution of dental surgeons, compared with the ethnic distribution in the general Sri Lankan population. It can be seen that the distribution of dental surgeons by ethnicity is largely similar to the population ethnic distribution.

Ethnic Group	**Percentage (dental surgeons)**	**Percentage (general population) ***
Sinhalese	83.0	73.9
Tamils	13.2	12.7
Moors	3.2	5.5
Others	0.6	7.1
Total	**100%**	**0.8**

Table 7.9. Ethnicity of dental surgeons compared with the general Sri Lankan population

** Source: Department of Census and Statistics 2008)*

90% of the dental surgeons were married. It is worth noting that the spouses of 21% of the dental surgeons were dental surgeons themselves, meaning that 10% of Sri Lankan dental surgeons were married to other dental surgeons. The overwhelming majority (97%) of the Sri

Lankan dental surgeons had graduated from the Faculty of Dental Sciences, University of Peradeniya. Furthermore, nearly one third of these graduates had entered the university from the Colombo district. Just over 3.4% of the dental surgeons in the country were foreign-qualified Sri Lankans. However there were no actual foreigners practising dentistry in Sri Lanka. Within the last ten years, 36 foreign-qualified Sri Lankan dental surgeons have entered the profession, 13 (36%) of whom are children of prominent dental surgeons in the country.

35% of the dental surgeons employed by the Department of Health, and 43% of the general dental practitioners lived in the capital district of Colombo. 93% of the university-employed dental surgeons lived in the Kandy district, while 49% of the Defence forces- employed dental surgeons lived in the Gampaha district. The inference is that dental professionals were concentrated in affluent districts close to the capital city of the country. In the case of Kandy district, it is where the sole dental school is located. Only 28% of the dental surgeons had attended a continuous professional education activity within the past year, and 49% had not attended any programme for more than three years.

All government dental practices/clinics were open every weekday from 8am to 4 pm, with a lunch break between 12 noon to 2pm, and on Saturdays from 8am to 12 noon. Government clinics were closed on Saturday afternoons, Sundays and other public holidays. Therefore a government dental surgeon worked for approximately 40 hours per week. 86% of the private practices/clinics were open every week day. During the weekends, 49% of the private clinics worked on both Saturday and Sunday, while 51% worked either on Saturday or Sunday. Opening hours during weekdays and weekends were 8.30am to 12.30pm and 3pm to 8pm where applicable. 97% of the part-time clinics were open only in the evenings. This is because the overwhelming majority of the part-time clinics were served by public sector-employed dental surgeons. On average, a full-time private clinic was open for nine hours per day, and a part-time private clinic for four hours. Accordingly the full-time private practitioners worked more than 50 hours per week, while the part-time private practitioners worked for nearly 25 hours per week.

7.1.8 Number of patients treated

According to Department of Health norms, a dental surgeon working in a government hospital dental clinic should treat 20-30 patients per day. However, according to the official

statistics of the Department of Health's Annual Health Bulletin, the number of patient visits per year for the entire workforce of Department of Health-employed dental surgeons was as shown in Table 7.10.

Year	Number of dental surgeons employed	Number of patient visits (millions)	Equivalent number of patients per day
2003	713	1.63	9
2005	774	1.76	9
2006	890	1.78	8
2007	947	1.82	7

Table 7.10 Number of patients treated in government dental clinics

(Source: Annual Health Bulletins Ministry of Health 2003-2007)

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The above analysis shows that even after allowing for under-reporting, as stated in section 6.2.1, the number of patients treated per day deviates markedly from the norm. Furthermore, the number of patients treated has not increased parallel to the increase in the number of dental surgeons. Table 7.11 illustrates the number of patients treated per day in full-time and part-time private dental clinics.

Type of clinic	Range (per day)	Median	Standard deviation
Part time	1-32	3	8
Full time	2-90	4	24

Table 7.11 Number of patients treated in private dental clinics

The number of patients treated in a full-time and a part-time clinic showed a wide range. However the median values were somewhat similar between the full-time clinics and part-time clinics, when compared to the range.

Table 7.12 illustrates the private dental practice/clinic ownership. Working in one's own clinic was the dominant type, while locum practice accounted for a substantial proportion. More than two thirds of the country's private dental practitioners worked in their own clinics. They were the owner-cum-principal partner (or only partner) of the practice.

Practice/Clinic ownership	Percentage
Own clinic	69
Locum	29
Both own and locum practice	1
Other arrangement	1

Table 7.12. Private practice ownership

Considering current market prices, to start up even a simple dental practice/clinic, a dental surgeon has to invest a minimum of Rs 450,000/- to Rs 600,000/. If the investment is on borrowed capital from a bank or other financial institution, a further 14-16% per annum interest has to be paid. The only revenue source of a dental practice is the fees received from the patients. This revenue has to be sufficient not only to recover the investment, but also to make a profit. This profit will be the dental surgeon's earnings. Therefore the dental surgeons are naturally very concerned about the number of patients they treat. This is all the more so for the full-time practitioner, as his/her clinic is the sole avenue of income. However, part-time practitioners, who are permanent employees of the state sector, have a permanent salary, and what they earn from private dental practice will be a supplement to their fixed income. Nearly 30% of the country's private dental surgeons worked as locum practitioners. Locum dental surgeons are generally paid on a daily basis. In Sri Lanka, locum dental surgeons receive between 35% and 55% of the total gross income from the practice/clinic, depending on the agreement with the clinic owner/-principal partner.

There may be several reasons contributing to the decision as to whether to start one's own clinic or to work as a locum practitioner. The difficulty in finding the capital to start a clinic may be the main reason to select a locum practice. Less responsibility in managing the day to day affairs of the practice/clinic and the opportunity to start one's own practice subsequently, in a more lucrative location, may be two of the many contributing factors. Furthermore, some may want to gain clinical hands-on experience by working as a locum practitioner before starting off on their own.

28% of the private dental practitioners owned the premises where their practice/office was located. However the majority (72%) of the dental surgeons were operating from rented premises. Of the dental surgeons who owned the practice premises, 66% were aged 40 years or over. They consisted of 65% male dental surgeons and 35% female dental surgeons. Moreover, of the dental surgeons who rented practice premises, 61% were 40 years or under

in age. As is evident in this study, the large majority of the private dental clinics in Sri Lanka, 56% and 87% in Colombo and other districts respectively, were situated in commercial buildings. Furthermore, nearly a half of the dental clinics in commercial buildings were in the premises of medical care institutions, such as small private hospitals or nursing homes, channelling centres and medical centres.

All the private dental clinics in Sri Lanka had electricity. All the private dental clinics in the Colombo district had piped water too. However 9% of the clinics in other districts used stored well water. In Sri Lanka in 2009, 75% and 31% of households had electricity and pipe-borne water respectively (Central Bank of Sri Lanka, 2009). Therefore it could be stated that the private dental clinics were located in buildings which had the basic facilities of electricity and water. This may be one of the reasons that the clinics were concentrated in town centres. All government dental clinics manned by dental surgeons had electricity and piped water, as they were mainly located within hospital premises.

7.1.9 Clinic staffing

Only one dental surgeon worked at any given time in the country's 547 part-time dental clinics, and most of the 329 full-time practices/clinics. Compared to the rest of the country, in the Colombo district, most dental surgeons worked on either a shift or rotation basis. There was no difference in the composition of the other staff between the Colombo district and other districts. In 96% of private dental clinics, the dental surgery assistant was the only staff other than the dental surgeon.

As revealed by this survey, a typical dental surgery assistant was a General Certificate of Education (GCE) Ordinary level qualified, in-house trained, non-uniform wearing girl in her early twenties. However nearly one third of the assistants were GCE Advanced Level qualified. There was a high job turnover for these dental surgery assistants. More than half of them had less than one year's experience, while a third had three or more years of work experience at their current clinic.

Dental Surgery receptionists in Sri Lanka were a near non-existent staff category. Only a few clinics had a receptionist. Dental laboratory technicians and labourers formed the other staff categories and were found only in a very small number of clinics. As revealed in the focus group discussions, in almost all clinics, the dental surgery assistant/nurse was not on a formal employment contract. There was no 'letter of appointment', or any other evidence, to prove

employment. No employee provident fund or trust fund contributions were made by the employing dental surgeon, and wages were very low. In the part-time clinics, the average salary was Rs 4000/ per month, and in full-time clinics it was Rs 7500/- .

A typical hospital dental clinic in the government sector was manned by a dental surgeon and a minor employee. In larger hospitals, dental clinics were manned by the dental surgeon, a staff nurse and a minor employee. In specialist units located in larger hospitals, the staff was comprised of the consultant, three house officers (dental surgeons), one staff nurse and two to three minor employees.

7.1.10 Patient records and equipment available

In the Colombo district as well as in the other districts, the overwhelming majority of private clinics (above 90%) maintained no patient records. In the Colombo district, 5% of the clinics used a computer for patient data management, compared with 2% in the other districts. However, as per Ministry of Health regulations, minimum patient records were mandatory at government clinics., although this was limited to the patient's name and age and the type of treatment received. The dental surgeon was responsible for completing a monthly return and sending it to the Medical Statistics division of the Ministry of Health.

In most of the private dental practices in Sri Lanka, modern dental units and equipment were used. However, in-house dental X-ray facilities and dental laboratory facilities were available in less than 3% of private clinics. Moreover, the majority of the clinics with X-ray and laboratory facilities were in Colombo. The most popular method of instrument sterilization, both in the Colombo district and other districts, was the 'water bath' or the 'sterilizer'. 12% of the Colombo district clinics, and 5% of the clinics in the other districts used autoclaves. As revealed by officials of the Department of Health, and the focus group discussions, the majority of government dental clinics had modern dental chairs and units. However dental X-ray machines, and hence the facility to provide dental X- rays, were limited to larger hospitals where there were dental specialists. A similar pattern was seen in the case of the dental laboratory. Dental laboratory facilities were essentially limited to larger hospitals. There were only 13 hospitals in the country which had dental laboratory facilities.

7.1.11 Types of treatment provided

The routine treatments provided in private general dental practices were dental extractions, restorations, scaling (cleaning) and dentures. Nearly all private practitioners provided all

these treatments. When non-routine treatment procedures, within the general dental practitioners' scope, were considered, the majority (above 60%) also practised root canal (nerve filling) treatment, removable orthodontic appliances and surgical removal of impacted 3rd molar teeth. Table 7.13 shows the types of advanced treatment provided by general dental practitioners in the private sector. It is evident that the large majority of general practitioners provided only the very basic advanced treatment in addition to routine procedures. Only around a fifth of the private dental practitioners performed periodontal surgery, soft-tissue biopsy and dental bridges. Fixed orthodontic appliances, dental implants and treatment modalities considered to be hi-tech and expensive were provided only by 1-2% of the private sector dental surgeons. Moreover, dental implants and cosmetic dentistry were limited to the districts of Colombo and Kandy.

Type of Treatment	Percentage of practising dental surgeons
Anterior Root Canal Treatment	94
Posterior Root Canal Treatment	61
Fixed Appliances	1.5
Dental Bridges	18
Dental Implants	1
Surgical Removal of Impacted 3rd Molar	59
Periodontal Surgery	19
Dentures	97
Soft Tissue Biopsy	21
Removal of orthodontic appliances	63

Table 7.13. Types of advanced treatment provided in the private sector

In the state sector, as evidenced by the Annual Health Bulletins of the Department of Health (MOH, 2010), approximately 50% and 26% of patients received dental extractions and dental restorations, respectively, from government dental clinics. In the government sector, only the larger hospitals had facilities to provide even the basic prosthetic treatment, such as partial and full dentures. Further, the simplest advanced treatment procedures, such as root canal treatment, were also limited to larger hospitals in the hospital hierarchy. Other advanced treatment procedures and orthodontic treatment were available only at specialist dental clinics in the government sector, but dental bridges and dental implants were not provided in any government hospital.

7.1.12 Dental Treatment Fees

Table 7.14 shows the average fees charged in the private sector for different treatment in all

districts apart from Colombo. The data for Colombo are shown in Table 7.15. It can be seen that there was a wide variation in the fees charged for the same procedure. In order to minimize the effect of extreme values, and for comparison purposes, we have considered the median values.

Treatment type	Range(Rs)	Median (Rs)	Standard deviation
Consultation/other	50-250	100	56
Temporary restorations	100-300	150	62
Extractions	150-750	250	134
Amalgam restorations	200-1800	350	368
GIC restorations	300-2000	400	420
Scaling	300-1750	450	468
LCC restorations	350-2000	600	481
Post Crown	500-2000	750	501
Partial dentures	600-3500	1500	742
Removable Appliances	750-3000	1750	802
ARCT	800-3500	1750	770
PRCT	1750-7500	2500	1652
Full dentures	3500-12500	4500	2633
Bridges(1 unit)	10,000-15,000	11,000	1622

(ARCT Anterior Root canal Treatment, PRCT –Posterior root canal treatment, LCC – Light Cure Composite restoration,s GIC-Glass inomerrestorations. Bridges –Single pont bridges)

Table 7.14 Private sector fees levied for different dental treatments, excluding Colombo

Treatment type	Range(Rs)	Median (Rs)	Standard deviation
Consultation/other	100-250	150	40
Temporary restoration	100-300	200	44
Extractions	200-800	300	98
Amalgam restorations	300-700	500	233
GIC restorations	250-2200	450	324
Scaling	400-2000	550	375
LCC restorations	400-2500	600	364
Post Crown	400-2000	1000	329
Partial dentures	800-3500	2500	544
Removable Appliances	1200-3000	2000	745
ARCT	1200-4000	2000	564
PRCT	2250-8500	3750	1256
Full dentures	4500-15000	6000	2469
Bridges (1 unit)	10000-20000	15,000	1387
Implants (1 Unit)	65,000-80,000	75,000	5014

(ARCT - Anterior Root canal Treatment, PRCT – Posterior root canal treatment, LCC – Light Cure Composite restorations, GIC - Glass inomer restorations; Bridges – Single pont bridges)

Table 7.15. Private sector fees for different treatment types in Colombo district

Figure 7.6 illustrates the comparison of fees (mean values) for different treatment procedures between the Colombo district and other districts (rest of the country).

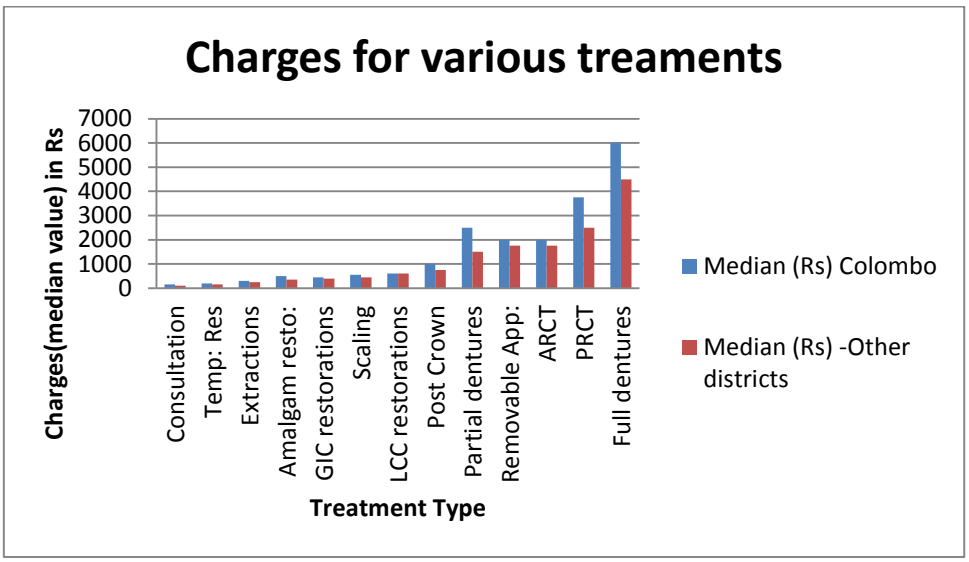


Figure 7.6. Comparison of fees between Colombo district and all other districts

It is clear that charges (fees) for all private dental treatments were higher in the Colombo district, as compared to other districts. By contrast to the private sector, all treatment procedures in the state sector, whether routine or advanced, were free of charge to the patient at all government dental clinics.

7.1.13 Employment opportunities in the Ministry of Health

The Ministry of Health is the single largest employer of dental surgeons in Sri Lanka. However it has not been able to provide employment for all graduating dental surgeons on a regular basis. As illustrated in Figure 7.7, there was no recruitment in 2002, 2005 and 2008.

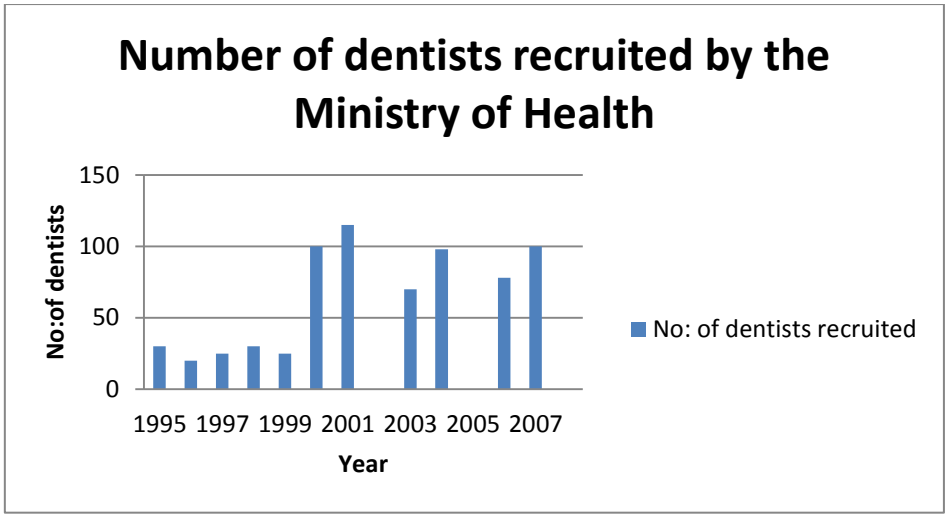


Figure 7.7. Number of dental surgeons recruited by the Ministry of Health (1995-2008)

Table 7.16 shows that there were more active female dental surgeons than male counterparts in the country. However in the case of private dental care provision, the male dental surgeons were clearly more involved, and dominated the sector.

Parameter	Male:Female ratio
Dental Surgeons (Sri Lanka total)	1:1.08
Dental Surgeons (Private Sector)	1:0.59
Clinic ownership	1:0.45
Locum practitioners	1:1.13
Working from own premises	1:0.39
Weekend practice	1:0.49

Table 7.16. Summary of male to female ratios (percentages)

7.2 Results of the dental student survey

These students represent the future dental workforce. All dental students in Sri Lanka in the academic year 2008 were considered. They were the students of the Faculty of Dental Sciences, University of Peradeniya. A total of 372 students, from the first year to the final year (5 batches) were surveyed. 341 students were attending the Faculty of Dental Sciences for lectures or clinical work during the period of data collection, which was done over five consecutive days, from Monday to Friday, during term-time. They were served a self-administered questionnaire. 339 students responded to the questionnaire, giving a response rate of 91%.

7.2.1 Demographics

Figure 7.8 shows the age distribution of the students surveyed. It can be seen that the age ranged from 20-28 years. When dental students from the first year to the final year were considered together as a group, the mean age was 22 years and 10 months, with a mode of 23 years. However the final years considered separately showed a mean age of 25 years and 3 months. Regarding gender, 60% were female and 40% male.

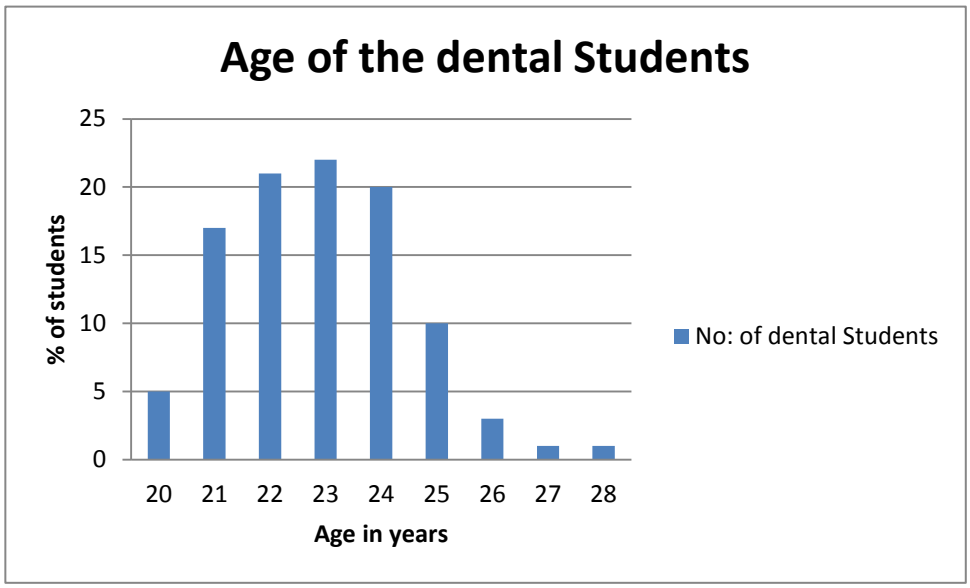


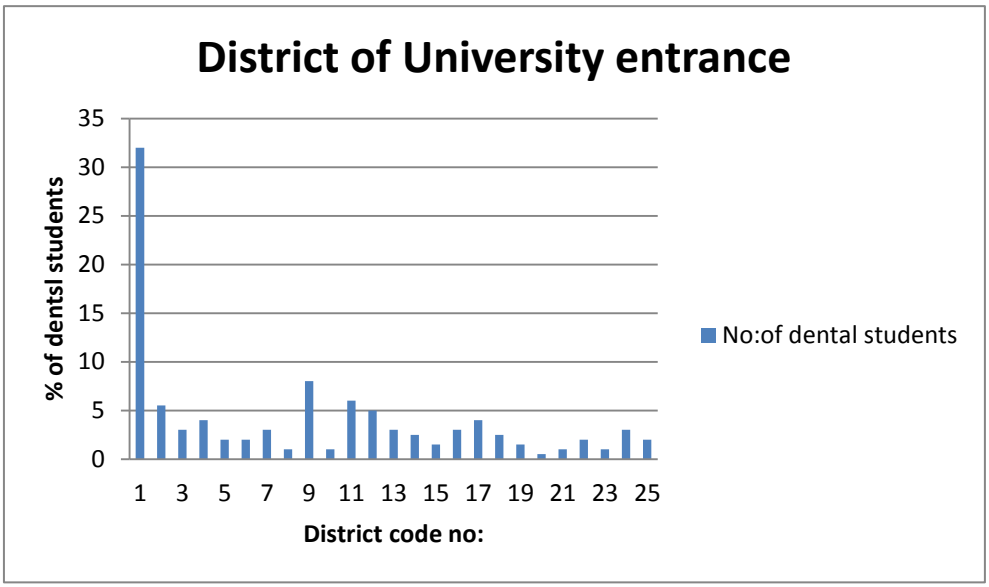
Figure 7.8. Age distribution of students

Sri Lanka uses the old UK examination system (GCE O-levels and A-levels). Table 7.17 shows the number of attempts at the GCE Advanced Level Examination level, in order to enter the Faculty of Dental Sciences, University of Peradeniya. It is noted that more than half of the students surveyed had entered in their second attempt, while more than a third had entered in their third and final attempt.

Attempts	Number of Students
1	41 (12%)
2	173 (51%)
3	125 (37%)

Table 7.17. Number of attempts at the GCE Advanced Level Examination

Figure 7.9 illustrates the districts from which the students had gained admission to the Faculty of Dental Sciences, University of Peradeniya. Nearly a third of the students had entered from the Colombo district, and the district which had the next highest number of students accounted for 7% of the students.



District code numbers as per table 7.4.

Figure 7.9 The district of university entrance-students

7.2.2 Employment expectations

Almost 75% of the students were aware of the scarcity of employment for dental surgeons in the public sector, even before they had entered the Dental School. However, more than a half (51%) of the students, still plan to join the Department of Health after graduation. 15% of students had decided to venture into the private sector, without seeking government employment, while nearly a third were undecided about their future employment. This high percentage of 'undecided' was acceptable, due to the fact that this study included first year students.

Of the students who wished to join the Department of Health, 82% hoped to engage in part-time private practice after hospital working hours, while of the students who were planning to engage in either full-time or part-time private practice, 78% wished to set up their own practices. Nearly 30% of the students were planning to establish practices/clinics in the Colombo district (Western Province) in the future. Only a very small percentage were willing

to establish themselves in districts other than Gampaha (Western province) and Kandy (Central province). 67 students, that is nearly one fifth (20%) of the student population planned to embark on postgraduate studies.

7.3 Demand

In keeping with WHO/FDI methodology described in Chapter 6, the dental disease burden was considered in three main categories: dental caries, periodontal (gum) diseases and need for prosthetic treatment (WHO/FDI, 1989). The results for each respectively are shown in Tables 7.18, 7.19 and 7.20. Recall that "DMFT" stands for Decayed, Missing or Filled Teeth.

Age/Age Group In years	DMFT teeth	FT (Filled teeth)	MT (Missing teeth)	Extraction needs*
0-5 (deciduous)	3.51	0.13	0.12	0
0-5(permanent)	0.05	0	0.01	0.01
15	1.53	0.12	0.17	0.16
35-44	8.39	0.51	4.93	4.76
65-74	17.12	0.07	15.21	10.28

Table 7.18. Disease burden of dental caries

**Need for dental extractions were derived from the DMFT index using the WHO/FDI (1989) recommendations. Details of the method used to derive the need for dental extractions are illustrated in the Restorative Care calculation sheet in Appendix 5*

Age Group (in years)	Sextants* needing basic treatment (e.g. scaling)	Sextants needing complex treatment (e.g. deep scaling)
0-12	1.49	-
12-15	1.84	-
35-44	3.04	0.37
65-74	1.52	0.52

Table 7.1 9 Disease burden of periodontal diseases.

** The mouth is divided into 4 sextants, each containing 8 teeth.*

Age Group (in years)	Percentage of the cohort needing a partial denture	Percentage of the cohort needing a full denture
15	1.6	-
35-44	70.3	4.8
65-74	73.4	77.2

Table 7.20. Need for prosthetic treatment

The need for more advanced prosthetic treatment procedures such as a fixed prosthesis (e.g. dental bridges and implants) were not considered in the above prosthetic treatment needs.

7.3.1 Results of the Sri Lanka Timing Inquiry

The Sri Lanka Timing Inquiry identified the time taken for various dental treatment modalities in the Sri Lankan context. This data complemented the relevance of 'timings' already recommended by the WHO/FDI (1989) for respective treatments. Further, the WHO/FDI (1989) recommended the number of treatment sessions and denture replacement periods in the case of periodontal (gum) treatment and prosthetic treatment respectively, for different countries, based on their broad socio-economic and health status. In the absence of relevant data indigenous to Sri Lanka, the WHO/FDI (1989) recommended values for a developing country (like Sri Lanka) were utilized in our calculations.

Tables 7.21 - 7.23 illustrate the time taken for various treatment modalities, based on the Sri Lanka Timing Inquiry and WHO/FDI (1989) recommended number of treatment sessions, and denture replacement periods for periodontal diseases and prosthetic treatment respectively.

Restoration (filling) of teeth is considered under the three categories recommended by the WHO/FDI (1989). Table 7.21 shows the time taken for tooth extractions and for various restorative procedures in different age groups. The age groups are those used in the 2003 National Oral Health Survey.

Treatment category	Age group	5 years	15 years	35-44 years	65-74 years
Atraumatic Resin Restoration T(ARR)		15	15	15	5
New Fillings (Surfaces) T(NFS)		20	20	20	20
Replacement Fillings (Surfaces) T(RFS)		20	20	20	20
Extraction T(Ext)		15	15	15	15

Table 7.21. Time (in minutes) for restorative treatments and extractions

As recommended by the WHO/FDI (1989), treatment for periodontal (gum) diseases was considered in two broad categories: basic and complex treatment. The number of treatment sessions for different age groups in each category is shown in Table 7.22 below.

Treatment category	Age 0-12	Age 12-15	Age 35-44	Age 65-74
Basic treatment	5 x2	5x2	5 x4	10 x5
Complex treatment	-	-	120 x1	120 x1.5

Table 7.22. Time in minutes per sextant, and number of treatment sessions per year, for periodontal (gum) disease treatment

Prosthetic treatments were considered in two categories: partial and full dentures. The replacement periods, as suggested by the WHO/FDI (1989), for the above two categories of dentures are shown in the table below.

Treatment category	0-15 years	35-44 years	65-74 years
Partial dentures	90 min, 10 years	90 min, 15 years	90 min, 15 years
Full dentures	-	120 min, 15 years	120 min, 15 years

Table 7.23. Time taken for prosthetic treatment, and the replacement period

7.3.2 Treatment time calculations

The data obtained from the Sri Lanka Timings Enquiry were then used to calculate the total time required for treating each individual patient in the relevant age category. Further details of these calculations can be found in Appendix A5.

7.3.3 Age group based treatment time calculation

Age Group	Treatment category	Unit Time allocation	Treatment units	Total time allocation
5 years	T(ARR)	15	3.42	51.3
	T(NFS)	20	0.21	4.2
	T(RFS)	20	0.11	2.2
	T(Ext)	15	0.01	0.15
Total				**57.85**
15 years	T(ARR)	15	1.32	19.8
	T(NFS)	20	0.21	4.2
	T(RFS)	20	0.09	1.8
	T(Ext)	15	0.16	2.4
Total				**28.2**
34 - 44	T(ARR)	15	4.12	61.8
	T(NFS)	20	3.29	65.8
	T(RFS)	20	2.92	58.4
	T(Ext)	15	4.76	71.4
Total				**257.4**
65 – 74	T(ARR)	5	4.02	20.1
	T(NFS)	20	7.07	141.4
	T(RFS)	20	8.61	172.2
	T(Ext)	15	10.38	154.20
Total				**487.9**

Table 7.24. Restorative treatments and extractions

The time required for periodontal (gum) disease treatment was calculated using the WHO/FDI (1989) recommended formula

*[W * **T(s)* P(s)**]/cohort age gap*

where W is the number of sextants which need treatment, T(s) is the time per sextant in minutes, and P(s) is the number of sessions required. The periodontal treatment need for the entire cohort period was calculated as shown in Table 7.25 by taking W from the National Oral Health survey (MOH, 2003), T(s) from the Sri Lanka Timings Inquiry, and P(s) from the standard values suggested by the WHO/FDI (1989).

Age Group	Treatment Type	Time (in minutes)*
0-15 years	Basic treatment: 1.84 x5 x2 Complex treatment - nil	18.4 -
35-44 years	Basic treatment: 3.04 x5 x4 Complex treatment: 0.37 x120 x1	60.8 44.4
65-74 years	Basic treatment: 1.52 x10 x5 Complex treatment: 0.52 x120 x1.5	76 93.6

**These times were for the entire cohort period*

Table 7.25. Periodontal treatments

Finally, prosthetic treatment need was calculated using the standard formula recommended by the WHO/FDI (1989):

$$\{\{R(2)-R(1)/100\} + \{(Y/U)X\ [R(2)+(R2-R1)/2]/100\}\}X\ Time\ allocation$$

where R2 is the need for dentures in a particular age cohort, R1 is the need for dentures in the preceding age cohort, Y is the number of years between the two successive age cohorts and U is the replacement period in years. Values for R1 and R2 were taken from the National Oral Health survey (MOH,2003), U from the standard values suggested by the WHO/FDI (1989) and time allocation from the Sri Lanka Timing Inquiry.

Denture Type	Age cohort	Calculations using the WHO/FDI formula	Total time allocation
Partial	0-15	{1.6% +[15/(2x10) x1.6%]}x 90	2.52
	35-44	{(70.3-1.6)/100+{(24.5/15)x[70.3+(70.3-1.6)/2]/100}}x90	215.10
	65-74	{(73.4-70.3)/100+{(30/15)x[73.4+(73.4-70.3)/2]/100}}x90	134.82
Full	35-44	{(4.8-0)/100+{(24.5/15)+[4.8+(4.8-0)/2]/100}} x120	19.20
	64-74	{(77.2-4.8)/100+{(30/15)+[77.2+(77.2-4.8)/2]100}} x120	359.04

Table 7.26. Prosthetic treatment times, in minutes

In addition to these three main categories, four further treatment types were considered: preventive care, special group care, surgical care and orthodontics. The time allocations for these were again based on values recommended by the WHO/FDI (1989), modified using expert opinion to suit the local scenario.

Preventive care relates to educating the population about dental hygiene. In Sri Lanka, this is normally carried out in a group setting.

Age Group	**Treatment time calculation**	**Time (in minutes) for the cohort period**
0-15	4 sessions per year x 15 minutes per individual + 15 minutes group (represents 450 minutes given to groups of 30)	75
35-44	5 sessions per year x15 minutes per individual	75
65-74	-	-

Table 7.27. Treatment times for preventive dental care

Special group care relates to domiciliary or institutional care. Further non-surgical care of oral tissues is also included under this category.

Age Group	Time allocation in minutes per year	Percentage of the population in need	Time (in minutes) for the cohort period
0-15	200	2	4
35-44	200	4	8
65-74	300	15	45

Table 7.28. Treatment times for special group dental care

Surgical care relates to surgical care for trauma, impactions and other minor oral surgical procedures.

Age Group	Time allocation in minutes per year	Percentage of the population in need	Time (in minutes) for the cohort period
0 - 15	60	10	6
35 - 44	150	10	15

Table 7.29. Treatment times for surgical care

Orthodontic care relates to treatment for irregularities of the teeth and occlusion.

Age Group	Time allocation in minutes per year	Percentage of the population in need (as per NOHS, 2003)*	Treatment (in minutes) for the cohort period
0 - 15	150	11.5	17.25
35 - 44	150	5	7.5
65 -74	-	-	-

**MOH 2003-NOHS- National Oral Health Survey*

Table 7.30. Treatment times for orthodontic care

Table 7.31 summarises all the preceding results, and forms a key part of the input data for the system dynamics model. The way that the "missing" age groups were accounted for is described in section 7.3.4 below.

Age cohort	Treatment type	Time allocation in minutes	Age range of the complete cohort	Total time per year within the cohort range
0-15	Preventive [(4x15)+15]	75		
Midpoint 7.5	Special group care [200x2%]	4		
	Surgical care [60x10%]	6		
	Orthodontic care [150x11.5%]	17.25		
	Periodontal care - basic	18.4		
	-complex	-		
	Prosthetic care - partial dentures	2.52		
	Prosthetic care – full dentures	-		
	Restorative care and extractions [57.85+28.20]	86.05		
TOTAL		**209.22**	**15 years**	**13.95**
35-44	Preventive [5x15]	75		
Midpoint 39.5	Special group care [200x4%]	8		
	Surgical care [150x10%]	15		
	Orthodontic care [150x5%]	7.5		
	Periodontal care - basic	60.8		
	-complex	44.4		
	Prosthetic care - partial dentures	215.1		
	Prosthetic care – full dentures	19.2		
	Restorative care and extractions	257.4		
TOTAL		**702.4**	**32 years**	**21.95**
65-74	Preventive	-		
Midpoint 69.5	Special group care [300x15%]	45		
	Surgical care[150x10%]	15		
	Orthodontic care [150x5%]	-		
	Periodontal care - basic	76		
	- complex	93.6		
	Prosthetic care - partial dentures	134.82		
	Prosthetic care – full dentures	359.04		
	Restorative care and extractions	487.90		
TOTAL		**1211.36**	**30 years**	**40.38**

Table 7.31 Summary of all treatment times

7.3.4 Converting need to demand

According to the WHO/FDI (1989) guidelines, when converting need to demand for dental care, the population was considered in three age groups of 0-15, 35-44, and 65-74 years of age. The level of demand was considered as a percentage of need for the respective age groups. The percentage values were arrived at taking into consideration the level of development of each country as a whole. The percentage values shown below are applicable to a country where need for dental care is moderate to high; Sri Lanka is considered to be in this category, as evidenced by the National Oral Health Surveys (MOH, 1984;1993;2003) and expert opinion.

For the 0-15 year age group, the demand was considered to be in a range of 65-100% of the need, for the 35-44 age group this figure was 30-65%, while it was 10-30% in the 65-74 age group. The lower limit of these ranges was considered as the 'low demand', while the upper limit was considered as the 'high demand'. The midpoint of the range was the 'moderate demand'. The low demand, moderate demand and high demand are denoted as L, M, or H, respectively, for all three age groupings. Table 7.32 shows the conversion of NEED to DEMAND under the three levels mentioned above.

Age cohort	Minutes of Need	% Demand			Demand in minutes			Cohort % of Population	Minutes per person under different demand scenarios		
		L	M	H	L	M	H		L	M	H
0-15	13.95	65	82.5	100	9.07	11.51	13.95	26	2.36	2.99	3.63
35-44	21.95	30	47.5	65	6.59	10.43	14.27	46*	3.03	4.80	6.56
65-74	40.38	10	20	30	4.04	8.08	12.11	28*	1.13	2.26	3.39
								Total	**6.52**	**10.05**	**13.58**

Table 7.32 Conversion of need to demand

Due to the gaps in the identified cohort age groups, the percentage of the population between 16-44 years was assumed to follow the same pattern as the population between 35-44 years in the calculation of demand for dental care. Similarly the percentage of the population above 45 years was assumed to follow the same pattern as the population between 65-74 years in dental demand calculations. This approach was adopted following discussion with local experts and the results are shown in Table 7.33. The population percentages were obtained from Department of Census and Statistics, (2009).

7.3.5 Total dental workforce hours

Scenario	Calculations	Demand in hours
Low demand	(6.52/60)*20,800,000	2,260,265
Moderate demand	(10.05/60)* 20,800,000	3,640,000
High demand	(13.58/60)*20,800,000	4,707,733

20,800,000 = total population of Sri Lanka. Department of Census and statistics 2009

Table 7.33. Total hours of demand for the entire population under different demand scenarios

In the calculation above, the number of active dental surgeons in both government and private sectors was identified and converted to 'full-time equivalent' dental surgeons. Subsequently the number of hours per day, and number of days per year that they worked were factored to full-time equivalents to calculate the total dental hours.

In the calculation of the number of working days per year for government sector dental surgeons, in addition to public holidays, the availability of vacation and casual leave were taken into consideration. In the case of private practitioners, in addition to public holidays, expert opinion was obtained to decide the average number of days' leave they take per year. Calculations are given in Appendix A6.

Chapter 8: The System Dynamics Model

In this chapter we describe in detail the SD model developed to answer the question "How many dentists does Sri Lanka need?" We present the results from simulation runs of different scenarios. The model was developed in the software *Stella*, version 9.1 (ISEE systems, 2010). A complete listing of the Stella code can be found in Appendix A4.

8.1 Model development

Stella is a specialized software package used to develop system dynamics models. It has a relatively user-friendly interface which allows the use to create structural diagrams, enhancing understanding of the system elements and their logical links. The basic building blocks of a Stella model are the 'stock', 'converter', 'flow' and 'connector'. All the elements of a Stella model, namely stocks, flows and converters, can be interconnected using the connector icon. After identification of particular processes and model construction is completed, its elements have to be defined and parameterized. This is facilitated by the availability of a list of built-in functions.

Subsequently, operation of the process can be simulated by running the model. If any alterations to the process elements or parameter values are needed, this can easily be done. Process elements could be redefined by typing in a new formula, while any parameter value may be changed by typing in a new value. The model can now be re-run (re-simulated) and re-tested. The above procedures could be repeated until we have a model which suits our task. This provides an iterative process for model development and simulation. Diagrams, charts, and animation available in the package help learners discover and apprehend complex relationships in dynamic systems.

The SD model was developed following the four stages proposed by Sterman (2001), namely:

1. **Conceptualization.** The purpose of the model is defined and the model boundary and key variables identified. The behaviour of the key variables is investigated and the basic mechanisms and feedback loops are diagrammatically represented.

2. **Formulation.** Having identified the relevant data for use in the model, the parameter

values were quantified and the level and rate equations defined.

3. **Testing.** The model assumptions were tested, and the model behaviour under different scenarios, including extreme conditions, was explored. Further, the model was simulated to test the different dynamic hypothesis.

4. **Implementation** The model was used to explore different policy options, and the results used to inform practical decisions.

SD models can be used either to explain the occurrence of a policy problem, or to suggest ways to mitigate the problem, or both. Policy in this context could be defined as a broad rule for decisions. In general, SD models facilitate the analysis of long-term implications of policies and structures in a system. As stated earlier, identification of cause-effect relationships constituted one of the most critical and earliest steps in the model development process, as it plays a central role in SD. In our SD model, identification of causal relationships and policy structures were not restricted to availability of quantitative data. The author's mental database, enriched by his wide experience in the field of dentistry, accepted practices and norms, together with expert opinion were used to identify and refine the causal relationships.

As Forrester (2007) urged, 'powerful small models' can be used to communicate the most crucial insights of a model to the public, who may not have the in-depth knowledge about the subject. Small models may consist of a few significant stocks and about seven major feedback loops. Further, many small SD models are capable of capturing vital, often counter-intuitive insights of a complex problem. These small models will enable policy-makers to easily understand complex issues.

From its inception, much effort was taken to keep our model to a 'small model', while keeping it generic in nature. Keeping the model generic in nature will enable it to be used to address similar policy issues, which in turn will help to enhance the value of the model. During the model development process, the aim was to construct the policy structures not only to illustrate or depict historical patterns, but also to remain valid under extreme conditions. The purpose of this was to make the model robust enough to encounter unexpected extreme situations. Furthermore, during model development, causal loop diagrams, flow diagrams and mathematical equations were kept as simple as possible. The purpose here was to make the various hypotheses transparent, and easily understood.

When developing this model, more emphasis was paid to the structure than to the parameter values. During the initial stages of model building the parameter values were selected using the author's knowledge of the subject matter, and expert opinion. Subsequently the more sensitive parameters were identified by means of sensitivity analysis. A detailed description of the model validation process and sensitivity analysis is given below.

8.1.1 Model Validation

For model validation two basic methods were used, namely structure based validation and behaviour based validation.

In structure based validation, we are concerned about model formulation and wish to ensure that the model is suitable for its purpose and is consistent with the real world system. In order to test the suitability for its purpose, we focused on the dimensional accuracy and consistency and ensured that the formulation made sense for extreme input values. By this method it was conformed that the model was well designed and fit for purpose.

Further testing of structural consistency involved judging the model's representativeness, and evaluating whether the model structure captured the perceptions involved in the operations of the actual system. This was facilitated by the author's familiarity and experience about the real system in operation. Structural validity was further enhanced by using historical data to run the model, and comparing the model parameters to what information was available.

Behaviour based validation involves conducting model simulations to probe the validity of the model construction. Once the simulation runs were performed the output parameters were judged to be realistic and convincing by those with day to day experience of the real system under consideration.

Model validity was further enhanced by extreme condition testing and looking for surprise behaviour by simulation with extreme values.

A multi-stage procedure was followed to validate the constructed model. Validation involved mainly qualitative judgement rather than quantitative analysis. The author's and Sri Lanka's leading dental health policy-makers' expertise was used to judge the appropriateness of the model purpose, boundary, causal structure and degree of detail. The SD model, so constructed, has the ability to generate behaviour similar to that of the real system, thereby enhancing its acceptability and validity.

The author's thorough understanding of the actual system in operation, the model developed to depict it, and the model behaviour facilitated the analysis of new policies. The author was thereby able to model for the dynamics of implementation of new policies. The SD model constructed was geared to explain the past and predict the future. Further, the suggested policy changes were realistic enough to be implemented.

Furthermore, in addition to the above model validation processes, **Predictive Validation** and **Parameter variability (Sensitivity Analysis)** were performed. In predictive validation, the model is used to predict (forecast) the system's behaviour, using historical data and then comparisons were made between the model's forecast and the present status to determine if they are the same. Table 8.1 shows the model results and the actual values (obtained from the Ministry of Health) for the period 1991-95.

Year	Government employment seekers		Waiting time for Govt. employment (months)	
	Model	**Actual**	**Model**	**Actual**
1991	29	26	7	6
1992	24	23	5	5
1993	37	35	8	7
1994	47	44	10	10
1995	56	55	12	12

Table 8.1. Comparison of actual values and model predictions for 1991-95

System Dynamics is a behaviour-oriented simulation discipline in which the effects of parameter uncertainty on the behaviour patterns can be important. Therefore sensitivity analysis is vital, as it allows the modeller to determine which of the model parameters are more important for the simulation output. The parameters to which the model output is more sensitive will require further data analysis in order to reduce the uncertainty in the parameter value. In conclusion, the effects of input uncertainty on the model output is analysed by sensitivity analysis. It also helps to develop intuition about the model structure, which in turn may help in the data collection endeavour.

In this research, as suggested by Sterman (2000); a variation of plus or minus 20% in the parameter values were used as the distribution range. As a first step, univariate analysis was performed, where one input variable was considered at a time. Those parameters that were sensitive, i.e., the parameters which caused significant changes in the model's behaviour or output were identified. Subsequently, for these parameters, the values were varied by plus or

minus 33% to check whether the model still made sense.

However, univariate sensitivity analysis may not be sufficient in a complex model, as simultaneous change in more than one parameter value may create an unexpected output change because of a nonlinear relationship among different model parameters. Therefore in the model validation univariate analysis was followed by a multivariate sensitivity analysis, taking two or more key input variables at a time. As proposed by Ford and Flynn (2005), simple correlation coefficients were used in order to determine important input model parameters. Input parameters to which the model was sensitive were given special attention during the model simulation.

Taking the key input parameters of the model as the independent variable and the number of dental surgeons seeking established employment (underemployed and unemployed dental surgeons) as the dependent variable, correlation coefficients were calculated. These calculations revealed that the highest correlation coefficient was -0.89, between the number of vacancies in the Department of Health (independent variable) and the number of dental surgeons seeking established employment (dependent variable), followed by +0.80 between the Training rate of dental surgeons (independent variable) and the number of dental surgeons seeking established employment (dependent variable). Accordingly the "number of vacancies in the department of health" and "training rate" were the two most important input variables; which demonstrated a major impact on the whole system.

Most of the model inputs were generated from the first part of this research. The model developed was simulated over many years, while exploring numerous policy options for better dental workforce planning in Sri Lanka. The model is robust enough to relate dental surgeons to population ratios, and to identify the number of dental surgeons in different service categories including those awaiting government employment, the waiting time to secure the same, and changing demand for dental care. Furthermore, the model is capable of matching actual demand and supply for dental surgeons in Sri Lanka.

8.2 Details of the model

The dental workforce model represents the key stakeholders of dental services, namely dental students, dental surgeons in different service categories, specialist trainees and dental specialists. Furthermore, the model represents service providers from both government and

private sectors. Figure 8.1 depicts the overall influence diagram showing dental workforce dynamics.

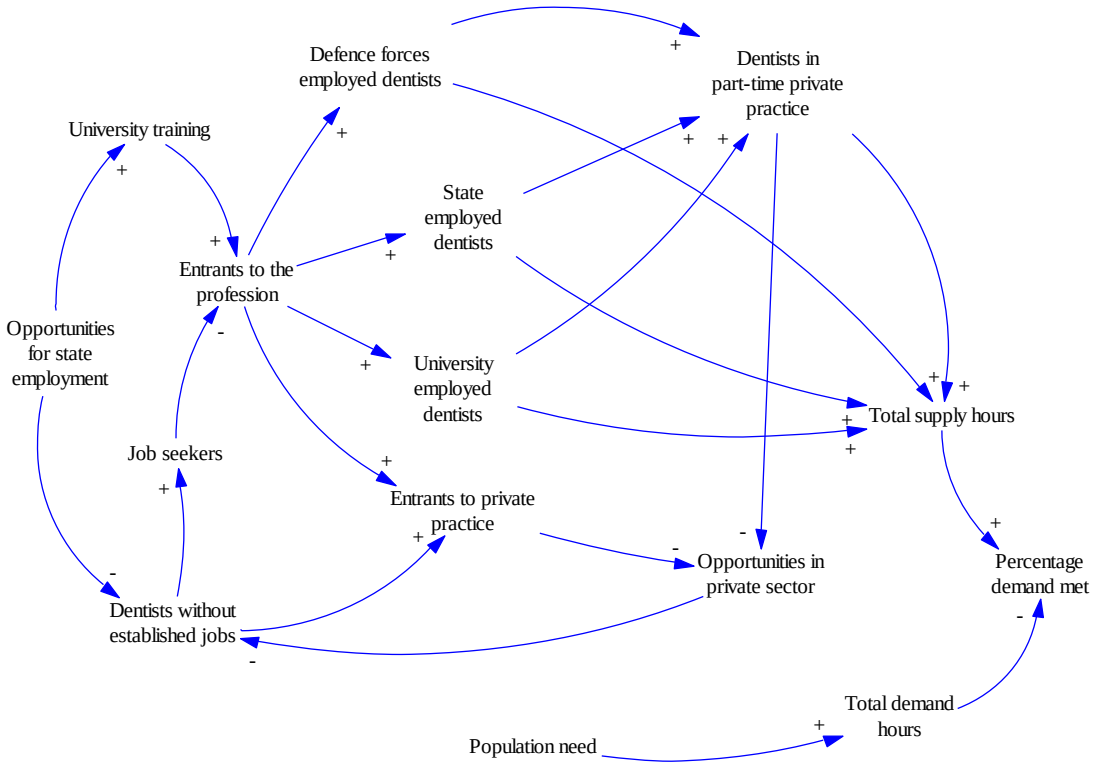


Figure 8.1. Influence diagram showing dental workforce dynamics

All active dental surgeons belonged to one or at most two of the principal service provider categories listed below:

a) Employed by the Ministry/Department of Health;
b) Employed by the University Dental School;
c) Employed by the Defence Establishment (Army, Navy, Air Force or Police)
d) Full-time established private practitioners and full-time unestablished private practitioners;
e) Part-time established private practitioners and part-time locum private practitioners.

The government sector-employed dental surgeons (categories a), b) and c above) are also allowed by law to engage in part-time private practice after official working hours, i.e.

mainly after 4pm on weekdays and after 1pm on Saturdays. Sunday is a public holiday in Sri Lanka.

Due to the lack of government employment, newly qualified dental surgeons may be forced to enter the private sector. While working in the private sector as a stopgap, they may continue to seek government employment, which is deemed to be more secure and recognized. However, once they secure government employment, they may also keep working in the private sector on a part-time basis. According to the records of the Directorate of Dental Services, Ministry of Health, as at September 2009, there were nearly 250 newly qualified dental surgeons awaiting government jobs (Directorate of Dental Services, 2010).

The model examines how the dental services sector can adapt to the shortage of government employment for dental surgeons in Sri Lanka. The dynamic hypothesis is that the rate of availability of government employment will alter the balance between various dental surgeon occupation categories. Low rates of availability will lead to more dental surgeons in un-established private practices who will continue to seek government employment. Furthermore, although working in unestablished private practices, they have to make a living from private practice, which in turn has an impact on a wide range of issues, namely the quality of services rendered, medical ethics and patients' perception of dental surgeons. Moreover there will be a long-term impact on the university admissions policy for dentistry.

The above hypothesis was conceptualized directly in terms of stocks and flows of dental surgeons in the model. The current numbers of dental surgeons in different stocks, as well as the current 'flow rates' were used as the initial values in the model. As explained in more detail below, converters were used to introduce different concepts relating to dental workforce issues, such as the number of dental surgeons seeking established government salaried jobs, waiting time for government employment, total active dental surgeon hours, total demand for dental services, and different dental surgeon to population ratios. A simplified version of the model, showing only the career pathways, is presented in Figure 8.2.

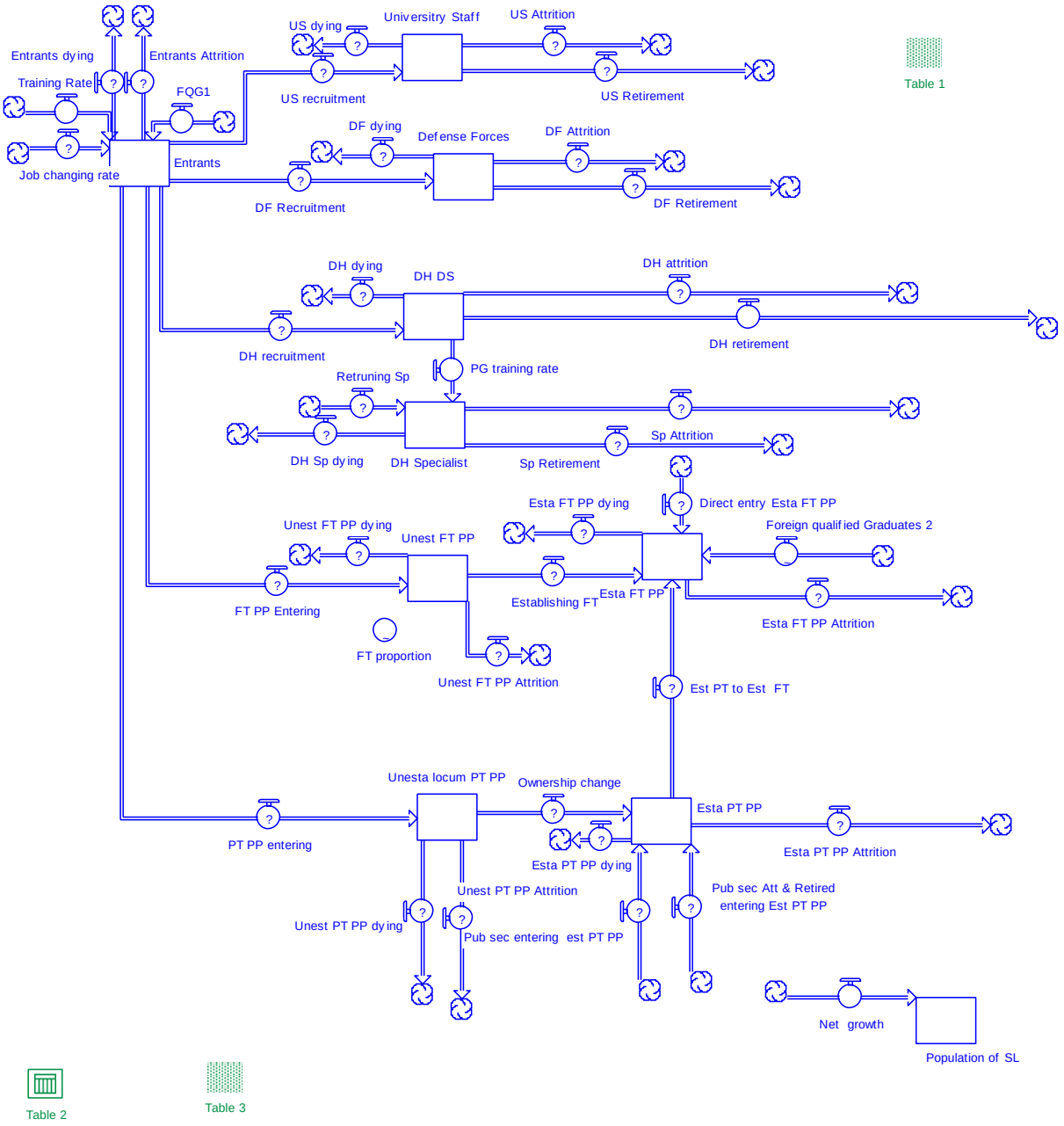


Figure 8.2. Career pathways in the Stella model

Having gained admittance to the country's sole training institution for dental surgeons (the Faculty of Dental Sciences, University of Peradeniya), a student spends four years studying before graduating as a dental surgeon. This process is depicted as the 'training rate'. Over the past ten years, the average annual intake to the Dental School has been 80 students. Hence the training rate was given an initial value of 80 in the model calculations. However it was increased in the model using a stepwise manner, according to the historical patterns of increasing the training rate.

Newly graduated dentists flow to a stock and flow network, commonly known as an experience chain, where they choose an employment category in dentistry and work as dental surgeons (possibly in different capacities within any given category), until they exit the system due to retirement, attrition, or death. Furthermore, some dental surgeons change their job category while remaining within the system.

As shown in Figure 8.1 above, after graduation all dental students enter a stock termed *Entrants.* The dental surgeons who change their job category also enter this stock, while in the process of changing their job (further explanation can be found under the *job changing category* explained later in this chapter). A very small number of foreign-qualified Sri Lankan dental surgeons also enter the *Entrants* stock. They are denoted as FQG 1 in the model.

Having entered the *Entrants* stock, the newly graduated dental surgeons, the job- changing dental surgeons and the foreign-qualified Sri Lankan dental surgeons have several options available to them to select as their principal occupation. These options are as follows:

i. Enter the Ministry/Department of Health;
ii. Join the university staff;
iii. Enter the Defence establishment;
iv. Enter into full-time private practice;
v. Enter into part-time private practice;
vi. Leave the profession altogether (due to attrition or death).

All the above options are captured in the model.

As explained earlier, the state sector-employed dental surgeons (Department of Health, university, or Defence establishment) are permitted to engage in private practice after official hospital working hours. This phenomenon is captured in a converter entitled *State emp new PT*, meaning state sector-employed dental surgeons who re-enter the system for their second job as part-time private service providers (see Figure 8.10). This is a significant component in the model and creates a very important feedback mechanism. This will be further explained later, as the model description continues.

Having entered any of the above employment categories, shown as a distinct pathway or

experience chain, a dental surgeon has liberty to return to the *Entrants* stock and seek another employment category, subject to employment contract restrictions in the chosen career pathway. For example, those who have joined the Defence establishment are bonded to serve for a certain minimum number of years, hence are not entitled to change job category at will during the bonded period.

All the data used in the model, and the mathematical formulae used to depict the relationships between model elements, are listed in Appendix A7. We now describe in detail the specific pathways in the model.

8.2.1 Specific employment pathways

The reader is advised to refer to the specific employment pathways in the context of the whole model, as shown in Figure 8.10.

i) **Enter Ministry/Department of Health**

Any dental surgeon registered with the Sri Lanka Medical Council is eligible to seek employment in the Department of Health. Up to the early 1990s, all newly qualified dental surgeons were recruited to the Department of Health immediately after graduation. However, the present situation is not so, and new graduates have to wait for three to four years to secure employment in the Department of Health.

Once recruited to the Department of Health, they follow the experience chain as shown in Figure 8.2 below. As illustrated in the experience chain, there could be attrition from the Department service, with dentists entering the specialist training pathway, retiring from service at the official retirement age, or dying while still in service. Any of the above events will lead to a depletion of the stock of dental surgeons in the Department of Health. All these events will have a feedback impact on public sector vacancies for dental surgeons, as shown in Figure 8.10. This is captured in a convertor named *DH vacancies* (Department of Health vacancies for dental surgeons). The flow rates of *Postgraduate training rate, Department of Health (DH) retirement rate, DH attrition rate and death rate of DH dental surgeons or DH dying* are all connected to the convertor *DH vacancies* to illustrate the above phenomenon. Figure 8.3 depicts the Government (DH) section of the model.

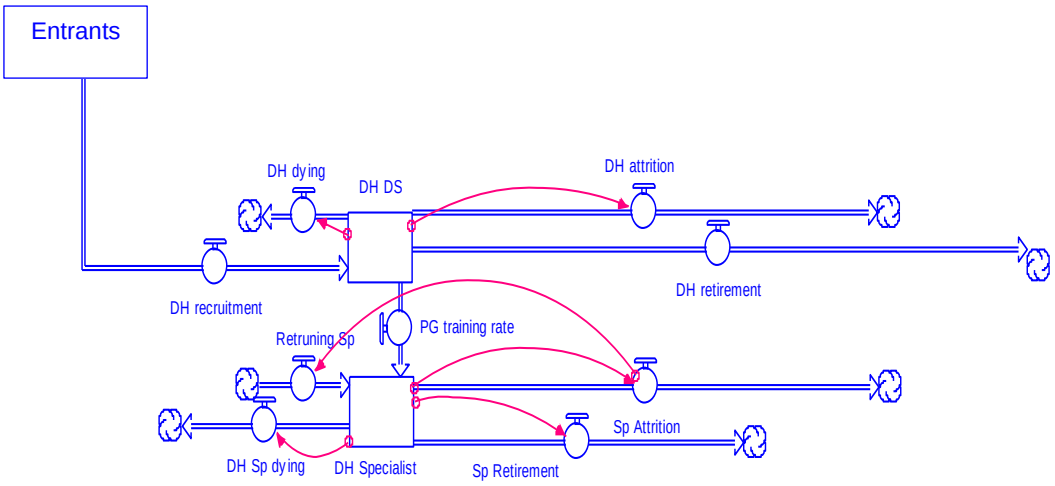


Figure 8.3. Department of Health career pathway

In the recent past, the Government has been creating a small number of new vacancies in the Department of Health, in an ad hoc manner. On average the number of new vacancies created amounted to 1.5% of the existing total number of vacancies, per annum. This phenomenon is illustrated by using a connector from the stock of *DH DS (Department of Health Dental Surgeons)* to the converter *DH vacancies*.

The number of *DH vacancies* arising has a feedback influence on the flow rate termed as the *recruitment rate*, shown in the model. However there is a delay (time gap) of approximately six months between the creation of a vacancy and recruitment. This delay is captured in the model.

The number of dental surgeons who leave the Department of Health prior to retirement in any given year is captured as the *DH attrition rate*. As already mentioned, *DH attrition rate* has an impact on *DH vacancies*. In addition, it has impacts on part-time and full-time private service provision. However, the annual attrition from the Department of Health is relatively small, at around 0.5% of the total workforce (Directorate of Dental Services, 2009). Therefore its impact on both vacancies and private service provision is not significant. Furthermore, the vast majority of attrition is due to migration out of the country, and so its impact on private practice becomes even more insignificant.

The dental surgeons who will be retiring from the Department of Health are included in the model. This is done by analysing their age structure from the data available in the Ministry of Health and the results of the empirical survey. The dental surgeons who undergo attrition or

retire from the Department of Health generally follow two pathways. Either they will enter part-time or full-time private practice, or not engage in any form of active dental service provision. The majority belong to the former group.

Dental surgeons who are successful at the very competitive examinations enter the specialist training programmes. They become specialists after a stipulated period of training, both locally and abroad, and completion of examinations. Once qualified, they are appointed to serve in the Department of Health as consultants. At the point at which they enter the specialist training programme, they leave the stock named *DH DS*. There are five major specialties recognized by the Department of Health, namely: Maxillo-Facial Surgery, Orthodontics, Restorative Dentistry, Oral Pathology and Community Dentistry. The majority of specialist dental surgeons in the Department of Health do part-time private practice. However their service provision in the private sector is mostly limited to general dental practice. Furthermore, the specialist dental surgeons who retire or leave (attrition), may engage in either part-time or full-time private practice. All these scenarios are captured in the model.

A negligible number of the Department of Health dental surgeons, who either leave or retire from the service, may seek employment in a different category apart from private practice. This is captured in a convertor named *changing job category*. They re-enter the system through the *Entrants* stock to join another job category (other than private practice). This scenario is also captured in the model.

The common depletion pathways from the stocks of *DH DS* and *DH specialists*, namely retirement, attrition and death, are also illustrated in the model.

ii) **Join university staff**

Sri Lanka has only one Dental School, the Faculty of Dental Sciences, University of Peradeniya. The Dental School has no plans for expansion in the foreseeable future. The academic positions in the school are already saturated, and new vacancies are very unlikely to be created on a regular basis. However vacancies may arise due to retirement and attrition of staff. Whenever a vacancy exists, the student who obtained the highest marks at the Final examination is generally recruited to the faculty staff. Once selected for the Dental School

academic staff, due to the brighter career prospects and the prestige given to university teachers in Sri Lankan society, they are unlikely to seek employment elsewhere within Sri Lanka, even if there are other opportunities. As stated earlier, university staff are also entitled to engage in part-time private practice. All these scenarios are captured in the model. Figure 8.4 depicts the University section of the model.

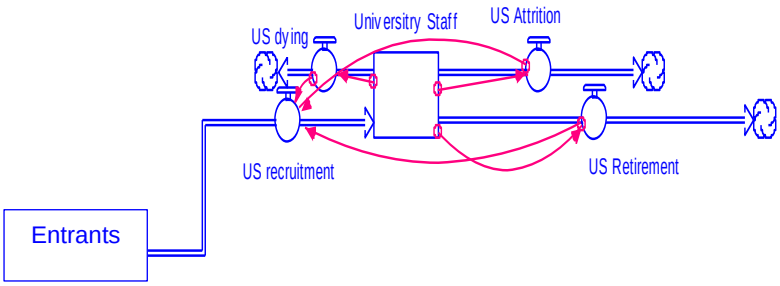


Figure 8.4. University staff career pathway

A very small proportion of university academic staff-employed dental surgeons, who leave or retire from service, seek employment in a different category other than engaging in private practice. As already mentioned, for Department of Health dental surgeons, this process is captured in a convertor named a *changing job category*, in which they re-enter the system through the *Entrants* stock to join another job category, other than private practice.

iii) **Enter Defence establishment**

A few newly graduated dental surgeons opt to enter the three armed forces or police department of the country, collectively known as the Defence establishment. However, due to the increased intake during the past few years, most of these positions are now filled. Furthermore, the separatist war that prevailed in the country since 1983 has ended, and hence it is very unlikely that there will be further mass scale recruitment drives by the Defence forces. Therefore there will only be a few new positions available in this sector for dental surgeons in the foreseeable future, other than vacancies arising due to natural attrition.

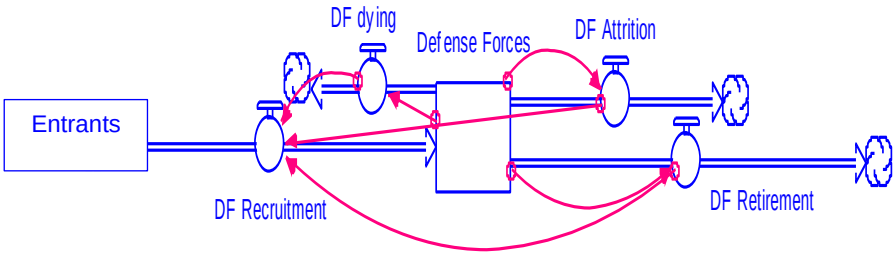


Figure 8.5. Defence establishment career pathway

The majority of dental surgeons employed by the Defence establishment do part-time private practice after official working hours. Having decided to accept employment in the Defence establishment, they cannot seek employment elsewhere, as they are bonded to serve for a minimum period of time, which is normally 12 years. Furthermore, a very a small proportion of the Defence establishment dental surgeons, who either leave the service after completing the mandatory service period, or retire from service, may seek employment in a different category other than engaging in private practice. As per Department of Health and university dental surgeons, this process is captured in a convertor named *changing job category*. They re-enter the system through the *Entrants* stock to join another job category, other than private practice.

iv) **Enter into full-time private practice**

It has been the tradition for all newly graduated dental surgeons to seek full-time salaried employment, either in the university system, Department of Health, or in the Defence establishment. However, 30-35 years ago, even when there were ample opportunities in the government sector, due to the lucrative business in the private sector, many dental surgeons opted to become full-time private practitioners, by leaving their government job after a few years of employment. Most of the stock termed the *Esta FT PP* (Established Full-Time Private Practitioners) consisted of these dental surgeons. The results from the empirical study presented in Chapters 6 and 7 confirm that 98% of the full-time private practices in Sri Lanka are solo practices.

At the time of this study, private dental care provision has become very competitive.

Therefore very few dental surgeons will take the risk of venturing into full-time private practice if they can secure a salaried job in the government sector (De Silva, 1999). However, when there are no vacancies in the above three principal salaried employment categories, new graduates are compelled to venture into private practice to make a living, even if it is not lucrative. Venturing into full-time private practice involves a large capital investment. Furthermore, new entrants to the private sector will have to compete with well-established senior colleagues, and may find it difficult to break even during the first few years of private practice. As a result they may become demotivated, as well as getting into financial difficulties, especially if they have taken out bank loans to start the practice. This casts doubt on the viability of private practice. Also these new graduates are not long-term oriented, because they always aim at securing traditionally preferred permanent salaried employment in the state sector, especially in the Department of Health. Due to the above reasons, those who enter the full-time private practice as new graduates are limited in number.

The full-time private practice section of the model is shown in Figure 8.6.

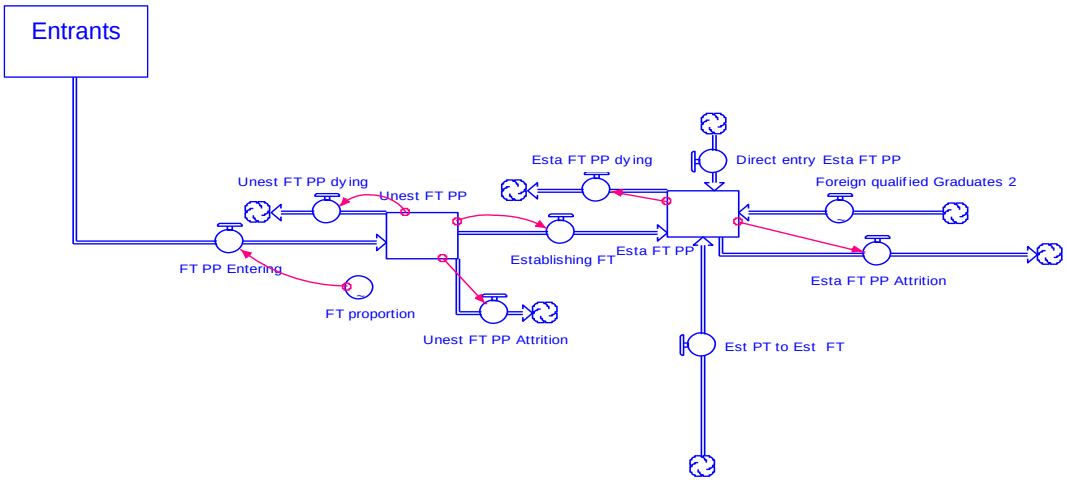


Figure 8.6. Full-time private practice career pathway

The current ratio (0.38:0.62) of full-time private clinics to part-time private clinics in the country, derived in the empirical study, is used as the initial value in the model. However, judging from the present status quo of unavailability of government employment for dental surgeons for three to four years after graduation, it is the expert opinion that more and more newly graduating dental surgeons will be compelled to enter full-time private practice, even though it is not going to be as lucrative as in the past. Therefore the percentage of newly qualified dental surgeons entering unestablished full-time private practice is modelled as

gradually increasing, using a graphical function (until the ratio of full-time practices to part-time practices reaches 0.54:0.46 over the simulated period of 15 years, as per expert opinion). This is depicted in Figure 8.7 below.

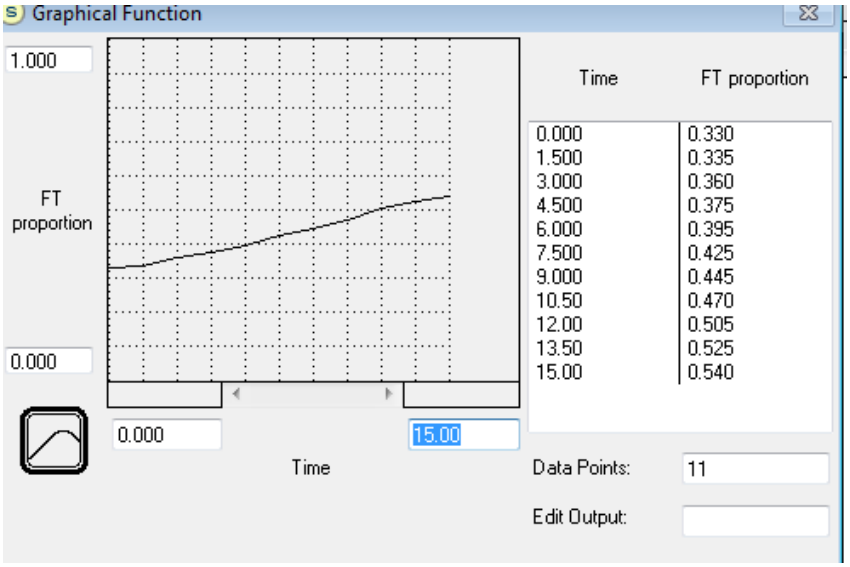


Figure 8.7. Stella graphical function showing increase over time in FT:PT ratio

Once dentists have entered into full-time private practice, they are captured in the stock termed *unesta FT PP* (Unestablished Full-Time Private Practitioners). As long as they are in this stock, their income is unstable and their job insecure. Therefore they continue to seek employment with the Department of Health. This is shown as a converter termed *Est employment seekers* (Seeking Established Permanent Salaried Employment).

A few dental surgeons move from the *Unest FT PP* stock into the stock termed *Esta FT PP* (Established Full-time Private Practitioners). The rate of conversion from un-established to established full-time private practice is denoted as a flow rate termed *establishing* and kept at 10% per annum in the model. This percentage value was obtained from a previous study by the author of this thesis (De Silva, 1999), and modified according to expert opinion, to suit the current situation. Having moved to established full-time private practice, these dental surgeons no longer seek government employment. They will continue to be in this stock until their retirement, attrition, or death.

In the model, three more distinct inflows are linked to *Est FT PP* stock. One is an inflow of dental surgeons entering established private practice, having either retired or left (attrition) state sector employment. These dental surgeons, by virtue of their experience in the state

sector and the goodwill earned while working as government dental surgeons, are capable of establishing themselves in full-time private practice without having to go through the *unesta FT PP* stock. This inflow is shown as a *direct entry to Esta FT PP*. Further, this inflow is linked to the converter termed *Pub sec Att & Ret entering FT PP*, which denotes dental surgeons who either leave or retire from government service to join full-time private practice. However there is a time delay for this scenario to happen, which is captured in the model. Using expert opinion, the time delay is kept at approximately two and a half months in the model. The second inflow is from the conversion of "Established part-time private practice" to Established full-time private practice", explained in detail in the following section.

The other inflow is from Sri Lankans who qualify as dental surgeons in foreign universities abroad. In absolute terms, the number of such graduates entering the private sector had been around four to five per annum. These graduates are mainly the children of well-established, rich dental surgeons in the private sector. Having failed to secure admission to the Faculty of Dental Sciences, University of Peradeniya, they study for a dental degree in a foreign country, financed by their parents' assets. On return to the country, they have to pass a mandatory statutory qualifying examination, conducted by the Sri Lanka Medical council, to obtain registration to practise as a dental surgeon in Sri Lanka. Thereafter they may join their parents to expand the already well-established private practice, or use the goodwill connections and wealth of their family to establish satellite clinics combined with their parents. Consequently these dental surgeons do not have go through the *unesta FT PP* stock. This inflow is shown as *foreign qualified graduates (FQG)2*.

Although the number of foreign-qualified dental surgeons has traditionally been very small in number, in the recent past there has been a rising trend in the number of foreign-qualified Sri Lankan dental surgeons entering the established full-time practice market segment (see results of the empirical study). Therefore a graphical function (shown in Figure 8.8) was used in the model to represent the above mentioned rising trend.

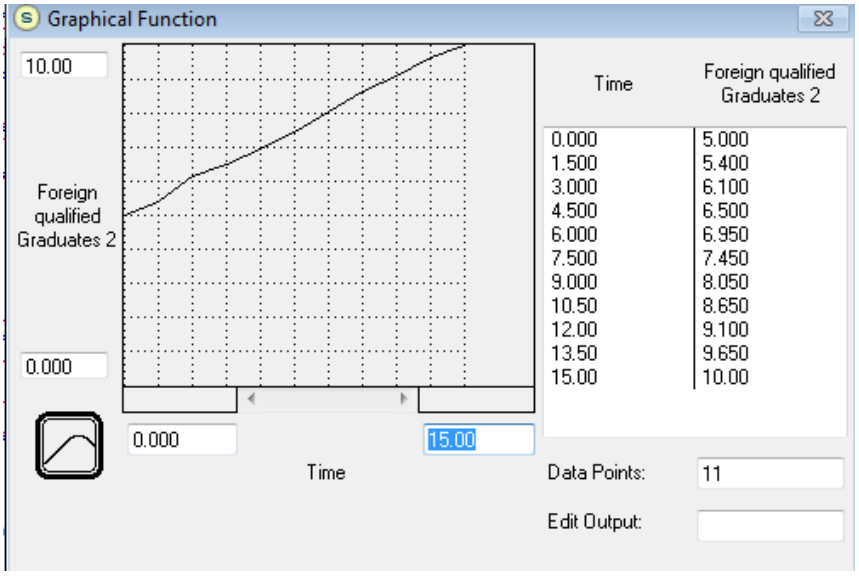


Figure 8.8. Stella graphical function showing increase over time in foreign-qualified dentists entering FT practice

Only very rarely does a foreign-qualified Sri Lankan dental surgeon apply for government employment. During the last 15 years, only two such dental surgeons have requested Department of Health employment. Those who request state sector employment are denoted as Foreign Qualified Graduates (FQG 1) and they enter the stock termed *Entrants*, as described elsewhere.

v) Enter into 'locum' part-time private practice

In the past, those who entered part-time private practice were state-sector-employed dental surgeons, using it as their second job. They started private practice after hospital working hours in the evenings and during the weekends. However with the rising unemployment of dental surgeons in the state sector, young dental surgeons looking for government employment tend to work in part-time clinics on a locum basis. This involves working in a clinic belonging to another dental surgeon on a profit- sharing basis or for a fixed salary. The main advantage of doing locum work is that there is no capital investment for the newly qualified dental surgeon, and hence no need to borrow money either from money- lenders or bankers, to establish a clinic. Furthermore, they can leave the practice with very short notice to the owner, either to work in a more lucrative locum practice, or to accept government employment. Therefore young dental surgeons consider locum practices as a more flexible option for employment. However, in a profit-sharing set-up, the owner of the clinic earns the

bulk of the share of income, while the locum practitioner could easily be sacked by the practice owner, as there is no formal contractual agreement between them.

However, part-time private practice remains the preferred employment category in the stopgap period for new graduates awaiting government employment (De Silva, 1999). The newly qualified dental surgeons venturing into part-time private practice as locums are shown as a stock termed *Unest locum PT PP* (Un-established Locum Part-Time Private Practitioners). This pathway is depicted in Figure 8.9.

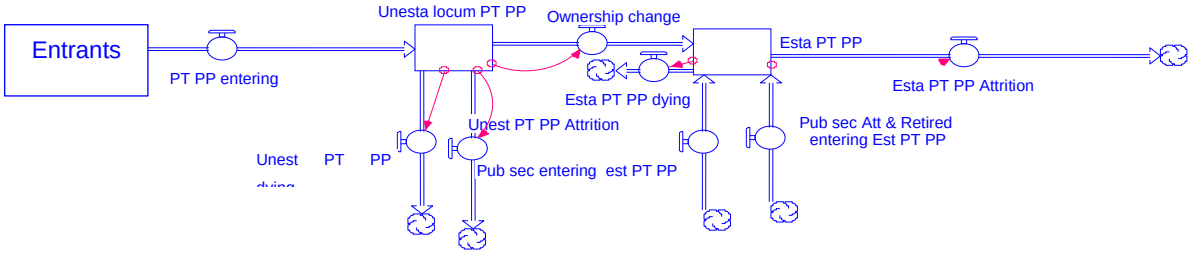


Figure 8.9. Locum part-time private practice career pathway

As stated above, the current ratio of 0.38:0.62 full-time private clinics to part-time private clinics in the country is used as the initial value. As shown by the pattern of employment category selection by newly qualified graduates over the past 15 years, when the waiting list for government employment gets longer and longer, they tend to consider entering full-time private practice more often than part-time locum practices. Therefore the percentage of newly qualified dental surgeons entering unestablished locum part-time practice is shown to decrease using the graphical function depicted in Figure 8.6, in keeping with the corresponding increase in entry to unestablished full-time private practice (until the ratio of full-time practices to part-time practices reaches 0.54:0.46, as per expert opinion, over the simulated period).

Common to both *unestablished full-time private practice* and *unestablished part-time private practice* is insecurity of employment, and hence it is always preferable to seek employment with the Department of Health. This is shown as a converter termed *Est employment seekers* (seeking established permanent salaried employment). A very small percentage (approximately 2%) of part-time locum practitioners, after working for many years in a locum practice, take over the practice, become the owner and continue to work there (De Silva, 1999). This is shown as a flow rate from the stock of *Unest locum PT PP* to *Est PT PP*

and is denoted as *ownership change*. It is kept at a constant 2% of the unestablished locum part-time private practices per annum over the simulated period, according to the results of a previous study (De Silva, 1999), modified to suit the present situation as per expert opinion.

As stated elsewhere, state sector-employed dental surgeons can do private practice after hospital working hours. Most of these dental surgeons do their private practice in the same town where their government hospital is situated, or at least within a 5-10 km radius, as shown by the empirical component of this research. These dental surgeons, by virtue of the fact that they are government hospital-employed dental surgeons, have experience (or at least the people of the area assume that they are experienced, as they work for the government hospital), and the goodwill earned by working in the area helps them to establish themselves in part-time private practice without having to go through the *unestablished part-time private practice* stock. This scenario is captured by the inflow termed *pub sector entering est PT PP* in the model. Furthermore, this inflow is linked to a converter termed *state sec emp new PT*, which denotes the state sector employees who enter part-time private practice while in government employment. According to expert opinion, in the model equation a time delay of approximately two and a half months is kept for the government dental surgeons to establish as part-time private practitioners.

A similar scenario is applicable to the government dental surgeons who either leave or retire from service and enter part-time private practice. This concept is captured in a converter termed *Pub sec Att & Ret entering PT PP*, and is linked to the flow rate of *Pub sec Att & Retd entering Est PT PP*. However, as per expert opinion, approximately two and a half months' time delay was allowed for these dental surgeons too, to get themselves established in the part-time private practice. Furthermore, after being in established part-time private practice for many years, few dental surgeons become full-time private practitioners. This group mainly consists of government-employed dental surgeons converting their part-time clinics to full-time on retirement, or after resigning from the government service. This is illustrated as an inflow from the *established part-time private practice* to *established full-time private practice*, termed *est PT to est FT*. This flow rate is kept constant at 2.5% per annum over the simulated period, as per results of a previous study (De Silva, 1999), and expert opinion.

8.2.2 Other features of the model

Again, we remind the reader that all the relevant data and mathematical formulae representing relationships between variables can be found in Appendix A7.

As identified by the first component of this research, in Sri Lanka 54% of state sector-employed dental surgeons are also engaged in part-time private practice. This means that creation of more government employment will also lead to more part-time private practitioners, which in turn will have a negative impact on new dental graduates entering the private sector, due to the competition from state sector-employed dental surgeons doing part-time private practice. This is an important feedback mechanism, which is captured in the model.

A very small number of dental surgeons in state sector employment and a large number of dental surgeons in un-established job categories change their employment (De Silva, 1999). This is captured in a converter termed *Changing job*. The changing job rate, which is an inflow to the stock *Entrants*, is influenced by dental surgeons changing their employment between different employment categories, denoted by the converter *changing job*. Those who change their job category have to go through the stock *Entrants.* According to expert opinion, there is a time delay of approximately three and half months for the process of changing jobs and securing employment in another category. This phenomenon is shown in the model calculations.

The attrition of dental surgeons is represented as outflows in the model. Only a small percentage of newly qualified dental surgeons leave the profession as soon as they graduate. The majority of them migrate to developed countries to start a career in dentistry. However, a small number of female dental surgeons go abroad to accompany their husbands, and remain housewives. In general, attrition is rare in all state sector employment categories, and in established private practices. When attrition takes place in state sector employment categories, it is mainly for outward migration from the country (De Silva, 1999).

The stock of dental surgeons in any job category could also be decreased due to death while in post. However this figure is limited, due to the small total workforce and the age distribution of the workforce (see Chapter 7).

Established employment seekers, shown as a converter in the model, is one of the key

concepts illustrated in the model. This converter captures the number of dental surgeons who are seeking permanent government salaried jobs at any given time (on an annual basis) during the simulation period. Established employment seekers are not considered as an accumulation, and hence not shown as a stock. These established employment seekers are engaged in unestablished private practice.

Waiting time for employment, also shown as a converter, is another key concept illustrated in the model. Here we are concerned with the time a dental surgeon has to wait to secure government sector employment (mainly in the Department of Health), which is deemed to be more recognized, stable and rewarding. The waiting time period is shown in months.

The model has captured all the possible scenarios pertaining to dental workforce and dental service provision or delivery. The dental workforce is expressed showing Full-Time Equivalent (FTE) dental surgeons for both private and government sectors separately, as well as a total sum for the country. Further, the FTE dental workforce is expanded to calculate the total number of dental surgeon hours available, taking into account government rules and regulations pertaining to leave for government-employed dental surgeons and the norms of private dental practice. Here too, the total number of dental surgeon hours is considered for private and government sectors separately, as well as a total sum for the country. The model also considers the population dynamics of Sri Lanka, thereby facilitating the calculation of different dental surgeon to population ratios as discussed in Chapter 7.

The total dental surgeon hours demanded to cater for the population's dental treatment needs are shown as a converter. The total demand hours are derived through the treatment needs, using the WHO recommended methodology, supplemented by the Sri Lankan Timings Inquiry, and fully explained in Chapter 7. The percentage of demand met is calculated by considering the total demand hours and total dental surgeon hours available.

8.2.3 Model outputs

The key model outputs are:

a) The number of dental surgeons seeking government employment;
b) The waiting time to secure government employment;

c) The numbers of dental surgeons in different service categories, such as the government sector and the private sector;
d) Total dental surgeon hours available and total dental demand hours;
e) Percentage of demand met;
f) Dental surgeon to population ratios.

A screenprint of the whole model, including all the connectors and convertors, is shown as Figure 8.9 overleaf.

8.3 Use of the model

The results from the empirical surveys and the total (treatment) demand hours, calculated according to the WHO/FDI (1989) methodology, were the main input data for the system dynamics model. After the model was tested for parameter variability and predictive validity, and parameterized with initial values, it was simulated for different alternative policy options, to explore various practical solutions to the impending problems pertaining to the dental workforce.

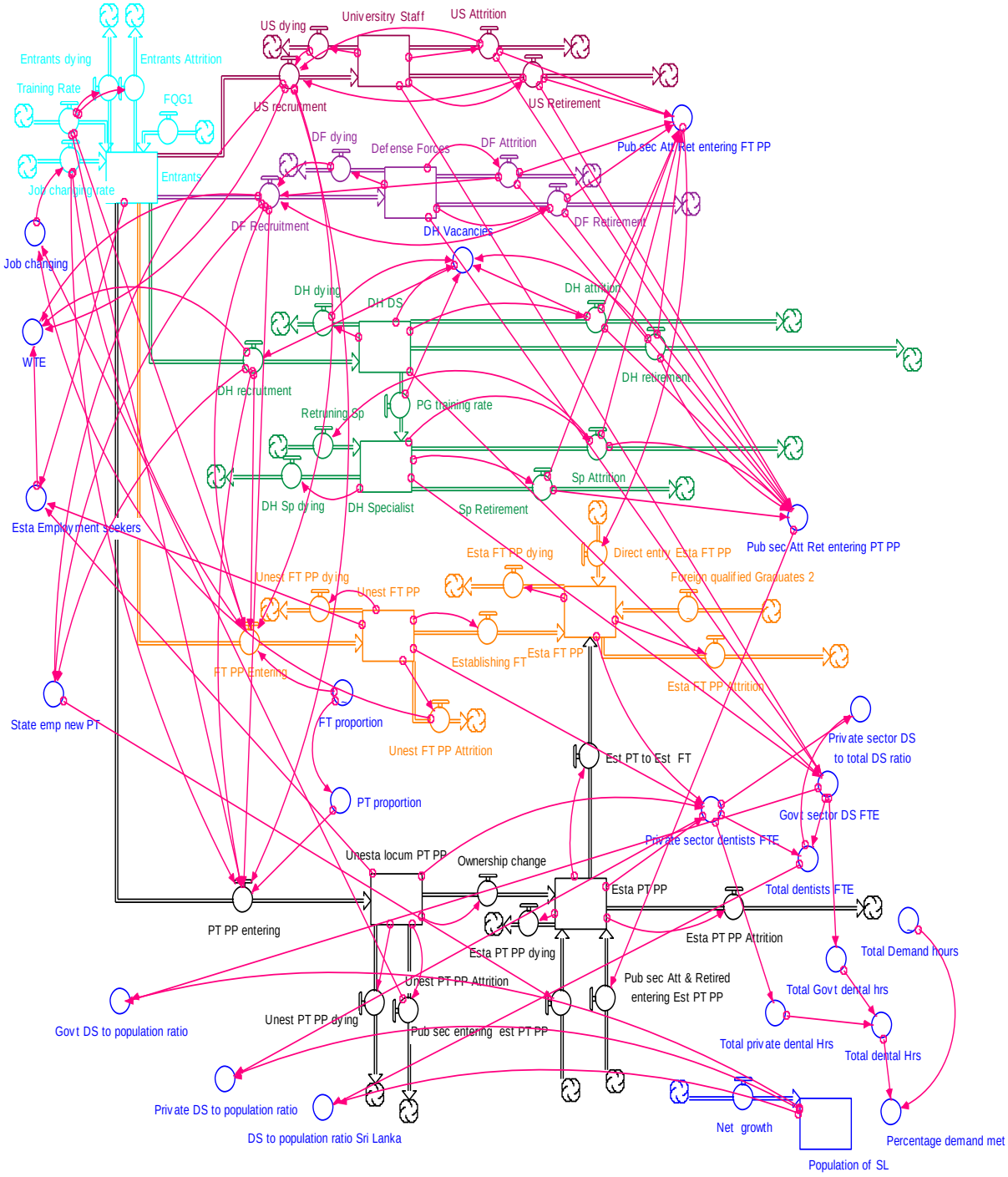


Figure 8.10. Screenprint of the entire Stella model

8.3.1 Results from the baseline scenario

Firstly the model was simulated over a planning horizon of 15 years for a particular scenario which (based on past trend analysis) was judged by expert opinion to be the most realistic and practical. This was called the 'baseline scenario'. The key concepts and features of the baseline scenario are as follows. The most sensitive parameters as identified by the sensitivity analysis (parameter variability) were addressed. The intake of 80 students to the University Dental School was to remain unchanged over the next ten years, and then to be increased up to 85 per year for the final five years of the simulation period. Furthermore, judging by the pattern of (new) employment creation for dental surgeons by the Ministry of Health, the number of vacancies was increased by 2% annually over the simulation period. In the model, supply (the availability of dental manpower) was shown as 'dental hours available'. In the baseline scenario, all other input parameters (such as employment opportunities in other sectors, private sector participation, migration and postgraduate training) were assumed to follow past trends. When the model was simulated on the baseline scenario parameters, the following results (key output parameters) were obtained, as shown in Table 8.2.

Table 8.2 shows the number of dental surgeons looking for government employment and the time period (in months) they have to wait to secure the same, throughout the simulation period up to the year 2025. The table also shows the improving dental surgeon to population ratios, total number of dental (manpower) hours available and the increasing participation in private sector dental care provision. It can be seen that over the simulation period, the dental surgeon (DS) to population ratio will improve from 1:11,295 to 1: 7,324. The improved dental surgeon to population ratio was mainly achieved by the increased participation in the private sector, as is evident by the vastly improved private dental surgeon to total dental surgeon ratio. This ratio increased by 44% during the 15 year simulation period under consideration.

Year	Employed by MoH	Training rate	Recruited to MoH	Retired from MoH	Government (established) employment seekers	Waiting time for MoH employment (months after graduation)	DS to population ratio	Private DS to total DS ratio	Total dental hours
2010	1050	80	43	10	250	57	11295	0.32	2328120
2011	1071	80	43	10	257	58	10825	0.33	2444990
2012	1092	80	44	10	264	59	10477	0.34	2562529
2013	1113	80	44	10	270	60	10154	0.36	2681198
2014	1135	80	45	10	274	60	9849	0.37	2801639
2015	1157	80	46	21	277	60	9543	0.36	2923168
2016	1168	80	57	21	280	50	9277	0.39	3043334
2017	1191	80	57	21	272	48	9012	0.40	3164051
2018	1215	80	58	21	263	46	8751	0.41	3291389
2019	1238	80	59	21	255	46	8751	0.40	3420068
2020	1262	85	59	14	247	42	8253	0.43	3550104
2021	1294	85	53	14	244	46	7994	0.44	3689737
2022	1319	85	54	14	248	46	7754	0.45	3831600
2023	1345	85	54	14	250	46	7533	0.45	3971425
2024	1371	85	55	14	252	45	7324	0.46	4112213

MoH-Ministry of Health. DS-Dental Surgeon

Table 8.2. Results from the Stella model - baseline scenario

Although the time period of waiting for government employment will shorten during the 15 year simulation period, it still remains unacceptably high, at 45 months, even by 2025. However, the number of dental surgeons seeking government employment will remain around 250 throughout the simulation period. Further, it may be observed that available dental hours will increase by 78% from 2.3 million to 4.1 million over the 15 year simulation period.

8.3.2 Scenarios assuming changing demand

Until now, we have highlighted only the supply side, or 'supply dynamics' of the baseline scenario. As explained earlier, demand for dental care was calculated through the need analysis methodology. The demand so calculated was considered under different scenarios, as shown below. The model was simulated for 15 years on baseline scenario parameters along with different demand scenarios, and the interactions between supply and demand were studied. In the model the number of dental (manpower) hours required was shown as 'demand hours' for treatment. Seven different demand scenarios were considered:

A. Demand to remain at low level throughout the simulation period

B. Demand to remain at moderate level throughout the simulation period

C. Demand to remain at high level throughout the simulation period

D .Demand to increase from low to moderate level during the simulation period

E. Demand to increase from low to high level during the simulation period

F. Demand to increase from moderate to high level during the simulation period

G. Moderate demand to increase by 1% annually over the entire simulation period.

The model gives the total number of dental (manpower) hours demanded under different demand scenarios throughout the simulation period.

The results of the interaction between supply and demand dynamics (total dental hours available against total dental hours demanded) over the simulation period is illustrated in Table 8.3 below. The table shows the percentage of demand met under different demand scenarios (A to G above) for a given year. When the 'percentage demand met' is less than 100, it is an undersupply, and when it is more than 100, it is an oversupply of dental hours (or, in other words, dental surgeons).

	Scenario						
Year	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Base	103.00	63.96	49.45	103.00	103.00	63.96	63.96
2010	108.17	67.17	51.94	104.01	102.27	66.39	66.56
2011	113.37	70.40	54.43	105.05	100.98	68.49	69.08
2012	118.62	73.66	56.95	105.73	99.27	70.26	71.53
2013	123.95	76.97	59.51	106.98	98.66	72.20	74.05
2014	129.33	80.31	62.09	108.20	97.48	73.98	76.59
2015	134.65	83.61	64.65	109.30	95.76	75.52	79.09
2016	139.99	86.92	67.21	110.53	95.39	77.09	81.40
2017	145.62	90.42	69.91	111.31	94.80	78.92	83.83
2018	151.31	93.96	72.65	111.50	93.87	80.90	86.25
2019	157.07	97.53	75.41	112.37	94.07	82.38	88.53
2020	163.24	101.37	78.38	113.40	94.11	84.09	90.97
2021	169.52	105.26	81.39	114.37	93.82	85.86	93.39
2022	175.71	109.11	84.36	114.61	91.75	87.74	95.97
2023	181.94	112.97	87.35	115.45	90.65	89.23	98.40
2024	188.19	116.86	90.36	116.86	90.35	90.35	100.66

Table 8.3. Results from the Stella model – percentage of demand met

Scenario A, constant low demand, results in a considerable oversupply of dental surgeons after 15 years. Scenario B, constant moderate demand, results in an undersupply of dental surgeons in the first 10 years, followed by an oversupply from 2020 onwards. Scenario C, constant high demand, unsurprisingly results in undersupply through the entire period.. In scenario D, where demand increases from low to moderate, we see an oversupply of dental surgeons throughout the entire simulation period. However scenario E, where demand increases from low to high, we have an oversupply of dental surgeons in the first two years followed by an undersupply throughout the rest of the period. Scenario F, where demand

changes from moderate to high, we obtain an undersupply of dental surgeons throughout the simulation period. Finally in scenario G, where demand is initially moderate but increases by 1% annually over the entire simulation period, we see an undersupply up to the year 2023, but in 2024, demand and supply will almost equalize.

In addition to the baseline scenario, the other different policy options considered in the SD model, based on suggestions from local policymakers and the dental community about what was plausible or achievable, were in the following broad categories:

- Reducing the number of dental surgeons trained per year;
- Introducing a voluntary retirement scheme for government dental surgeons;
- Placing restrictions on government dental surgeons doing private practice;
- Increasing private sector participation;
- Increasing employment opportunities in the government sector;

These policy options are now considered one by one. In Tables 8.4 to 8.8, "EES" denotes the number of dental surgeons seeking established employment in the Department of Health, and "WTS" denotes the waiting time in months to secure employment in the Department of Health after graduation. Table 8.4 illustrates the effect over 15 years of reducing the number of dental surgeons trained per year when the intake is reduced from the present level of 80 to 60, 50, or 40 students per year, respectively.

	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
60	EES	250	237	226	216	205	195	186	166	147	130	113	99	92	84	77	70
	WTS	57	54	51	48	45	42	33	30	26	23	20	19	17	15	14	13
50	EES	250	227	207	188	171	154	139	116	98	82	70	59	49	42	35	30
	WTS	57	52	47	42	37	33	26	22	19	17	14	12	10	9	7	6
40	EES	250	218	189	162	137	115	96	81	68	58	49	41	34	29	24	20
	WTS	57	50	42	36	31	26	23	20	17	14	12	10	9	7	6	5

Table 8.4 Employment scenarios for different annual student intakes

Introducing a voluntary retirement scheme for government-employed (Department of Health) dental surgeons was also considered. Based on past experiences and expert opinion of similar early voluntary retirement schemes, it was estimated that around 6-7% of Department of Health employed dental surgeons might opt to accept such a scheme. Table 8.5 shows the effects of a 5% and a 10% take-up.

	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5%	EES	250	204	211	216	221	224	227	219	210	202	194	191	195	198	199	200
	WTS	57	46	47	48	48	48	41	39	37	35	33	36	36	36	36	35
10%	EES	250	152	159	164	169	172	175	167	158	150	141	139	143	145	147	147
	WTS	57	34	35	36	37	37	31	30	28	26	24	26	27	27	27	26

Table 8.5 Employment scenarios for different % uptakes of voluntary retirement

We next considered the option of banning part time private practice by state sector employed dental surgeons. If this were to happen, there would be more opportunities in the private sector for new graduates, as there will be less competition in the private sector, especially in the part time segment which is where most state-employed dentists practice. Therefore the conversion of Unestablished FT PP to Established FT PP ("Establishing FT flow rate" in the model) was increased from 10% to 20%, while at the same time the conversion of established part time private practices to established full time practices ("Est PP to Est FT flow rate") was increased from 2.5% to 10% and the conversion of unestablished locum part time private practices to established part time practices ("ownership change flow rate") was increased from 5% to 25%. These percentages were derived through expert opinion. The outcomes are shown in Table 8.6.

	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	EES	250	216	191	172	157	145	136	119	105	94	85	84	90	93	95	97
	WTS	57	49	43	38	34	31	24	21	18	16	15	16	17	17	17	17

Table 8.6 The effects of banning private practice by state-employed dental surgeons

Increasing private sector participation by state-employed dental surgeons was another option considered. Two scenarios were modelled, a twofold and a threefold increase in the conversion of Un-established Full time Private practice to Established Full Time private Practice (the flow of establishing FT) and in the conversion of Un-established locum Part Time Private practice to Established Part time private practice (the flow rate of ownership change), respectively. The results are shown in Table 8.7.

	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2-fold	EES	250	240	233	226	219	214	209	193	180	167	157	152	155	156	156	155
	WTS	57	55	52	50	48	46	37	34	32	29	27	29	29	29	29	28
3-fold	EES	250	223	204	189	176	166	159	141	127	115	105	102	106	108	109	108
	WTS	57	51	46	42	39	36	28	25	22	20	18	19	20	20	20	19

Table 8.7 The effects of increasing private sector participation

Finally, we evaluated the results of increasing the number of Government sector posts. Table 8.8 illustrates the situation that arises with the immediate recruitment (at time zero) of 250 new dental surgeons to the Department of Health, followed by the recruitment of additional 150 dental surgeons over the simulation period (i.e. 10 extra per year over 15 years). This scenario would mean the creation of 400 new vacancies in the Department of Health over the whole 15-year period.

	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	EES	0	23	44	62	78	92	89	75	63	63	45	37	35	32	27	22
	WTS	0	4	9	12	15	14	12	10	8	7	6	5	5	4	3	3

Table 8.8 The effect of creating 400 new state-sector posts over 15 years

8.3.3 Graphical illustration of key results

Figure 8.11 is a Stella graph from the baseline run, showing the number of dental surgeons waiting for government employment and waiting time (in months) to secure the same. It shows that the two variables follow a similar pattern of change. Note that these two variables are plotted on different scales in Stella. The number of dental surgeons waiting for government employment (termed as established employment seekers) will be almost the same at the beginning and at the end of the simulation period, with a rise during the initial years. However the waiting time to secure government employment (WTE) will be much less at the end of the simulation period when compared to the beginning.

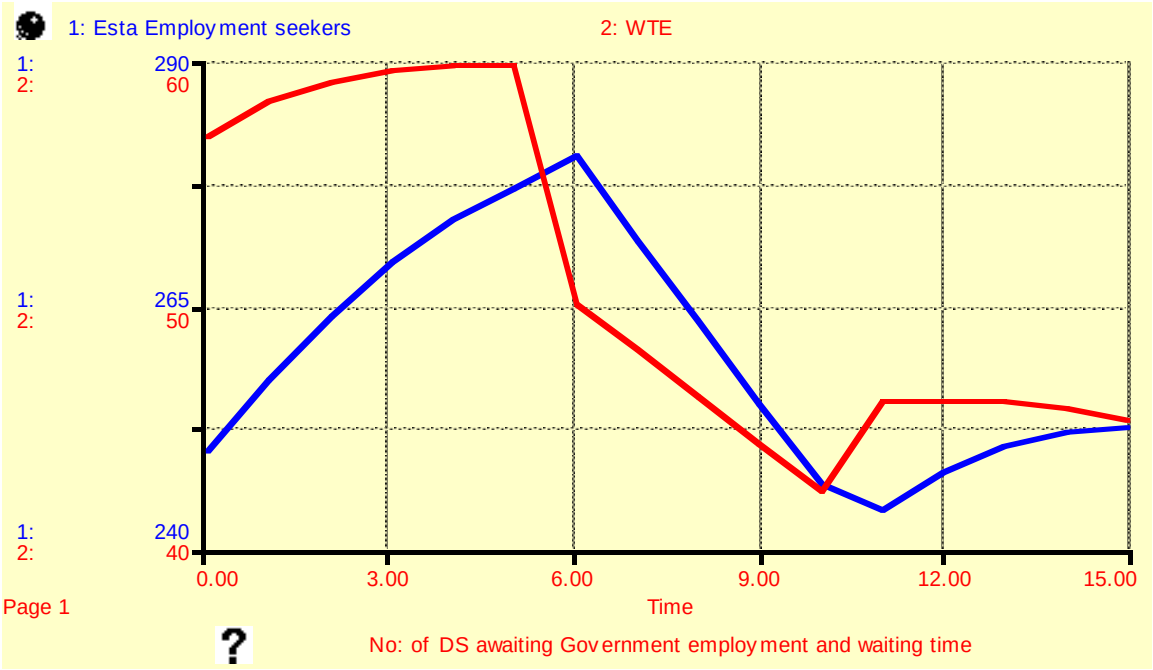


Figure 8.11. Number of dentists awaiting government employment, and waiting time

X- axis: Time in ***years****,*

Y-axis: Blue line- Esta Employment seekers: ***Number of dental surgeons*** *seeking state employment.*

Red line -WTE- *Waiting Time in* ***months*** to *secure state employment*

The scenario of moderate demand increasing by 1% annually over the simulation period (scenario G) was considered as the most probable demand scenario, according to expert opinion. Figure 8.12 illustrates this demand scenario with the total dentist hours available (supply dynamics) within the dental care system of the country. As shown in the figure, supply will lag behind demand until the 15th year of simulation, 2025.

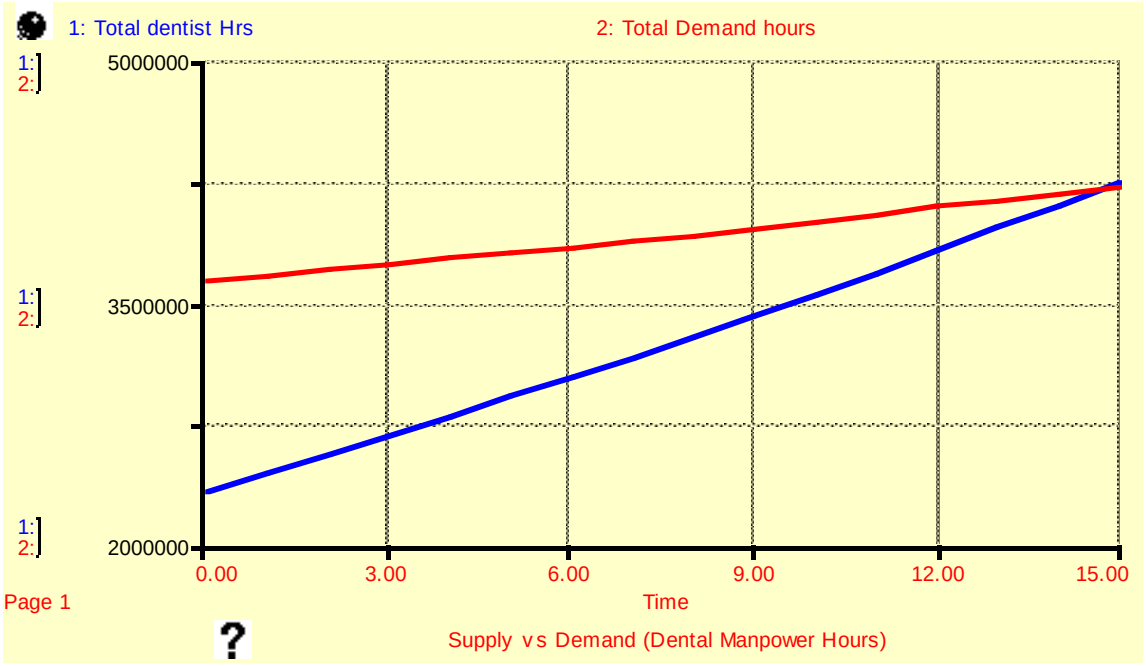


Figure 8.12 Supply and demand for dental care, scenario G

X- axis: Time in ***years***

Y-axis: Blue line-Total dentists ***hours;*** *Red line- Total demand* ***hours***

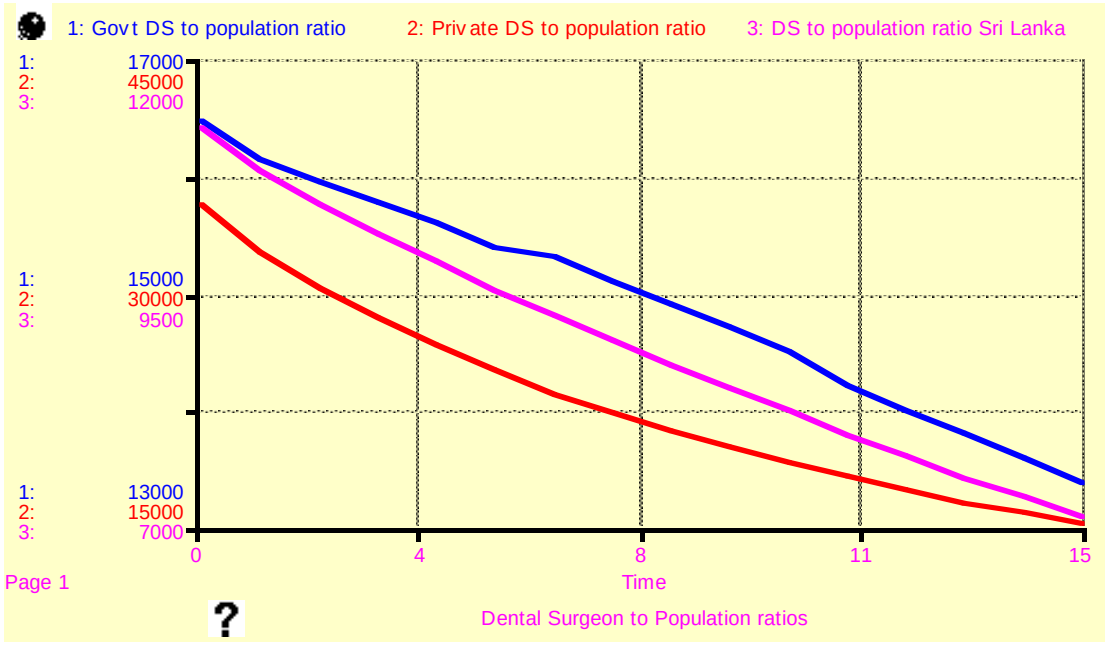


Figure 8.13 Dental surgeon to population ratios

X- axis: Time in ***years***

Y-axis: Blue line- Government ***dental surgeon to population ratio***

Red line- Private ***dental surgeon to population ratio***

Pink line - Sri Lanka's ***dental surgeon to population ratio***

As seen from Figure 8.13, Sri Lanka's dental surgeon to population ratio will improve from approximately 1:11,000 to 1:7,000 over the 15-year simulation period. This improvement in the dental surgeon to population ratio will mainly be achieved by the increased number of dental surgeons in the private sector.

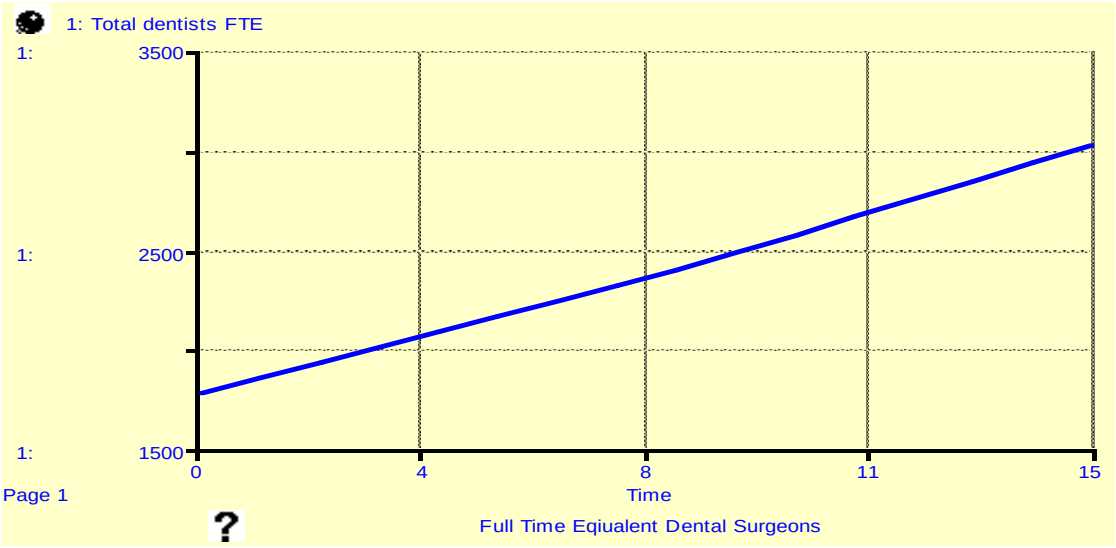


Figure 8.14 Full-time equivalent dental surgeons

*X- axis: Time in **years***

*Y-axis: **Number** of Full time equivalent dental surgeons*

Figure 8.14 shows that full-time equivalent dental surgeons will increase from approximately 1,800 to 3,000, or by 70% during the simulation period of 15 years from 2010 to 2025.

Figure 8.15 shows the increasing trend in the number of dental surgeons employed in Ministry of Health (MOH) and established full and part-time practices during the simulation period from 2010 to 2025. However it can be seen that the number of established full-time private practices showed the highest growth (from approximately 200 to 800, or 300%) followed by established part-time practices (from approximately 400 to 900, or 110%). Comparison growth in the number of dental surgeons employed by the MOH was small (from 1,000 to 1,400, or 33%).

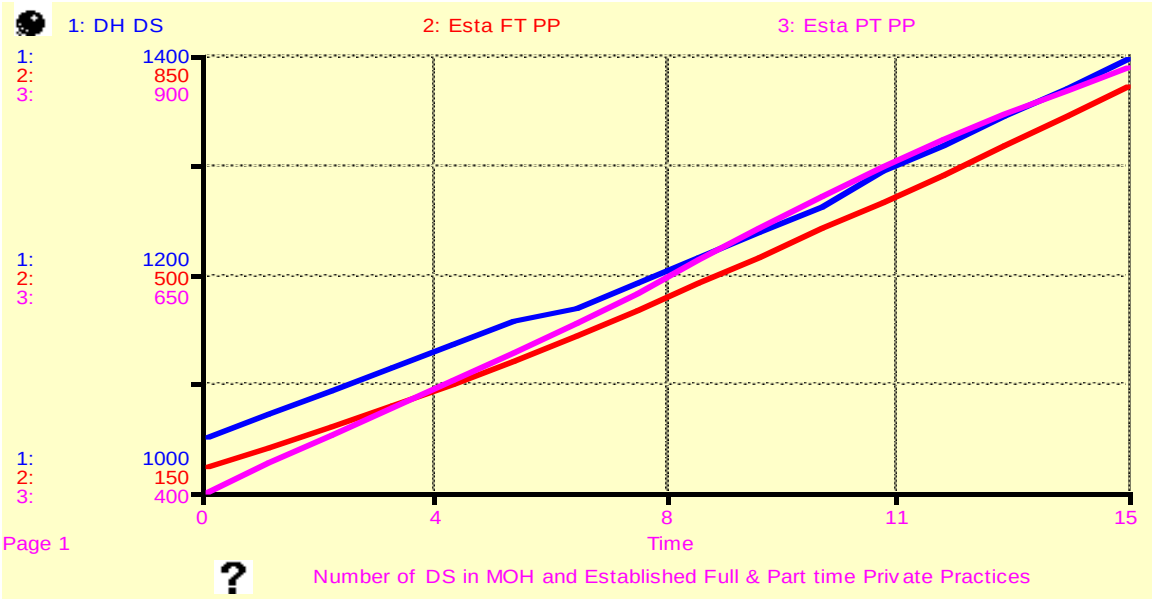


Figure 8.15 Number of dental surgeons in MOH and established full and part-time private practices

*X- axis: Time in **years***

*Y-axis: Blue line- **Number of** Department of Health dental surgeons*

*Red line - **Number of** Established Full time private practices/offices*

*Pink line - **Number of** Established Part time private practices/offices*

8.3.4 Summary of model findings

The model produced many outputs, but the most important output parameters were the number of dental surgeons seeking government employment, the waiting time to secure government employment, private sector service contribution, and different dental surgeon to population ratios. The model was designed to explain past behaviour and explore future policy scenarios. The model was simulated over 15 years, while exploring numerous policy options for better dental workforce planning in the development context. The different policy options, in both demand and supply domains were considered.

In the domain of supply dynamics, the results shown in Table 8.1 were obtained by simulating the model for 15 years, for a particular scenario which (based on past trend analysis) was judged by expert opinion to be the most realistic and practical, and was termed the baseline scenario. From the results of the baseline scenario we observed that:

a) There will be approximately 250 dental surgeons seeking government employment throughout the 15 year simulation period;
b) Although there will be a decline in the waiting time for government employment, it will still be around four years, even by 2024;
c) Sri Lanka's dental surgeon to population ratio will show a marked improvement over the next 15 years;
d) Private sector participation in dental care provision will increase over the next 15 years.

As far the dental workforce supply dynamics are concerned, the conclusion is that the supply of dental manpower will increase markedly over the next 15 years, and the available 'dental hours' in the system will grow by 78%. With stagnated or marginally increasing employment opportunities in the government sector, the private sector will be the main employer for dental surgeons in the future. However if the existing paradigm of seeking government employment by all graduating dental surgeons continues, there will be a long waiting time of three to four years to secure jobs in the Department of Health, even by 2025.

The dental surgeon to population ratio will improve markedly in the future. However even the ratio at the end of 15 years (1:7324) is far behind the present ratios of the developed world. In the UK and USA, the dental surgeon to population ratio in 2009 was 1:1976 and 1:1724 respectively (Malmö University, 2009).

We have analysed the demand for dental care under different scenarios. There will be an oversupply and undersupply of dental surgeons, under low demand and high demand scenarios respectively. Given the country's level of development, as evidenced by per capita income and the Human Development index, it could be argued that neither the low demand nor the high demand scenario will prevail. Further, considering the present political stability of the country and the fact that 25 years of civil war has ended, local experts believe that demand for dental care will increase in the near future. Therefore if we consider a moderate demand scenario, there will be undersupply during the first ten years, followed by oversupply from the eleventh year onwards. Furthermore, considering fast changing customer demand patterns due to better education, more awareness, increased buying power and the fact that people keep their teeth for a longer duration, we have considered another plausible scenario, where the moderate demand will increase by 1% annually. Under this scenario, which is accepted as the most likely scenario by the local experts, there will be undersupply up to year

2023. In year 2024, demand and supply will almost equalize.

8.4 Policy implications

We conclude this chapter by discussing the practical feasibility of implementing the five proposed alternative policy options.

The first possibility was reducing the annual student intake. It can be seen from Table 8.4 that even if the annual intake of students is reduced by 25% (from 80 to 60), there will still be around 110 trained dentists awaiting government employment, with a waiting time of 20 months, after ten years. Moreover even a drastic reduction by 50% (from 80 to 40) will lead to nearly 50 qualified dentists waiting for over a year for government employment after ten years. Table 8.4 shows clearly that reducing the intake will take a considerable amount of time (a minimum of 5 years) to yield results, due to the long undergraduate training period.

Moreover, at a policy level, neither of these options is practicable. Reducing the number of dental surgeons being trained will not be feasible, as the Government's policy is to provide more higher education opportunities. Furthermore, it would lead to underutilization of the training capacity. In addition there are strong lobby groups against curtailing free higher education. Therefore, it is clear that reducing the intake of dental students will not be a viable option.

The second option was introducing a voluntary retirement scheme for government (Department of Health) dental surgeons. Voluntary retirement schemes have been tried out before, with very limited success. However even if we assume that such a scheme to be successful in the future and 10% of the existing department of health dental surgeons will accept the scheme and retire from the government service, Table 8.5 shows that there would still be around 140 dental surgeons waiting government jobs after ten years and they would have to wait 24 months for such employment. Therefore, a voluntary retirement scheme cannot be considered as a solution to the problem under consideration.

Banning private practice for the state sector employed dental surgeons was never a serious option, for professional reasons. Given the fact that government doctors including dental surgeons have enjoyed the privilege of doing part-time private practice for nearly 35 years, restricting this in future will not be possible, as the powerful Government Dental Surgeons Association would object strongly to any such move. However, even if we assume that such a

ban on private practice would be implemented, it will not yield the results we would like. Table 8.6 shows that there will still be around 85 dental surgeons waiting for 15 months to secure government employment at the end of year 10. Therefore banning private practice by government employed dental surgeons is not a practical solution to the problem.

An increase in private sector participation would reduce the burden of producing government employment for dental surgeons. However increasing private sector participation is a less straightforward approach, as it is related to the wider socio-economic development of the country. Moreover, even if we assume a highly unrealistic 3-fold rise (300% increase) in private sector participation, Table 8.7 shows that there still will be around 105 dental surgeons waiting for government employment for more than 18 months by the end of year 10. Therefore this option is also not a viable solution to our problem.

The final option was to increase Government sector employment for dental surgeons. Table 8.8 shows if 400 new state-sector posts were to be created, of which 250 would be created immediately and the balance 150 spread equally over next 15 years, by the end of year 10 there will be only 45 dental surgeons waiting government employment and they would have waited only for 6 months for employment. Furthermore by year 15 there will be only 22 dental surgeons waiting for government employment, with a waiting time of 3 months. Therefore it could be argued that increasing the government sector employment would be one of the better options to address the impending dental workforce crisis in the country, because it is the government policy to provide free health care for all Sri Lankans, the majority of the people in Sri Lanka use free dental services provided by the government, provision of government employment for all graduating dental surgeons was the norm in the past, nearly all newly graduating dental surgeons seek government employment, and all professional bodies and trade unions support and endorse this move.

Chapter 9: Discussion

This chapter discusses the main practical outcomes and raises some policy implications resulting from the empirical aspects of this study. This discussion is enriched by the vast experience of the author and his professional colleagues. The author is a qualified consultant dental surgeon holding a doctor of medicine in Dental Public Health and a MBA degree with over 15 years' experience in dental health service management at the national level. His professional colleagues who were consulted for expert opinion are also post graduate qualified experts in dentistry with more than 20 years practical experience at regional, national and international levels. Some of these colleagues were clinicians, but the majority were health planners, health administrators and senior health managers. Moreover they represented both state and private sectors.

9.1 Summary

The present investigation may be seen as a piece of policy-oriented health services research at a fairly crucial juncture in the development of dental services in Sri Lanka. In Sri Lanka, all governments have been committed to a policy of economic liberalization since 1977. Secondly, broad trends in economic policy have been accompanied by a growing recognition of the role of the private sector in the provision of health care, amidst the inability of governments to afford the increasing high cost of modern health care. Thirdly, unlike in the past, where graduating dental surgeons in Sri Lanka automatically received government appointments, today entire batches of dental graduates are compelled to make a living in the private sector (at least for several years), due to rigorous controls in state sector jobs. Indeed, there have been periodic street demonstrations of unhappy dental students complaining of 'unemployment'. This situation has focused attention on the viability of private sector dentistry in Sri Lanka, amidst questions as to whether or not there is potential for dental surgeons to make a decent living in private practice. Finally, the rapid increase in the number of dental surgeons going into private practice has coincided with rising public anxiety about what is seen as a decline in medical ethics in Sri Lanka, especially in relation to private patients. The convergence of these four trends at the present time underlines the need for rational national policies regarding dental care provision, based on accurate scientific information. It is in this broad context that the present study was conceived.

Unlike the UK or other developed countries, as a developing country, Sri Lanka had no databases containing information on its dental workforce (De Silva, 1999). Therefore it was necessary to collect primary data on the current dental workforce in order to apply the operational research technique of system dynamics to address future dental workforce issues. Hence this study consisted of two main components: data collection, and modelling. The first part of the study concerned the empirical surveys used to collect data relating to the present and future dental workforce. As a result, the author was able to create a comprehensive and up-to-date list of names and addresses of all active dental surgeons in the country. They were served a postal questionnaire. Developing a database of dental surgeons was itself an achievement. In the subsequent years of 2010 and 2011, many dental professional bodies, as well as the Department of Health, requested and obtained information from this database for various activities of their organizations. As the methodology adopted to develop the dental database was generic in nature, it could easily be used to create databases for other health professionals. Further, the methodology used may be even suited for other developing countries with similar healthcare settings.

The results of the first part of study were used to advise the relevant authorities regarding the mal-distribution of the dental workforce, characteristics of private dental practices, importance of provision of in-service training and as input data for the SD model. The results of the SD model simulation were used to provide advice on deciding the correct number of dental surgeons to be trained according to the country's health needs and capacity to employ them productively.

9.2 Provision of dental care

9.2.1 Geographical distribution

The provincial concentration of dental clinics has to be viewed with the population of the province in mind. The Western province is the most developed and most densely populated province in the country, accounting for nearly 25% of the country's population. The country's commercial capital (Colombo) and administrative Capital (Sri Jayawardena Pura Kotte) are both located in the district of Colombo within the Western province. The country's sole dental school is located in the Central province, which accounts for 7% of the country's population (Department of Census and Statistics, 2009).

As shown by this study, Sri Lanka had a national average of 4.5 private dental clinics per 100,000 population in 2009, with marked disparity between districts and provinces.

As stated before, the dental surgeon or dental practice to population ratio tells us the number of practices there are in a given geographical area, and the amount of competition. However in the field of dental services, the reason to evaluate the potential of a given geographical area is not only to analyse the competition, which may be illustrated by the dental practice to population ratio, but also to understand the market for dental services. The market for dental services in the private sector can be understood by studying the per capita expenditure on dental care (for a given geographical area or region).

A hypothetical situation analysis (Radjabli, 2009) is used to explain the above theoretical notion. Suppose District X has a dental surgeon to population ratio of 2149, whereas District Y has a ratio of 2520. Based on the standard dental surgeon to population ratio, the two districts of X and Y seem similar, in fact Y is slightly better from the competition point of view, as it has a slightly lower number of dental surgeons per person (or higher dental surgeon to population ratio). Suppose furthermore that the hypothetical per capita expenditure on dental care of the two districts is 190 in district X and 100 in district Y. When per capita expenses are taken into account there is a significant difference, with almost twice as much per person spent in District X as in District Y. This example illustrates the fact that while there is the same amount of competition in Districts X and Y, the dental market per se is vastly different. However, if we use an adjusted dental surgeon to population ratio, which is a mathematical relationship which incorporates both competition and the dental services market, we obtain a different ratio: 2720 for District X and 1345 for District Y. Thus there is much higher potential in District X than in District Y, by virtue of the fact that there were a lower number of dental surgeons per person, or higher dental surgeon to population ratio in District X.

The inference is that the traditional dental surgeon to population ratio alone will not give a true picture about the potential of a locality in which to start a dental service. Therefore it highlights the fact that when evaluating a location, it is important to understand both the dental market as well as the competition in the area. Only the two factors combined can give a clear picture of the proposed site's suitability and potential as far as potential income is concerned. Furthermore, describing the dental workforce in terms of dental surgeon to population ratio, or number of dental clinics to population, whilst ignoring the productivity of the service provider, may not give the true picture of dental care provision and utilization.

As stated earlier, factors that affect the demand for dental care are also not well accounted for in the dentist to population ratio. Changes in the financing mechanisms have been shown to alter the demand for dental service (Robinson, 2004). Furthermore, technological changes may rapidly create changes in demand levels, and the establishing of a dentist to population ratio as acceptable or ideal may be arbitrary (Goodman, 1990).

Having considered all private dental clinics, both full-time and part-time, along with the population of the respective districts, the conclusion was that private dental care provision was highly concentrated in the Colombo district. Excluding the Northern and Eastern provinces and the districts of Nuwara-Eliya, Badulla and Moneragala, most of the other districts had a moderate level of private dental care provision, mainly provided by the Department of Health dental surgeons, working as part-time general practitioners after hospital working hours. The Northern and Eastern provinces cannot be considered in comparison to other provinces, due to the terrorist activities and civil war that prevailed for nearly 30 years in those two regions.

Misdistribution of human resources for health is a worldwide phenomenon and may appear in different dimensions. Moreover the concentration of health professionals in more developed regions within a country is a common occurrence, especially in developing countries (WHO, 2006). Therefore it could be stated that concentration of dental surgeons in the country's most developed regions (district or province) was not an issue unique to Sri Lanka. Exacerbated by misdistribution, interlinked with many other factors, inequalities in health are a problem in all developing countries, as well as the developed countries. Many countries reported increasing levels of health inequality during the 1980s and 1990s. However, countries differ in their definitions of inequalities in health and their assessment of the scale of the problem. Inequalities in health was most commonly presented as the difference in health status between socio-economic groups, but were also described by geographic location, employment status, gender and ethnic group (WHO-European Office, 2005).

Tackling inequalities is one of the main aims of all public health policies. However, the complexity of the causes of inequalities in health means that multifaceted, and therefore multi-sectored, action is required to tackle the problem. Interventions must address the macro environmental factors (income and education) and the physical and social environment, as well as adverse health behaviours and access to healthcare issues (WHO-European Office, 2006).

In the Sri Lankan context, private dental surgeons should be encouraged to set up clinics in rural areas. They should be provided with incentives to do so by the Government. Provision of capital to start dental clinics on easy repayment schemes, and tax concessions on motor vehicles for dental surgeons could be suggested as possible incentives. As far as government sector dental care provision is considered, the Ministry of Health should ensure that more dental clinics are opened up in the rural parts of the country, and should appoint dental surgeons to staff them.

9.2.2 Unqualified dental practitioners

On the topic of distribution of dental care providers, the distribution of unqualified dental practitioners (UDP) showed a similar pattern to the distribution of qualified dental surgeons. Most of the UDPs were practising in the capital district of Colombo, the Western province accounting for the highest number of UDPs. These were also the district and province, respectively, that accounted for the highest overall number of dental surgeons. This research finding thus rejects the anecdotal evidence that UDPs opened up clinics due to the lack of qualified dental surgeons. In previous studies of UDPs in Sri Lanka by Ekanayaka (1989) and De Silva (2007), it was found that the fees they levy were similar to the fees charged by qualified practitioners. The findings of the present study, as exemplified by the high positive correlation coefficients (+0.98) between the number of clinics manned by the qualified dental surgeons and unqualified dental practitioners illustrated in page 90, showed that UDPs were not substitutes for qualified dental practitioners , but they were in direct competition with them.

9.2.3 Private dental care provision by state-employed dentists

Permission to engage in private practice, after hospital working hours, was a privilege granted by the Government for all state sector-employed doctors and dental surgeons since the mid-1950s. This privilege was withdrawn in the early 1970s and reintroduced in the late 1970s. It was the belief of the Department of Health that at least three quarters of its dental surgeons were engaged in part-time private dental care provision (De Silva, 1999).

The results of this study revealed that dental surgeons from all three key state organizations, namely the Department of Health, Ministry of Higher Education (Universities) and Ministry of Defence, shared a more or less similar amount of participation in private dental care service provision. On average, half (50%) of state sector-employed dental surgeons were

engaged in private care provision after official (hospital) working hours. These results refuted the belief of the Department of Health, that nearly 75% of its dental surgeons were engaged in part- time private practice (De Silva, 1999).

9.2.4 Dental clinic staffing levels

The number of dental surgeons working in a government hospital dental clinic depended on the hierarchical status of the hospital. In rural and district hospitals, the dental clinics were manned by a single dental surgeon, while in larger hospitals there would have been three practitioners. In general and teaching hospitals there were four to five dental surgeons working in outpatient department (OPD) dental clinics. The three specialized dental hospitals had around 25 dental surgeons attached to OPD clinics. In addition to the above, the general, teaching and specialized hospitals had specialist/consultant dental clinics which were manned by three dental surgeons and a consultant. In total, the Department of Health operated around 700 dental clinics in the country.

This study also revealed that solo practices accounted for 97% of private dental practices, while group and other kinds of practices accounted for the balance of 3%.In the private dental care segment, solo practices tend to be the predominant service provider unit throughout the world. According to the American Dental Association, 79% of the nation's private dental surgeons are working alone in solo practices (ADA, 2006). In Australia the corresponding figure was 64%. (AIHW, 2008).

In a solo practice, only a single dental surgeon works (with an assistant or assistants). The solo practices have inherent advantages, all the patients being seen by the same dental surgeon every time they visit. Hence the patients may feel more at ease and comfortable, which will help make for a better dentist-patient relationship. It is unlikely that the treatment plan will change during the course of the treatment, as it is invariably the same dental surgeon who sees the patient. The entire profit from the practice is taken by the single practitioner. Therefore he/she is more motivated to improve the practice. Investment decisions are straightforward, as there is no concurrence to obtain from any other practitioner.

The main disadvantage of the solo practice is that the practice/clinic will be closed on the days the dental surgeon cannot attend the practice. In the long run, if the dental surgeon decides move to another region, the continuation of the practice will be in doubt.

Group practices are defined as practices formally organized to provide dental care through

the services of two or more dental surgeons. One reason for dental surgeons working together in group practices is to obtain economies of scale from sharing office space, equipment, supporting staff, information systems and discounts on bulk purchases. Furthermore, large group practices can afford to have assistants who specialize in support functions. Even in a group practice, the patients could be assigned to the same dental surgeon for all their treatment needs, but there is a possibility of being treated by different members of the group. Some patients do not like to be treated by different dental surgeons. In group practices, investment decisions have to be taken by all the group members concerned, which may delay certain investment plans. Finally, from the advantage point of view, a group practice will not be closed due to the absence of a dental surgeon. Further the 'going concern' of the practice is more guaranteed in group practices.

Less than 1% of the private dental clinics were limited to a specialty, meaning that almost all private dental clinics were involved in the provision of general dental care. The inference is that almost all private dental practitioners in Sri Lanka were generalists. A similar pattern could be observed not only in developing countries like Sri Lanka, but also in developed countries such as the USA and UK. More than a half of Sri Lanka's private dental clinics have been in existence for less than five years, while more than two thirds (nearly 70%) were less than ten years old. According to expert opinion, if the longevity of the present practice is considered as a proxy indicator for the stability of the practice, it could be stated that the majority of the private practices in Sri Lanka were not well-established. When a practice is still in its infancy, it nonetheless has to develop a client base, so the practitioners have to work hard, long hours to achieve this. Lack of a good client base may have a major impact on the income level of the practitioners.

The high output of dental graduates, at a rate of 89 per annum since 1997, combined with the scarcity of government employment, may have contributed to this outcome. Dental surgeons who graduated after 2008 are yet to receive government employment, and almost all of them are engaged in some sort of private practice. It is also evident that two to three years ago, the majority of new private dental clinics were established in the Colombo district. This pattern has now changed, and during the last two years, more and more new practices have been started outside of the Colombo district. According to expert opinion, a dental clinic was considered as 'young' when it had been in existence for less than five years. Accordingly at present an almost equal mix of 'young' and 'old' practices were to be found in Sri Lanka. This was because the results were from a cross-sectional study which gives a snap shot view

of the situation. With the existing trend of an increasing number of new practices starting up, the balance will shift to more young practices in the near future.

9.2.5 Dental appointments

In government dental clinics there was no appointment system for the first visit. Patients were treated on first-come-first-served basis in the outpatients department (OPD). However patients were given an appointment for subsequent treatment. For specialist clinics, patients had to be referred from the OPD. A similar appointment system to that of the OPD was in force in specialist clinics. Generally in both OPD and specialist clinics, routine appointments were given within a period of two weeks.

It is interesting to note that dental appointments stated that the patient had to come for treatment in the morning (between 8am-12noon) or afternoon (between 2-4pm) session on a particular date, but did not give an exact time. The natural tendency of the patients was to come as early as possible for the given session. This resulted in all patients booked for a particular session reporting at the commencement of the session, either at 8am or 2pm. Therefore even the patients coming with appointments had to be treated on a first-come-first-served basis. This appointment procedure led to long waiting times for consultations. In the Sri Lankan government hospitals counterpart in the UK- NHS hospitals - appointments were more precise, and stated the appointment at a particular time on a given date. However, in the NHS system, patients had to wait for a long period to obtain an appointment. Furthermore, the majority of clinics ran behind schedule, necessitating long waiting times for consultations, even though the patients came with a scheduled appointment.

Only 6% of the dental practices in the private sector used an appointment system. By contrast, in countries such as the UK, USA and Australia, all patients (other than the emergencies) had to book appointments prior to seeing a dental surgeon. However in the majority of the private dental clinics in developing countries, a prior appointment system did not exist. Furthermore, according to senior private practitioners, the majority of their patients who obtained prior appointments often failed to turn up for the appointment. This is a common problem seen even in the NHS in the UK. According to the British Dental Association (The Daily Telegraph, 2011) there are at least 3.5 million missed dental appointments in England a year making it more difficult for patients to access NHS care.

9.2.6 Profile of dental practitioners

The main reason for the relatively young (approximately 40 years old) cohort of dental surgeons in the country is the increasing number of dental surgeons trained, during the recent past, by the sole dental school in the country. Out of the 2,396 dental surgeons trained by the Dental School, University of Peradeniya in its long history, expanding over 60 years, nearly half have qualified during the last 15 years. The relatively young cohort of dental practitioners means that they will remain active within the system for a long time. This fact is very important in dental workforce planning.

The number of foreign-qualified Sri Lankan dental surgeons entering the local market is insignificant in absolute terms, as evidenced by the fact that there were only 36 of them for the last ten years. However what is significant is that the vast majority of them were children of the country's leading dental practitioners. The inference is that the more affluent well-established dental surgeons preferred their children to become dental surgeons, to continue their private practices. However the children of these dental surgeons may have been unable to enter the university Dental School, due to the intense competition for university admission. Having lost the opportunity for free university education, these children were sent abroad, spending heavily to study dentistry in private dental schools. On their return, they joined their parents and further expanded the already established private practices. Only two foreign-qualified Sri Lankan dental surgeons had obtained government employment during the last ten years. This shows that they were not keen on fixed salaried government employment, but preferred to be in the private sector.

9.2.7 Training and CPD

Capacity building of oral healthcare personnel could be considered as the cornerstone in influencing policy goals of ensuring quality and equitable oral healthcare services in developed, as well as in developing countries. Capacity building has been defined as an array of activities that strengthen the knowledge, abilities, skills and behaviour of individuals, and improve institutional structures (e.g. services, learning institutions) and processes to allow organizations to efficiently meet their missions and goals in a sustainable way (Talbot et al., 2009). Moreover, capacity building of healthcare workers, in terms of education and in–service training has been intrinsically interwoven into health-care systems (WHO, 1972). Furthermore, oral healthcare personnel in both public and private sectors in Sri Lanka have emerged as an important category of health workers who need skill/capacity building to keep

abreast with the advances and modernizations of concepts, practices and technologies in dentistry.

Regularly upgrading knowledge and skills, or 'Continuing professional development, is essential to maintaining high levels of professional competence in any profession. Lifelong Learning, Continuing Education, Continuing Professional Education, Continuing Vocational Training and Post Qualification Development are the commonly used terms to describe the concept of CPD. However, the study revealed that almost 50% of dental surgeons have not attended any CPD activity or in-service training programme, academic seminar, or conference related to dentistry for three years.

A dental surgeon's first degree, or primary qualification is only the first step in their education, which lasts throughout their practising life. CPD should ensure that all dental surgeons keep their knowledge current, and encourages the development of new skills, with the ultimate objective of better patient care, and to give patients confidence in the profession. A CPD activity could range from private study time to attending formal training programmes and courses. In developed countries all dental health personnel have to undertake CPD programmes to maintain their registration with the relevant regulatory bodies (Nieri, 2008). They offer diverse, multi-faceted educational activities, reinforcing awareness and the importance of lifelong learning, self-motivation, self-assessment and the development of self-learning skills. In the UK CPD was made compulsory for dental surgeons by the General Dental Council (GDC) in January 2002.

In the Sri Lankan health system there is no formalized CPD scheme, and neither is it necessary to attend courses or obtain a certain number of credits to renew one's registration with the Sri Lanka Medical Council to practise as a dental surgeon. Leaving aside the 4% of dental surgeons who undergo specialist training to become consultants (De Silva, 2007), for the vast majority of Department of Health dental surgeons, the only formal training they can obtain after obtaining their first degree (BDS), is after a minimum of six years of service. This is also only if they decide to do the post-graduate Diploma in Hospital Dental Practice (DHDP), conducted by PGIM, which is not mandatory as far as the Department of Health is concerned. Similarly, private sector-employed dental surgeons can do the Diploma in General Dental Practice (DGDP) after four years of working experience. The School of Dental Therapists (SDT) has no in-service training or programme for career advancement whatsoever for their students after passing out as SDTs. Moreover there is no formal training or in-service training conducted by the Department of Health for chair side assistants.

Due to the lack of organized CPD training courses or programmes, only a very few dental surgeons had the opportunity to participate in them, even though, in order to update their knowledge and provide a better service to the patient, it was of importance that they attended regular training programmes, conferences, or seminars on a regular basis. This lack of formal in-service training programmes for practising dental surgeons was a drawback in the Sri Lanka health delivery system. The vast majority of the dental surgeons had not been provided with any in-service training since their primary degree, right through until retirement.

Therefore, there is a long-standing need for provision of in-service training and activities pertaining to CPD for all categories of oral health personnel in Sri Lanka.

9.2.8 Dental workforce productivity

The international labour regulations of 37.5 hours' work per week is the generally accepted norm for all workers. In Sri Lanka, dental surgeons, especially those in the private sector, worked for longer hours and more days per week. The long hours of work could be due to either too many or too few patients. It was observed that young dental surgeons who were trying to establish themselves in the private sector were working longer hours when compared to their senior and more experienced counterparts. Private sector dental surgeons who had many patients spent more time in the clinic to cope with the demand. This is economically productive labour. The dental surgeons who had less, or no patients spent more time in the clinic waiting for patients. This was economically unproductive labour.

According to expert opinion in the Sri Lankan context, full-time and part-time private sector dental surgeons could treat 30 patients and 12 patients, respectively, per day, without undue work stress. Therefore judging by the median value of patients treated in Sri Lankan private dental clinics, it may be stated that full-time practices experienced more unproductive labour than the part-time practices.

Analysing the total number of patient visits in government hospitals against the total number of dental surgeons employed by the Ministry of Health, it is clear that the number of patients treated had not increased in proportion to the number of dentists employed. There may be many factors contributing to this observation. Provision of advanced treatment, better quality treatment by spending more time on patients, or less productivity, coupled with increased idling time could be the reasons. Furthermore, a controversial study had reported that in government hospital dental clinics nearly half the working time of dental surgeons was unproductive (Wimalaratna, 1997).

9.2.9 Ownership of private dental practice and clinic premises

The results of this study showed that the more experienced and mature dental surgeons tended to own their dental practices, as well as the premises. The majority of the inexperienced young dental surgeons preferred locum practices. The main reason for the above observation was that many dental surgeons in their early career start by working in locum practice. Once they have gained enough experience, they may decide to start their own clinic, initially in a rented building. Once their own practice is established they either purchase the clinic or relocate to a nearby building.

A clinic or a practice in a rented building is not the best of situations, for the 'going concern' concept and for the long term success of the practice. The going concern concept is one of the cornerstones of the financial accounting world. In essence, it says that the balance sheet of a company must reflect the value of that company if it is to remain in existence for or beyond the foreseeable future. When a clinic is located in a rented building, this vital economic concept is challenged. This is because the owner of the building can ask the tenant dental surgeon to leave, either at the end of the agreed period, or in extreme cases, with one month's notice, depending on the rental agreement. Therefore dental surgeons practising in rented buildings were reluctant to invest in their clinics, which in turn would affect the ability of the practice to attract new and high profile clients. Also the rent for premises is a major overhead which reduces the profits. On the other hand, the ownership of the clinic will motivate the dental surgeon to invest more in the practice as he/she is not facing the risk of being asked to vacate the premises.

As revealed by this study, dental surgeons preferred to locate their clinics in commercialized areas. Further, they believed that locating practices within a medical establishment such a channelling centre, nursing home, or medical centre would add more goodwill to the dental practice. It would enhance the stature and amount of recognition, and bring more publicity to the dental clinic. The public would identify the dental clinic with the name of the medical establishment. In some instances, it could be useful to share the patient waiting area, parking facilities, and even the services of the nurses.

In the district of Colombo, although 56% of the private clinics were located within commercial buildings, it was substantially less than the corresponding percentage (87%) in other districts. This difference is statistically significant at 95% confidence interval. In the district of Colombo, 44% of the dental clinics were located in residential buildings, as

compared to 13% in other districts. Colombo being the financial capital and the business hub of the country, there is a great demand for business premises. Therefore the comparatively high 'key money' (initial non-refundable deposit charged by the building owner) and the very high monthly rentals for commercial buildings may be a contributory factor to the locating of more private dental clinics in residential buildings in Colombo.

9.2.10 Types of dental treatment provided

The findings indicated that the vast majority of private sector dentistry in Sri Lanka is still limited to the provision of very basic, routine and less advanced dental procedures. The reasons for the above findings can be viewed from both service recipient and provider perspectives. Other than for the very affluent society, for the average Sri Lankan, routine dental visits for preventive care were not the norm. In Sri Lanka the majority of the people will go to the dental surgeon only when they have a (severe) toothache. Therefore by the time the patient sees a dental surgeon, it may be too late for the tooth to be restored with a normal restoration (dental filling). Under these circumstances, the dental surgeon is left with only two options, either to remove the tooth (extraction), or to preserve it by doing a root canal filling (nerve filling/endodontic treatment) and a crown.

Although there is a great need for advanced restorative treatments, the majority of Sri Lankans do not have the desire or capability to seek such treatment, mainly due to lack of knowledge or interest and financial capacity. Therefore, especially in the Sri Lankan private sector, barring the affluent districts of Colombo and Kandy, there was only a limited demand for nerve fillings, bridges and other advanced restorative procedures. Conversely, only a few dental surgeons practised the above treatment procedures outside the affluent districts.

In the private sector, it is not economically viable from the dental surgeon's point of view to undertake certain treatment procedures until he/she has a minimum number of patients demanding that particular treatment. For an example, a dental surgeon will not invest in dental implants if he/she gets only couple of patients per year wanting dental implants. Therefore even if there are a few patients who can afford advanced restorative treatment procedures, they have to be satisfied with less advanced procedures, as their dental surgeon is not offering what they require, unless they decide to change dental surgeon, or the dental surgeon refers them to a centre where the advanced procedures are practised.

The types of treatment provided at government dental clinics depended on the hierarchy of the hospital, as revealed by the Chief Dental Officer, focus group discussions, and the dental statistics of the Annual Health Bulletins (MOH, 2010). In rural and district hospitals, the treatment available was limited to dental extractions, and basic restorative and periodontal procedures. Base hospitals, which are further up in the hierarchy than the aforementioned types of hospitals, provided basic (anterior) root canal treatment in addition to the treatment available at rural and district hospitals. At the general hospital level basic prosthetic treatment, such as dentures were available in addition to the treatments provided by the base hospitals. Teaching hospitals (the highest in the hospital hierarchy), and the two specialized dental hospitals provided a larger spectrum of advanced treatment than the general hospitals.

There were only 14 consultant orthodontists for the whole country in the Department of Health in 2009, and they were based in a few key general and teaching hospitals and the two specialized dental hospitals. All orthodontic treatment was limited to hospitals where there was a consultant orthodontist. However specialist government dental clinics manned by consultant oral and Maxillofacial surgeons provided very basic and urgent orthodontic treatment occasionally in the absence of an orthodontist. There were 20 Oral and Maxillofacial Surgeons working in the Department of Health as of 2009 (Directorate of Dental Services, 2009).

In the case of advanced restorative treatment, procedures such as crowns and dental bridges were limited to government dental clinics, where a consultant in restorative dentistry was available. However, there were only six consultant restorative dentists in the country working for the Department of Health in 2009, and they were based in the two specialized dental hospitals. Dental implants were not done in any of the government dental clinics (Directorate of Dental Services, 2009).

According to the Annual Health Bulletins (MOH, 2008; 2010), more than half of dental surgeon activity was limited to the extraction of teeth. Lack of advanced restorative treatment, such as root canal therapy, is one of the main reasons for the high number of dental extractions seen in the government sector dental clinics. Further, as stated earlier, all dental treatment in government dental clinics was free to the patient.

9.2.11 Support staff in dental clinics

In the private sector, Dental Surgery Assistants (DSA) were the only support staff category employed in almost all private dental clinics in Sri Lanka. In the vast majority of the dental

practices, there was only one DSA. Nearly 95% of DSAs have had no formal training. Also they do not require registration with the Sri Lanka Medical Council. Even in the UK, over 55% of dental nurses (staff category analogous to DSA in Sri Lanka) have no formal training or registration in the General Dental Council (John et al., 2002). However, registration with the General Dental Council was recently made compulsory for dental nurses in the UK.(General Dental Council, 2009).

DSAs showed a very high job turnover. Low wages, lack of job security and poor career prospects may be the reasons for the high job turnover. Employing dental surgeons should take steps to retain their in-house trained assistants. Both horizontal and vertical job expansion could be utilized to motivate them. DSAs should be provided with in-service training. The minimum number of supporting staff, and the minimum amount spent on their salaries and other expenses reduce the overheads of the practice. This contributed to the high gross to net profit ratio in the Sri Lankan private dental care market.

In the Government sector, support staff were limited to a minor employee in the vast majority of the government dental clinics. However in the larger hospitals, a nursing officer was attached to the dental clinic, in addition to the minor employee/s. The nursing officers attached to dental clinics had received a three-year training programme in general medical care in government-run nurse training schools, and had opted to work in dental clinics. However, they had not received any formal training related to dental care other than the knowledge and experience gained by working in a dental unit. The nursing officers were registered in the Sri Lanka Medical Council. The minor employees, too, had not received any formal training. All staff members of the dental clinics were permanent employees of the Department of Health, and were on transferable posts. They were paid a fixed salary and other allowances by the Government.

Provision of training should be made for all support staff in the government dental clinics. As the majority of dental clinics had only a minor employee (labourer) as the support staff, they should be trained at least in basic infection control methods. All support staff, including the nurses, should be given training on dental materials and handling of dental equipment. This proposed training could be carried out either at institutional level, central level, or both.

9.2.12 Patient records

As revealed by this study, only about 10% of the private dental practices kept any records on their patients. However in the government dental clinics it was mandatory to maintain basic

patient information and clinical records. By convention all doctors/dental surgeons should keep patient records. Every practising dental surgeon has a responsibility and a moral obligation to maintain accurate good quality clinical records. Clinical records are an essential and vital component, fundamental to the process of the delivery of good dental care. At a micro-level, clinical records will contribute to patient management and ensure that patients receive appropriate and safe treatment. Furthermore, medical records will be of immense value in a case of litigation. Therefore the keeping of patient records is vital, both from a clinical perspective and from a legal point of view. At a macro-level, patient records will enable the practitioner to understand the need and demand for dental care. The importance of patient records has been clearly stated by the General Dental Council and reinforced by bodies such as the British Dental Association.

A major issue in government dental clinics in Sri Lanka was the accuracy and quality of the data in dental surgeons' monthly returns, and whether these were sent in on time to the centrally located Medical Statistics division. As revealed from the Annual Health Bulletins of the Department of Health, specialist dental units do not send any statistics to the Medical Statistics division. Further, there had been no statistics from the country's two specialist dental hospitals (MOH, 2008; 2010).

In the case of private dental practices, even the few who maintained patient records, statistics were not sent to any central database for analysing and planning purposes. Therefore there was no data maintained about private dental patients, or the private dental services of the country. Lack of accurate records at the clinic level extended to lack of information at a national level. This in turn has affected the planning and monitoring of dental service provision for the entire country.

9.2.13 Use of dental equipment and sterilization of dental instruments

It was interesting to note that Sri Lankan private dental clinics have followed dental clinics in the developed world in certain aspects, such as the utilization of modern electronic chairs, ultrasound dental scaling machines and light curing machines. However, private dental clinics in Sri Lanka have still not reached international standards in dental instrument sterilization methods. The 'water bath', or sterilizer was typically used in more than 90% of the private dental practices in Sri Lanka. As we live in an era of HIV and Hepatitis B, especially in the developing world, proper instrument sterilization should be one of the most important aspects in dental care provision. Usage of water bath or sterilizer is an outdated

method in the developed world. Today, no dental clinic in the UK uses the water bath or sterilizer for dental instrument sterilization. All dental clinics in the UK use autoclaves for dental instrument sterilization.

As far as the utilization and sterilization of dental equipment and instruments were concerned, most of the government dental clinics showed a similar pattern to that of private dental clinics. However, a few of the smaller hospitals, and nearly all large government hospitals used autoclaves for dental instrument sterilization.

9.2.14 The future dental workforce

The age at which a dental surgeon enters the profession is important from a manpower supply perspective. As revealed by this study, at the time of graduation most of the dental students were around 26 years of age. A contributing factor for the increased age at graduation was that more than half of the dental students had entered the university in their second attempt at the GCE Advanced Level Examination. Therefore Sri Lankan dental surgeons often start their career at the relatively high age of 26-27 years, when compared with other countries.

The present dental student cohort was 60% female. Therefore the number of female dental surgeons entering the profession from this cohort of students within the next five years will outnumber their male counterparts.

Of the students wishing to join the Department of Health, 82% hoped to engage in private practice on a part-time basis. This was statistically a significantly higher percentage, when compared with the 54% (as per the findings of this research) of the Department of Health dental surgeons engaged in private practice at present. Of the dental students planning to engage in either full-time or part-time private practice, 78% wished to set up their own practices. At present, nearly 70% of the private sector dental surgeons (both full-time and part-time considered together), worked in their own clinics. The above result showed an increasing trend of dentists working from their own clinics. Nearly a third of the dental students were planning to establish their future private clinics in the Colombo district (Western province). Only a very small percentage was willing to establish themselves in districts other than the Gampaha (Western province) and Kandy (Central province). Therefore the present trend of dental surgeons clustered in the Western province is to be continued. Further, the districts which are under-served at present will continue to be so, for the next five years at least.

One fifth (20%) of the present dental students wanted to do postgraduate studies. However, as at September 2008, only 4% of the dental surgeons were undertaking specialist post- graduate training at the Postgraduate Institute of Medicine, University of Colombo, the only postgraduate centre for medicine and dentistry in Sri Lanka. This finding showed that although many dental undergraduates wanted to do postgraduate studies once they graduated, availability of the limited postgraduate places, and hence, the intense competition, had prevented them from doing so. A country of 20 million population had only 49 specialist dental surgeons. The ratio of specialist dental surgeons to non-specialist dental surgeons in the Department of Health was approximately 1:25. This ratio was very low when compared to other developing countries (Malmö University, 2009).

As stated elsewhere, in Sri Lanka there were no private dental schools or universities offering either undergraduate or postgraduate dental degrees. The Faculty of Dental Sciences, University of Peradeniya and the Postgraduate Institute of Medicine, University of Colombo were the only institutions offering dental undergraduate and postgraduate qualifications respectively. Therefore the authorities should at least try to accommodate more trainees for dental postgraduate programmes at the Postgraduate Institute of Medicine, University of Colombo.

9.2.15 Gender issues in the dental profession

The study revealed the male to female dental surgeon ratio in Sri Lanka as 1:1.1. However the number of female dental surgeons entering the profession within the next five years from the present student cohort will outnumber their male counterparts by a margin of 20%. This will lead to an even more prominent presence of females in the dental profession in Sri Lanka. This is consistent with the worldwide phenomenon of more females entering the dental profession (Newton et al., 2000).

However in the private dental care segment, the male dental surgeons' contribution was significant. In the domains of participation in private dental care provision, clinic ownership, working from own premises and weekend practices, male dental surgeons contributed more than their female counterparts. Only in the domain of locum practices did the female dental surgeons contribute more.

As identified by this study, 54% of the Department of Health dental surgeons were engaged in part-time private practice. However when this percentage value was further analyzed, it was revealed that 70% of the male dental surgeons and 30% of the female dental surgeons

employed by the Department of Health were engaged in part-time private practice. When the number (percentage) of male and female Department of Health dental surgeons engaged in part-time private practice was compared, the difference was statistically significant at 95% confidence interval. The reasons for less female participation in private dental care provision could be multi-factorial, but they are likely to be mainly cultural, social and economic reasons.

Chapter 10: Conclusion

This final chapter summarises the main achievements (and limitations) of this research, discusses the academic contribution of the thesis, and suggests some directions for further research.

10.1 Summary

This study addresses the issues pertaining to the training of dental surgeons and the demand for dental care in Sri Lanka and considers its impact on the overall health system and on the country's development. As a result of this study, the Sri Lanka higher education and health authorities have taken active steps to address these issues, and the recommendations of the study have already begun to be implemented.

10.2 Research Contribution

The overall question underpinning this research was "How many dental surgeons does Sri Lanka need?" To answer this question, this study described the dentist workforce profile and developed a system dynamics model to address supply and demand dynamics of dental care provision and suggest ways to mitigate from the problem of dentists becoming unemployed or underemployed.

The methodologies used in the empirical surveys of this research (to identify dental workforce profile and dental clinic location) could be used in any country which lacks well maintained databases on its health human resources. The research findings helped to develop and update a comprehensive database on the dental workforce. Various governmental, professional and business organizations have already began to seek information from this database.

The study's results stressed the importance of continuous professional development and in-service training for the dental workforce. The Department of Health, having been convinced of this, has already commenced an in-service training programme for all dental care personnel for the first time in history, in the newly established Institute of Oral Health.

The first part of this research (empirical surveys) was carried out in order to describe the profile of the Sri Lanka dental workforce and to obtain input data for the second part of the research, which was in the broader discipline of system thinking. The second part of the research helped to better understand interdependency in the key determinants that govern the dental workforce dynamics.

The immediate achievement of this research was that it helped to generate employment for newly qualified dental surgeons who were awaiting government employment. Moreover, the overall result of this study has helped the Ministry of Health to achieve a sustainable, optimum dental health human resource utilization strategy, which could be an important component of the overall health development strategy of Sri Lanka.

10.3 Practical impact of the research

The SD model developed and used in this thesis has been kept generic in nature as far as possible. The training of dental surgeons and provision dental services in Sri Lanka is very similar to the training of medical doctors and the provision of general medical services. Both dental and medical undergraduates are selected by the University Grant Commission from a common GCE Advanced Level examination and are trained in state run universities in Sri Lanka. Moreover the career path of a medical doctor is similar to the career path of a dental surgeon in all respects, including engagement in part-time private care provision by the state sector employed health care professionals. Furthermore, the cultural influences in health care seeking behaviour, the professional setup and norms as well as the socioeconomic development of the country affect both dental services and medical services in almost exactly the same way. Therefore this model could be easily adapted for workforce planning of medical doctors in Sri Lanka. Furthermore within the boundaries of the model, with a few amendments to several input variables, it could also be used for medical laboratory technicians, radiographers and other similar health care professionals.

Due to its generic nature the model could be easily modified to suit many developing countries whose health care system is similar to Sri Lanka's. As a Commonwealth country, Sri Lanka shares many similarities in the provision of health care services with many other commonwealth countries.

The system dynamics model described in this research is easy to apprehend, even by the medical fraternity, generic in nature, and as described above it could be modified easily to

analyse different health- care professionals. Most importantly, using simulation modelling, this study was able to identify the dental workforce requirements to match the country's development. By illustrating various policy options with the model simulation for 15 years, the author was able to convince the Ministry of Higher Education and the Ministry of Health, that if the status quo continues, the dental workforce supply dynamics over the next 15 years will be almost the same as today. There will be around 250 dental surgeons seeking government employment throughout the simulation period from 2010 to 2025. Furthermore, although the waiting time to secure government employment will improve, it will be more than three and a half years, throughout the above period.

Based on this model illustration, the Ministry of Higher Education decided not to increase the intake of dentistry students for the next ten years. Moreover, the Ministry of Health also accepted the study results and was convinced, based on the advice and recommendations of the author, of the long-term adverse consequences of having unemployed dental surgeons. The Ministry decided to obtain special Cabinet approval to create 400 additional vacancies in the Ministry of Health within the next three years. With the implementation of this proposal, most of the country's dental treatment needs could be met, while harnessing the potential of trained dental manpower in a productive manner to enhance the country's health development.

The model showed that the creation of these 400 new vacancies (together with controls on the training rate of dental surgeons) will enable the supply and demand for dental surgeons to stabilize to an acceptable level. Hence future dental surgeons will have better employment opportunities in the state sector. They will be able to cater for the country's dental health needs, while one of the basic aims of higher education, the building of human resource capacity by facilitating the transfer of knowledge for practical benefit, will be achieved. Moreover, Sri Lanka, being a developing country, will not be wasting scarce resources to train dental health professionals who will not contribute at optimum level to the nation's health development.

10.4 Limitations

System dynamics models by definition seek to predict dynamic implication of policy but do not provide numerical forecasts. Furthermore SD models cannot be used for point prediction or optimization. The SD model developed and simulated in this thesis generated a policy

tool to explain the behaviour of the complex issue of dental workforce planning in Sri Lanka. Though the overall results of this model simulation would be of immense importance to the Sri Lanka health policy makers and other parties concerned; David Lane (2000) had argued that in general SD models are never more than 40% accurate.

Model conceptualization is one of most important and curial phases in SD model development as it laid the foundation for both qualitative and quantitative analysis. The conceptualization of the model described in this thesis was heavily if not entirely depended on the author's experience about the "system" under consideration. As there is limited formalization of the conceptualization process in SD modeling; initially it may be difficult for a newcomer or to an outsider to apprehend the SD model discussed here.

The school dental therapists who cater for school children up to the age of 13 years have not been considered either in the empirical surveys or in the SD model due to time and logistic constraints. However this limitation is relatively less important due to the following reasons,

- School dental therapists work only in the government sector and they are not entitled to engage in private dental care provision.
- Their service coverage is less than 5% of the target population (Family Health Bureau, 2011)

In supply dynamics the author has calculated the "total dentist hours" by considering the number of full time equivalent dentists, the number of days of work (per year), the number of hours of work per day as per the results of the empirical survey and the dentists' productivity according to expert opinion. In deciding the productivity these experts had considered the government and private sector dentists separately. The experts, in the case of government dentists had considered the number of leave available, level of absenteeism, lack of financial incentives for treating more patients, and lack of motivation of staff in deciding productivity. In the case of private dentists, experts had considered the level of absenteeism, the financial gains by treating more patients and the motivation of staff to be competitive, in deciding the productivity. Although experts have considered a wide range of factors in determining the dentists' productivity, the lack of a comprehensive scientific investigation to analyze the productivity could be considered as a limitation of this research.

This study has highlighted the fact that unqualified practitioners were the third largest group of dental practitioners in the country and that they were in direct competition with the qualified dental surgeons. Though their services are illegal they do a substantial volume of

work, as implied by their number. However the SD model has not considered their "service" contribution.

Judging by the past records of the Faculty of Dental Sciences and the Post Graduate Institute of Medicine there had been approximately 1% undergraduate and 5% post graduate dropouts. Though the absolute number of dropouts was small and hence its impact on the overall system was minimal, these rates should have been accounted for in the SD model, which has not been done. The SD model also assumes that all dentists in the department will retire at 60 years of age, which the maximum age for retirement. Though this had been the pattern in the past, whether the same trend will continue in the future is debatable.

Another limitation of this research was the method used to identify the demand for dental care. This method was proposed by the WHO and FDI, two of the key international organizations involved in dental health planning and development. In this method, disease prevalence both at the present time and in the future among different age cohorts was considered, while dental need was converted to demand using certain percentage values termed 'modifying factors'. These modifying factors had been calculated by an international expert panel, taking into account a wide range of issues in the social, political, economic, education and health sectors of particular countries. However, Bronkhorst et al., (1991) has criticized the WHO/FDI methodology stating that in "calculating needs for restorative and prosthetic care it had looked at what had happened in the past and assumed that same will happen again in the future" and challenging the appropriateness and validity of deriving the modifying factors to convert need to demand.

In retrospect, bearing in mind the perspective that operational research tools and techniques have long been applied to a similar issues, the author also feels that the need analysis and the calculation of demand for dental care would have been more comprehensive and complete had he used an OR methodology, which could not be done due to lack of data and time constraints.

Oral cancer is the number one cancer in males in Sri Lanka (Cancer Registry, 2009). Almost all oral cancers are surgically removed by the Maxillo Facial surgeons, which is a sub specialty within the field of dentistry. However due to lack of data, the complexity and the spectrum of the treatment involved, the treatment need for oral cancers was not included in the need-demand analysis and therefore not accounted for in the SD model. Moreover the "Sri Lanka Timing Inquiry" concentrated mainly on non-specialist dentists and on general

dental services. Hence it did not consider the "timings" of the complex and complicated specialist services such as maxillo-facial surgery, orthodontics and advanced restorative treatment. This was again due to time and logistic constraints.

The conversion rates of unestablished part-time and full-time private practices to established part-time and full-time practices respectively, and the conversion rate of established part-time to full-time private practice, are based on past trend analysis and expert opinion. Considering the economic development Sri Lanka is experiencing, especially in the post-war era, one would challenge whether the past patterns would hold true. Further as noted in the literature review dental care is a service commodity with high income elasticity of demand. Though the "influence of the income" on dental demand was considered by the experts in deciding above conversion rates, lack of a comprehensive economic evaluation of the dental demand was a limitation in this research.

10.5 Further research

There have been only three published articles (Ekanayake, 1989; De Silva, 2007, 2012) about unqualified dental practitioners (UDP) in Sri Lanka. These were limited to charges levied by UDP, and their geographical distribution, respectively. As revealed by this research unqualified practitioners were the third largest group of dental practitioners in the country. Taking into account the magnitude of the problem, and the facts that these untrained workers cause more harm than good and, in some cases, do irreparable damage to the patient (De Silva, 2012) and that blood borne diseases such as HIV and Hepatitis B could be easily spread due to the use of unsterile instruments in unqualified practices, it is crucial, important and timely to further study on this topic. Therefore further research could be suggested to analyze the "service" contribution by the unqualified practitioners. Considering the nature of the problem and means to control it, collaborative research by dental and legal professionals could be proposed.

The method of calculating the productivity of dentists was a limitation in this research. A variety of methods including the share of time health workers spend on clinical activities (Chaudhury, 2004) the number of health services provided (e.g. doctor's visits or inpatient days) by a particular type of health worker (Vujicic et al, 2009) could be suggested in a future research of productivity of dentists, in the absence of a universally accepted "gold standard"

measure of health workforce productivity.

Training of health manpower in general and dentists in particular is not a standard universal product which can be applied unchanged to every country. The training should be geared to the country's needs and the capacity to employ the trained manpower gainfully. It transpired in the empirical survey that Sri Lanka has one of highest "training rate" for dentists in the region, which has contributed to the problem this research is attempting to answer. Therefore research in the broader field of dental health manpower training would be appropriate and timely. In this perspective not only the training of dentists, but also the training of dental auxiliaries such as school dental therapists and dental laboratory technicians should to be evaluated.

Future studies using operational research theories and tools in the domain of demand for dental care would be suggested. One such approach would be to construct a conceptual map using qualitative SD approaches, considering the lack of data availability. Subsequently a quantitative SD model can be developed to analyze the demand patterns for dental care. The model can be populated with demographic data, treatment need data, and treatment seeking behavior to simulate patterns of demand and system bottlenecks. Using simulation, effects of different demand scenarios can be analyzed combined with the supply sub model of the SD model described in this thesis. Moreover healthcare problems are complex and exhibit both detail and dynamic complexity. In this perspective it could argued to use a hybrid model to address dental workforce issue in Sri Lanka. In the case of a hybrid model discrete event simulation would be able to address the problem components exhibiting detail complexity, while system dynamics, with its focus on a holistic perspective, would be able to comprehend dynamic complexity (Chahal, 2008).

As there is no evaluation of specialist dental services in Sri Lanka, future research in this subject area could be proposed.

With the end of a 30 year long conflict in Sri Lanka, presently the country is undergoing rapid development. It has already moved upwards into a middle income country during the year 2012 and is experiencing a reverse migration. As explained elsewhere dental care is a service commodity with high income elasticity of demand. Therefore research in the domain of dental economics, to analyze how demand for dental care will change in the backdrop of a rapid social and economic development could be appropriate.

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Appendices

A1. Postal Questionnaire to all practising dentists

Confidential

Questionnaire for Dental Surgeons registered in the Sri Lanka Medical Council

1) Age

2) Gender Male Female

3) Ethnicity Sinhala Tamil Muslim Other

4) Civil Status Married Unmarried any other

5) If married is your spouse a dental surgeon? Yes No

6) Is any of your children a dental surgeon or a dental student (either in Sri Lanka or abroad)

Yes / No

7) Did you graduate from University of Peradeniya Yes / No

8) If yes, from which district did you enter the university ?.....

9) In which year did you graduate**?.....**

10) In which district do you reside at present? .....

11) What is your primary occupation? Please mark one response only

Grade dental surgeon in the Department of Health	
Medical administrator in the department of health	
Consultant in department of Health	
Dental surgeon in the Defence Forces (Army, Navy, Air Force, Police)	
Consultant in the Defence forces(Army, Navy, Air Force, Police)	
University Teacher (Professor/ Senior Lecturer/Lecturer)	
General Dental Practitioner	
Dental surgeon working in a Private Hospital	
Any other. Pl specify	
Currently not employed	

12) In which district do you work at present?.....

13) When did you last attend a continuing educational program?

a) More than 2 years ago
b) More than 1 year ago
c) More than 6 months ago
d) More than 3 months ago
e) Within last 3 months

14) Do you do private practice ? Yes / No

If your answer is "No", please do not proceed beyond this question. Thank you very much for participating.

15) If the answer is "Yes" for question 14.

a) Are you engaged in full time private practice? Yes / No

b) Are you engaged in Part time private practice? Yes / No

16) Do you work in

a) Own private clinic
b) Locum practice
c) Group practice
d) Any combination of above a,b or c
e) Any other arrangement? Please specify .....

17) If it is your own private practice, who owns the premises?

a) You are the owner
b) Is on rent
c) Any other arrangement

18) In how many private clinics/hospitals do you practise at present? .....

a) 1 b) 2 c) 3 d) > 3

19) Where is/are the private practice/s located ? Please indicate the district/s.....

20) For how long have you been practising at the present clinic/s? .....

21) Is/are your private practice/s limited to a specific specialty such as oral surgery, orthodontics or restorative dentistry? Yes / No

22) Do you see patients by appointment only? Yes / No

23) How many hours per day and how many days per week do you do private practice?

Weekdays- hours per day..... days per week.....

Weekends -hours per day..... days per weekend .....

24) On average how many patients do you see/treat for a day in the private practice?

Weekday.....

Weekend.....

25) On average how many patients do you think that could be seen/treated for a day (without working extra hours etc) .....

26) Out of the following, what treatment modalities do you offer to your patients?

Anterior Root canal	
Posterior Root canal	
Removable Orthodontic appliances	
Fixed Orthodontic appliances	
Bridges	
Implants	
Surgical removal of impacted 3rd molars	
Periodontal surgery	
Soft tissue biopsy	
Dentures	
Any other- please write	

27) Do you stock medicine (drugs) in your practice to be issued to your patients? Yes / No

28) If the answer to question number 27 above is yes, what type of medicine (drugs) do you stock? Please write the group of the drug: eg antibiotics, ...

29) In your private practice: please indicate about the employment of other staff categories, availability of basic facilities, Equipment, X-ray facilities, patient record keeping. For staff, please indicate (if you employ such staff)

- how many, gender, and age
- Education qualifications
- Any formal training?

- How long have they worked for you?
- Do they wear uniform?
- How much are they paid?

Dental surgery assistant ☐ ☐

Receptionist ☐ ☐

Dental Lab Technician ☐ ☐

Labourer ☐ ☐

Electricity ☐ ☐

Pipe water ☐ ☐

Water bath/sterilizer ☐ ☐

Autoclave ☐ ☐

Electronic dental Chair ☐ ☐

Scaling Machine ☐ ☐

Light cure machine ☐ ☐

Dental X- Ray ☐ ☐

Patient record keeping ☐ ☐ If yes, manual records or computerized records?

30) Where applicable please indicate the average fees you charge for following treatment .

Treatment type	**Fee(Rs)**
Consultation/other	
Temporary restorations	
Extractions	
Amalgam restorations	
GIC restorations	
Scaling	
LCC restorations	
Post Crown	

Partial dentures	
Removable Appliances	
ARCT	
PRCT	
Full dentures	
Bridges(1 unit)	

Any you have any comments about this survey please write here:
.....
.....
.....
.....
.....
.....
.....

Thank you for your participation

A2. Dental Students' questionnaire

Questionnaire for Dental Undergraduates

Confidential

1) Age

2) Gender Male Female

3) Ethnicity Sinhalese Tamil Muslim Any other

4) Civil status Married Unmarried

5) If you are married is your spouse a dentist, or a dental student? Yes / No

6) Is/was your father or mother a dentist? Yes / No

7) In which year did you enter the university?

8) In which attempt at GCE Advanced level examination did you enter the university?

a) First b) second c) Third

9) From which district did you enter the university? .....

10) Before entering the Faculty of Dental Sciences as a dental student, did you know that there was an unemployment problem for dentists? Yes / No

11) Now as a dental student do you know that there is an unemployment problem for dentists in Sri Lanka? Yes / No

12) What do you plan to do after graduating as a dentist/dental surgeon? (mark only one response)

a) Join the department of Health
b) Join the university staff
c) Join the defence services (Army/Air Force/Navy/Police)
d) To work full time in the private sector
e) Find employment in another field
f) Not yet decided

13) If you join the department of health (or government service) as a dental surgeon, do you intend to engage in part time private practice ? Yes / No

14) If the answer to question 13 above is yes; what sort of private practice do you plan to do?

a) Practise in your own surgery

b) Practise as a locum practitioner

15) If the answer to question no: 14 above is response a); in which district do you want to set up your practice? .....

Thank you for your participation

A3. The Sri Lanka Timings Enquiry

RESTORATIVE TREATMENT RECORD SHEET

(Please use one sheet for each patient)

1) Name of the Hospital ……..……..

2) Date…….……

3) Time in (please write the actual time the patient enters the treatment room/surgery, e.g. 9.30 am, 10.45 am etc) …….

4) Time taken for Examination (Please state in minutes)……..

5) Time taken for Diagnosis and Treatment Planning (Please state in minutes) ……

6) Mark the tooth you have decided to restore/fill.

(Consider only one tooth) 8765432112345678

8765432112345678

or EDCBAABCDE

EDCBAABCDE

7) Please **underline the type of restoration** you are going to perform on the selected tooth (select only one treatment option eg Temporary Filling, Amalgam Class II, Root canal 2nd visit etc)

A) ZnO-Eu Temporary Filling.

B) Amalgam Filling which is a) Class I b) Class II c) Class V d) MOD

e) Any other Please specify……

C) Light Cure Composite which is a) Class I b) Class II c) Class III d) Class IV

e) Class V f) Any other Please specify……..

D) Chemical Cure Composite which is a) Class I b) Class II c) Class III d) Class IV

e) Class V f) Any other Please specify……..

E) Glass Inomer Cement (GIC) which is a) Class I b) Class II c) Class III d) Class IV

e) Class V f) Any other Please specify……..

F) Root Canal Treatment (RCT) a) 1st visit b) 2nd visit c)3rd visit

(For permanent teeth only) d) Final visit e) Any other-Please specify……

8) Time taken for above selected treatment in minutes……..

9) Time out (Please write the actual time the patient leaves the treatment room/surgery e.g. 10.15 am, 11.30 am etc) …….

PERIODONTAL TREATMENT RECORD SHEET

(Please use one sheet for each patient)

1) Name of the Hospital ……..

2) Date…….

3) Time in (Please write the actual time the patient enters the treatment room/surgery e.g. 9.30 am, 10.45 am etc) …….

4) Time taken for Examination (Please state in minutes)……..

5) Time taken for Diagnosis and Treatment Planning (Please state in minutes) ……

If the treatment is only Oral Hygiene Instructions and/or brushing advice; please go to question number 8)

6) **Underline the TREATMENT** you are going to perform on this patient (please underline only one response)

A) Anterior scaling (using hand instruments)

B) Full mouth scaling (using hand Instruments)

C) Anterior Scaling (using electronic scaler)

D) Full mouth scaling (Using electronic scaler)

7) Time taken for above selected treatment in minutes……..

8) Did you give Oral Hygiene Instructions and/or brushing advice **before or after any of the above treatments** ? Yes/No

9) If the answer to the question number 8 above is "Yes", how many minutes did you take ? …….

10) Time out (Please write the actual time the patient leaves the treatment room/surgery e.g. 10.15 am, 11.30 am etc) …….

TOOTH EXTRACTION TIME RECORD SHEET.

Only simple extractions are considered. Please keep the patient in the dental chair until anaesthesia is obtained, checked and extraction is completed. (Please use one sheet for each patient)

1) Name of the Hospital …….

2) Date……..

3) Time in (Please write the actual time the patient enters the treatment room/surgery, e.g. 9.30 am, 10.45 am etc) ……

4) Time taken for Examination (Please state in minutes)……..

5) Time taken for Diagnosis and Treatment Planning (Please state in minutes) ……

6) Mark the tooth you have decided to extract.

(Consider only one tooth) 8765432112345678

8765432112345678

or EDCBAABCDE

EDCBAABCDE

7) How many minutes did it take to administer Local anaesthesia ?.....

8) How many minutes did it take to obtain aneasthesia ?..... …….

9) How many minutes did it take for the extraction?.....

10) How long did it take for post extraction procedures such as placing cotton wool, giving post extraction advice and prescribing any medicaments? ……..

11) Time out (Please write the actual time the patient leaves the treatment room/surgery, e.g. 10.15 am, 11.30 am etc) …….

A4. Stella model: code listing

Defense_Forces(t) = Defense_Forces(t - dt) + (DF_Recruitment - DF_dying - DF_Attrition - DF_Retirement) * dt

INIT Defense_Forces = 60

INFLOWS:

DF_Recruitment = 1+DF_Attrition+DF_dying+DF_Retirement

OUTFLOWS:

DF_dying = Defense_Forces*.001

DF_Attrition = Defense_Forces*.05

DF_Retirement = Defense_Forces*.025

DH_DS(t) = DH_DS(t - dt) + (DH_recruitment - DH_dying - DH_attrition - DH_retirement - PG_training_rate) * dt

INIT DH_DS = 1050

INFLOWS:

DH_recruitment = Delay(DH_Vacancies,0.5)

OUTFLOWS:

DH_dying = DH_DS*.001

DH_attrition = DH_DS*.005

DH_retirement = 10+STEP(11,5)+STEP(-7,10)

PG_training_rate = 6

DH_Specialist(t) = DH_Specialist(t - dt) + (PG_training_rate + Retruning_Sp - DH_Sp_dying - Sp_Attrition - Sp_Retirement) * dt

INIT DH_Specialist = 50

INFLOWS:

PG_training_rate = 6

Retruning_Sp = Sp_Attrition*0.01

OUTFLOWS:

DH_Sp_dying = DH_Specialist*.001

Sp_Attrition = DH_Specialist*.05

Sp_Retirement = DH_Specialist*.02

Entrants(t) = Entrants(t - dt) + (Training_Rate + Job_changing_rate + FQG1 - Entrants_dying - Entrants_Attrition - US_recruitment - DF_Recruitment - DH_recruitment - FT_PP_Entering - PT_PP_entering) * dt

INIT Entrants = 0

INFLOWS:

Training_Rate = 80+STEP(5,10)

Job_changing_rate = Delay(Job_changing,0.3)

FQG1 = 1+STEP(1,5)+STEP(1,10)+STEP(1,15)

OUTFLOWS:

Entrants_dying = Training_Rate*.001

Entrants_Attrition = Training_Rate*.02

US_recruitment = US_Retirement+US_Attrition+US_dying+1

DF_Recruitment = 1+DF_Attrition+DF_dying+DF_Retirement

DH_recruitment = Delay(DH_Vacancies,0.5)

FT_PP_Entering = ((Training_Rate+Job_changing_rate)-(US_recruitment+DF_Recruitment+DH_recruitment))*FT_proportion

PT_PP_entering = ((Training_Rate+Job_changing_rate)-(US_recruitment+DF_Recruitment+DH_recruitment))*PT_proportion

Esta_FT_PP(t) = Esta_FT_PP(t - dt) + (Establishing_FT + Est_PT_to_Est__FT + Direct_entry_Esta_FT_PP + Foreign_qualified_Graduates_2 - Esta_FT_PP_Attrition - Esta_FT_PP_dying) * dt

INIT Esta_FT_PP = 190

INFLOWS:

Establishing_FT = Unest_FT_PP*.10

Est_PT_to_Est__FT = Esta_PT_PP*.025

Direct_entry_Esta_FT_PP = DELAY (pub_sec_Att_Ret_entering_FT_PP,0.2)

Foreign_qualified_Graduates_2 = GRAPH(TIME)

(0.00, 5.00), (1.50, 5.40), (3.00, 6.10), (4.50, 6.50), (6.00, 6.95), (7.50, 7.45), (9.00, 8.05), (10.5, 8.65), (12.0, 9.10), (13.5, 9.65), (15.0, 10.0)

OUTFLOWS:

Esta_FT_PP_Attrition = Esta_FT_PP*.005

Esta_FT_PP_dying = Esta_FT_PP*.001

Esta_PT_PP(t) = Esta_PT_PP(t - dt) + (Pub_sec_entering__est_PT_PP + Ownership_change + Pub_sec_Att_&_Retired_entering_Est_PT_PP - Esta_PT_PP_dying - Est_PT_to_Est__FT - Esta_PT_PP_Attrition) * dt

INIT Esta_PT_PP = 400

INFLOWS:

Pub_sec_entering__est_PT_PP = Delay(State_emp_new_PT,0.5)

Ownership_change = Unesta_locum_PT_PP*.05

Pub_sec_Att_&_Retired_entering_Est_PT_PP = DELAY(Pub_sec_Att_Ret_entering_PT_PP,0.2)

OUTFLOWS:

Esta_PT_PP_dying = Esta_PT_PP*.001

Est_PT_to_Est__FT = Esta_PT_PP*.025

Esta_PT_PP_Attrition = Esta_PT_PP*.005

Population_of_SL(t) = Population_of_SL(t - dt) + (Net__growth) * dt

INIT Population_of_SL = 20049000

INFLOWS:

Net__growth = STEP(166000,1)+STEP(2000,2)+STEP(1000,3)+STEP(-46000,4)+STEP(1000,5)+STEP(0,6)+STEP(1000,7)+STEP(1000,8)+STEP(-47000,9)+STEP(0,10)+STEP(0,11)+STEP(0,12)+STEP(0,13)+STEP(-34000,14)+STEP(0,15)

Unesta_locum_PT_PP(t) = Unesta_locum_PT_PP(t - dt) + (PT_PP_entering - Unest_PT_PP_dying - Unest_PT_PP_Attrition - Ownership_change) * dt

INIT Unesta_locum_PT_PP = 160

INFLOWS:

PT_PP_entering = ((Training_Rate+Job_changing_rate)-(US_recruitment+DF_Recruitment+DH_recruitment))*PT_proportion

OUTFLOWS:

Unest_PT_PP_dying = Unesta_locum_PT_PP*.001

Unest_PT_PP_Attrition = Unesta_locum_PT_PP*.10

Ownership_change = Unesta_locum_PT_PP*.05

Unest_FT_PP(t) = Unest_FT_PP(t - dt) + (FT_PP_Entering - Establishing_FT - Unest_FT_PP_dying - Unest_FT_PP_Attrition) * dt

INIT Unest_FT_PP = 90

INFLOWS:

FT_PP_Entering = ((Training_Rate+Job_changing_rate)-(US_recruitment+DF_Recruitment+DH_recruitment))*FT_proportion

OUTFLOWS:

Establishing_FT = Unest_FT_PP*.10

Unest_FT_PP_dying = Unest_FT_PP*.001

Unest_FT_PP_Attrition = Unest_FT_PP*.07

University_Staff(t) = University_Staff(t - dt) + (US_recruitment - US_Attrition - US_Retirement - US_dying) * dt

INIT University_Staff = 55

INFLOWS:

US_recruitment = US_Retirement+US_Attrition+US_dying+1

OUTFLOWS:

US_Attrition = University_Staff*.025

US_Retirement = University_Staff*.025

US_dying = University_Staff*.001

DH_Vacancies = (DH_attrition+DH_dying+DH_retirement+PG_training_rate)+(DH_DS)*.02

DS_to_population_ratio_Sri_Lanka = Population_of_SL/Total_dentists_FTE

Esta_Employment_seekers = Unesta_locum_PT_PP+Unest_FT_PP+Entrants

FT_proportion = GRAPH(TIME)

(0.00, 0.33), (1.50, 0.335), (3.00, 0.36), (4.50, 0.375), (6.00, 0.395), (7.50, 0.425), (9.00, 0.445), (10.5, 0.47), (12.0, 0.505), (13.5, 0.525), (15.0, 0.54)

Govt_DS_to_population_ratio = Population_of_SL/Govt_sector_DS_FTE

Govt_sector_DS_FTE = Defense_Forces+DH_DS+DH_Specialist+University_Staff

Job_changing = (Unest_PT_PP_Attrition*.80)+(Unest_FT_PP_Attrition*.70)+3

Percentage_demand_met = (Total_dental_Hrs/Total_Demand_hours)*100

Private_DS_to_population_ratio = Population_of_SL/Private_sector_dentists_FTE

Private_sector_dentists_FTE = Esta_FT_PP+Unest_FT_PP+(Esta_PT_PP+Unesta_locum_PT_PP)/2

Private_sector_DS_to_total_DS_ratio = Private_sector_dentists_FTE/Total_dentists_FTE

PT_proportion = 1-FT_proportion

Pub_sec_Att_Ret_entering_FT_PP = (DF_Attrition+DF_Retirement+DH_attrition+DH_retirement+Sp_Attrition+Sp_Retirement+US_Attrition

+US_Retirement)*.33

Pub_sec_Att_Ret_entering_PT_PP = (DF_Attrition+DF_Retirement+DH_attrition+DH_retirement+Sp_Attrition+Sp_Retirement+US_Attrition +US_Retirement)*.33

State_emp_new_PT = (DF_Recruitment+DH_recruitment+US_recruitment)*.54

Total_Demand_hours = GRAPH(TIME)

(0.00, 3.6e+006), (1.50, 3.7e+006), (3.00, 3.7e+006), (4.50, 3.8e+006), (6.00, 3.8e+006), (7.50, 3.9e+006), (9.00, 4e+006), (10.5, 4e+006), (12.0, 4.1e+006), (13.5, 4.2e+006), (15.0, 4.2e+006)

Total_dental_Hrs = Total_Govt_dental_hrs+Total_private_dental_Hrs

Total_dentists_FTE = Govt_sector_DS_FTE+Private_sector_dentists_FTE

Total_Govt_dental_hrs = Govt_sector_DS_FTE*1128

Total_private_dental_Hrs = Private_sector_dentists_FTE*1710

WTE = (Esta_Employment_seekers/(DF_Recruitment+DH_recruitment+US_recruitment))*12

A5. WHO/FDI Restorative care calculation formulae

Source: WHO/FDI, Pages 32 & 33

1	2	3	4	5	6	7	8	9	10	11	12
Cohort	DMFT	FT	MT	Restorative Fraction (RF)= (FT/DMFT) Col 3/Col 2	NFT Col 5 x Col 2	RFT (Age range x RFXDMFT) /Replacement period* *In Mixed dentition further divided by 2	Ratio S/T	Sealants Col 6 X Col 8	NFS Col 6 X Col 8	RFS Col 7 X Col8	Ext
0-14 Deciduous	dmf			a	a.dmf	15/2R (a.dmf)	V	(1-a)dmf	Col6.V	Col7.V	
0-14 Permanent	DMF(i)	F(i)	M(i)	A	A.DMF(i)	15/2R (A.DMF(i)	W	(1-A)DMF(i)	Col6.W	Col7.W	M(i)
15-29	DMF(ii)	F(ii)	M(ii)	B	B[DMF(ii)-DMF(i)]	15/R[F(i)+0.5B[DMF(ii)-DMF(i)]	X	(1-B) [(DMF(ii)-DMF(i)]	Col6.X	Col7.X	M(ii)-M(i)
30-64	DMF(iii)	F(iii)	M(iii)	C	C[DMF(iii)-DMF(ii)]	35/R[F(ii)+0.5C[DMF(iii)-DMF(ii)]	Y	(1-C)[(DMF(iii)-DMF(ii)]	Col6.Y	Col7.Y	M(iii)-M(ii)
65-74	DMF(iv)	F(iv)	M(iv)	D	D[DMF(iv)-DMF(iii)]	15/R[F(iii)+0.5D[DMF(iv)-DMF(iii)]	Z	(1-D) [(DMF(iv)-DMF(iii)]	Col6.Z	Col7.Z	M(iv)-M(iii)

Key:DMF- Decayed, Missing, Filled teeth. FT- Filled teeth,MT-Missing teeth, NFT- New fillings teeth,RFT- Replacement fillings teeth, Ratio/ST- Surfaces divided by teeth, NFS-New fillings surfaces, RFS-Replacement fillings surfaces, R- Mean replacement period in years

Calculation of Restorative care according to the above WHO/FDI Formulae; using secondary data from National Oral Health Survey 2003/4.

1	2	3	4	5	6	7	8	9	10	11	12
Cohort	DMFT	FT	MT	Restorative Fraction (FT/DMFT) col 3/col 2	NFT Col 5 x Col 2	RFT (Age range x RFXDMFT) /Replacement period* *In Mixed dentition further divided by 2	Ratio S/T	Sealants Col 6 X Col 8	NFS Col 6 X Col 8	RFS Col 7 X Col8	Ext
0-5yr Deciduous	3.51	0.13	12	0.04	0.14x3.51= 0.14	(5x0.04x3.51)/(2x5) = 0.07	1.5	(1-0.04) x 3.51 = 3.37	0.14x1.5 =.21	0.07x1.5	-
0-5yr Permanent	0.05	0.00	0.01	0	0x.05=0	(5x0x.05)/2x15=0	1.5	(1-0).05 = 0.05	0x1.5=0	0x1.5=0	0.01
15 yr	1.53	0.12	0.17	0.14*	.14(1.53-.05)= 0.21	(12.5x.21)/ (2x15)=0.09	1	(1-0.14) (1.53) =1.32	0.21x1= 0.21	0.09x1 =.09	0.17-.01 = 0.16
35-44 yr	8.39	0.51	4.93	0.40**	0.4(8.39-1.53)=2.74	(24.5/15)(0.12+1/2x0.40 (8.39-1.53) = 2.44	1.2	(1-0.4)(8.39-1.53)=4.12	2.74x1.2= 3.29	2.44x1.2 =2.92	4.93-0.17 =4.76
65-74 yr	17.12	0.07	15.21	0.54***	.54(17.2-8.39)= 4.71	(30/15)(0.51+1/2x0.54 (17.12-8.39)=5.74	1.5	(1-0.54) (17.12-8.39) =4.02	4.71x1.5= 7.07	5.74x1.5= 8.61	15.21-4.93 =10.28

* [(0.12-0) + (0.17-.01)/2]/(1.53-0.05) =0.14

** [(0.51-0.12)+(4.93-0.17)/2]/(8.39-1.53) =0.40

*** [(0.07-0.51)+(15.21-4.93)/2]/(17.12-8.39)= 0.54

A6. Calculation of total dentist hours

Total dentists hours is the summation of Government dentists hours and the private sector dentists hours.

A) Government sector dentist hours- is calculated as follows

[Full time equivalent dental surgeons[1] x No: of days of work per year[2] x No: of hours of

work per day[3] x Productivity[4]]

1 and 3 taking from the results of the empirical survey,

2 -according government norms and regulations as follows:

No:of days per year	365
Less Sundays	(52)
Saturday is a half day (52/2)	(26)
Public holidays	(20)*
No: of working days per year	267

* Sri Lanka has one of highest number of public holidays per year in the world. Public holiday include: 13 Buddhist religious(Poya) holidays + 2 New year holidays +1 Independent day holiday + 4 other religious holidays including Christmas

Working hours from 8am to 12 noon and 2pm to 4pm

Total number of hours day = 6hrs

Total hours per year 267x6 = 1602 hrs

Active number of hours 1128 - considering 70% productivity[4]

Following facts were considered in arriving at the productivity ratio[4]

a) The total number of leave entitled for dental surgeons per year= 28 Vacation leave + 21 causal leave . Most of the dental surgeons avail the privilege of taking 49 days paid leave.
b) Dental Surgeons are not motivated to treat more patients as there are no financial incentives.
c) Supporting staff is not motivated to treat more patients as there are no financial incentives
d) Working hours cannot be extended at the dental surgeon's discretion

B) Private sector dentist hours- is calculated as follows

[Full time equivalent dental surgeons^{p} x No: of days of work per year^{q} x No: of hours of work per day^{r} x Productivity^{s}]

p and r taking from the results of the empirical survey,

q -according to norms and practises in the private sector as follows:

No:of days per year	365
Less Sundays	(52)
Public holidays	(20)*
No: of working days per year	293

s as per Expert opinion

Working hours from 9am to 12 noon and 4pm to 8pm

Total number of hours day = 7 hrs

Total hours per year 293x7 = 2051 hrs

Active number of hours 1710 - considering 83% productivity^{s}

Following facts were considered in arriving at the productivity ratio^{s}

a) Private sector dental surgeons take minimum number of leave
b) Dental Surgeons are motivated to treat more patients as there are financial incentives
c) Supporting staff is motivated to treat more patients as there are financial incentives
d) Working hours could be easily extended at the dental surgeon's discretion.

A7. Data used in the Stella model

The time values are in years unless specifically stated as otherwise.

STOCK	DESCRIPTION	INITIAL VALUE
Defense_Forces(t)	Defense_Forces(t - dt) + (DF_Recruitment - DF_dying - DF_Attrition - DF_Retirement) * dt	60
Universitry_Staff(t)	Universitry_Staff(t - dt) + (US_recruitment - US_Attrition - US_Retirement - US_dying) * dt	55
DH_DS(t)	DH_DS(t - dt) + (DH_recruitment - DH_dying - DH_attrition - DH_retirement - Returning_Sp - PG_training_rate) * dt	1050
DH_Specialist(t)	DH_Specialist(t - dt) + (Returning_Sp + PG_training_rate - DH_Sp_dying - Sp_Attrition - Sp_Retirement) * dt	50
Entrants(t)	Entrants(t - dt) + (Training_Rate + Job_changing_rate + FQG1 - Entrants_dying - Entrants_Attrition - US_recruitment - DF_Recruitment - DH_recruitment - FT_PP_Entering - PT_PP_entering) * dt	0
Esta_FT_PP(t)	Esta_FT_PP(t - dt) + (Establishing_FT + Est_PT_to_Est__FT + Direct_entry_Esta_FT_PP + Foreign_qualified_Graduates_2 - Esta_FT_PP_Attrition - Esta_FT_PP_dying) * dt	190
Esta_PT_PP(t)	Esta_PT_PP(t - dt) + (Pub_sec_entering__est_PT_PP + Ownership_change + Pub_sec_Att_&_Retired_entering_Est_PT_PP - Esta_PT_PP_dying - Est_PT_to_Est__FT - Esta_PT_PP_Attrition) * dt	400
Population_of_SL(t)	Population_of_SL(t - dt) + (Net__growth) * dt	20049000
Unesta_locum_PT_PP(t)	Unesta_locum_PT_PP(t - dt) + (PT_PP_entering - PT_PP_dying - Unest_PT_PP_Attrition - Ownership_change) * dt	160
Unest_FT_PP(t)	Unest_FT_PP(t - dt) + (FT_PP_Entering - Establishing_FT - Unest_FT_PP_dying - Unest_FT_PP_Attrition) * dt	90

FLOW RATES

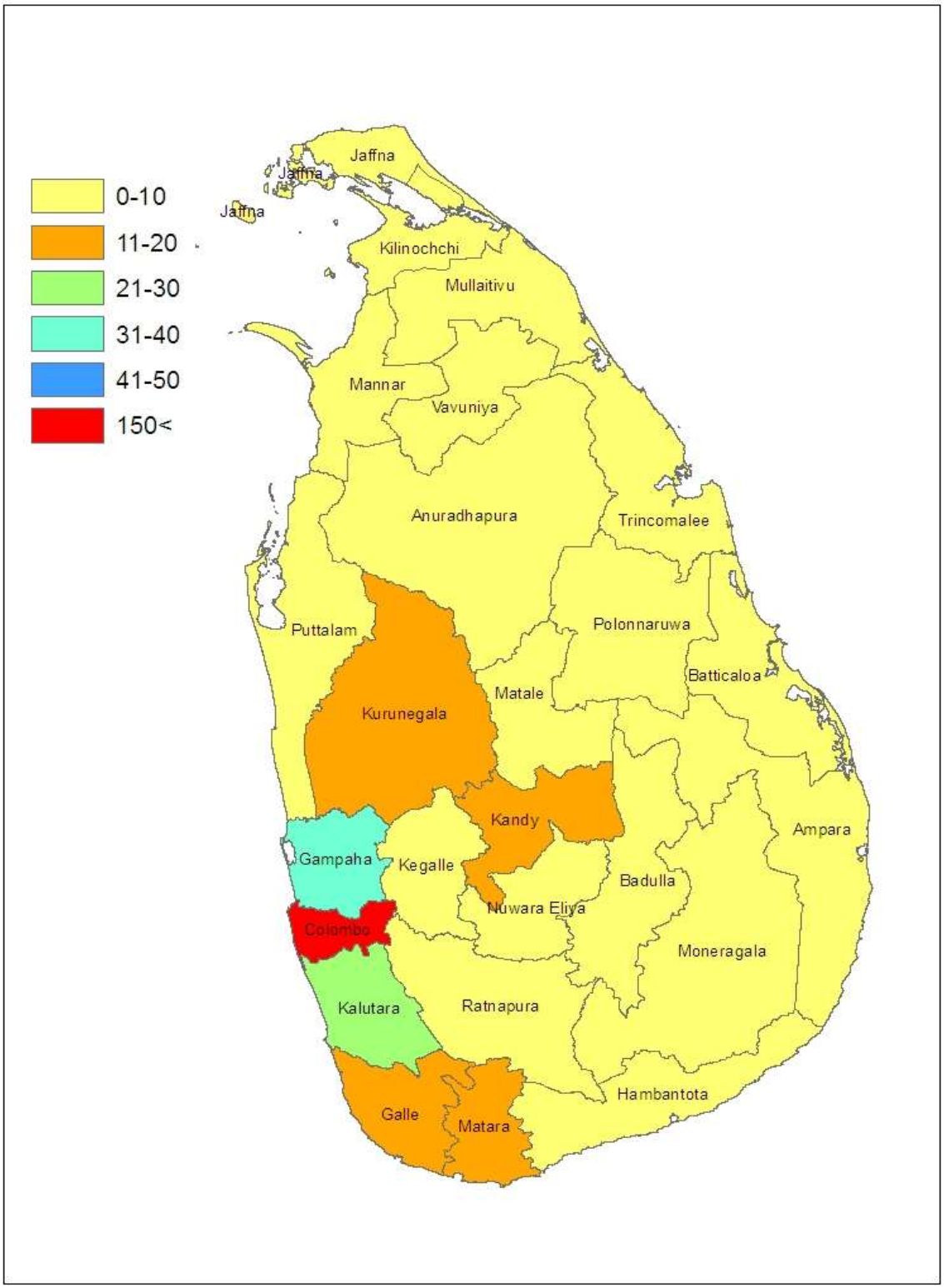
Description	Value
Training_Rate	80+STEP(5,10)
Job_changing_rate	Delay(Job_changing,0.3)
DF_Recruitment	1+DF_Attrition+DF_dying+DF_Retirement
DH_recruitment	Delay(DH_Vacancies,0.5)
Returning_Sp	Sp_Attrition*.01
PG_training_rate	6
FQG1	1+STEP(1,5)+STEP(1,10)+STEP(1,15)
Establishing_FT	Unest_FT_PP*.10
Est_PT_to_Est__FT	Esta_PT_PP*.025
Direct_entry_Esta_FT_PP	DELAY (pub_sec_Att_Ret_entering_FT_PP,0.2)
Foreign_qualified_Graduates_2	GRAPH(TIME) (0.00, 5.00), (1.50, 5.40), (3.00, 6.10), (4.50, 6.50), (6.00, 6.95), (7.50, 7.45), (9.00, 8.05), (10.5, 8.65), (12.0, 9.10), (13.5, 9.65), (15.0, 10.0)
Pub_sec_entering__est_PT_PP	Delay(State_emp_new_PT,0.5)
Ownership_change	Unesta_locum_PT_PP*.05
Pub_sec_Att_&_Retired_entering_Est_PT_PP	DELAY(Pub_sec_Att_Ret_entering_PT_PP,0.2)
Net__growth	STEP(166000,1)+STEP(2000,2)+STEP(1000,3)+STEP(-46000,4)+STEP(1000,5)+STEP(0,6)+STEP(1000,7)+STEP(1000,8)+STEP(-47000,9) +STEP(0,10) +STEP(0,11) +STEP(0,12) +STEP(0,13)+STEP(-34000,14)+STEP(0,15)
PT_PP_entering	((Training_Rate+Job_changing_rate)-(US_recruitment+DF_Recruitment+DH_recruitment)) *PT_proportion
FT_PP_Entering	((Training_Rate+Job_changing_rate)-(US_recruitment+DF_Recruitment+DH_recruitment)) *FT_proportion
US_recruitment	US_Retirement+US_Attrition+US_dying+1
DF_dying	Defense_Forces*.001
DF_Attrition	Defense_Forces*.05
DF_Retirement	Defense_Forces*.025
DH_dying	DH_DS*.001
DH_attrition	DH_DS*.005
DH_retirement	10+STEP(11,5)+STEP(-7,10)
DH_Sp_dying	DH_Specialist*.001
Sp_Attrition	DH_Specialist*.05
Sp_Retirement	DH_Specialist*.02
Entrants_dying	Training_Rate*.001
Entrants_Attrition	Training_Rate*.02
Esta_FT_PP_Attrition	Esta_FT_PP*.005
Esta_FT_PP_dying	Esta_FT_PP*.001
Esta_PT_PP_dying	Esta_PT_PP*.001
Esta_PT_PP_Attrition	Esta_PT_PP*.005
PT_PP_dying	Unesta_locum_PT_PP*.001

Unest_PT_PP_Attrition	Unesta_locum_PT_PP*.10
Unest_FT_PP_dying	Unest_FT_PP*.001
Unest_FT_PP_Attrition	Unest_FT_PP*.07
US_Attrition	University_Staff*.025
US_Retirement	University_Staff*.025
US_dying	University_Staff*.001

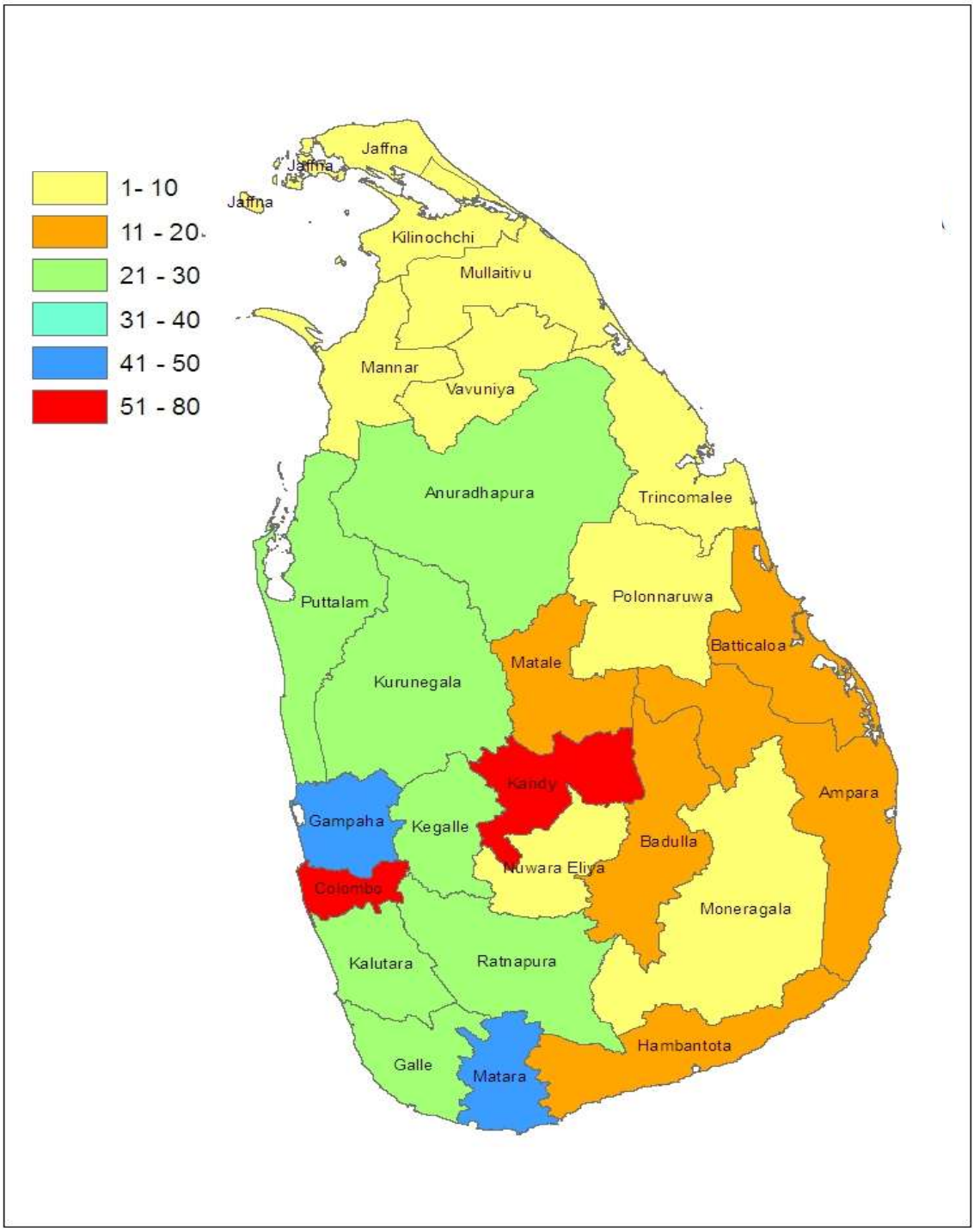
Auxiliary Variables

Auxiliary Variable	**Value Description**
DH_Vacancies	(DH_attrition+DH_dying+DH_retirement+PG_training_rate)+ (DH_DS)*.02
DS_to_population_ratio_Sri_Lanka	Population_of_SL/Total_dentists_FTE
Esta_Employment_seekers	Unesta_locum_PT_PP+Unest_FT_PP+Entrants
Govt_DS_to_population_ratio	Population_of_SL/Govt_sector_DS_FTE
Govt_sector_DS_FTE	Defense_Forces+DH_DS+DH_Specialist+Universitry_Staff
Job_changing	(Unest_PT_PP_Attrition*.80)+(Unest_FT_PP_Attrition*.70)+3
Percentage_demand_met	(Total_dental_Hrs/Total_Demand_hours)*100
Private_DS_to_population_ratio	Population_of_SL/Private_sector_dentists_FTE
Private_sector_dentists_FTE	Esta_FT_PP+Unest_FT_PP+(Esta_PT_PP+Unesta_locum_PT_PP)/2
Private_sector_DS_to_total_DS_ratio	Private_sector_dentists_FTE/Total_dentists_FTE
PT_proportion	1-FT_proportion
Pub_sec_Att_Ret_entering_FT_PP	(DF_Attrition+DF_Retirement+DH_attrition+DH_retirement+Sp _Attrition+Sp_Retirement+US_Attrition+US_Retirement)*.33
Pub_sec_Att_Ret_entering_PT_PP	(DF_Attrition+DF_Retirement+DH_attrition+DH_retirement+Sp _Attrition+Sp_Retirement+US_Attrition+US_Retirement)*.33
State_emp_new_PT	(DF_Recruitment+DH_recruitment+US_recruitment)*.54
Total_dental_Hrs	Total_Govt_dental_hrs+Total_private_dental_Hrs
Total_dentists_FTE	Govt_sector_DS_FTE+Private_sector_dentists_FTE
Total_Govt_dental_hrs	Govt_sector_DS_FTE*1128
Total_private_dental_Hrs	Private_sector_dentists_FTE*1710
WTE	(Esta_Employment_seekers/(DF_Recruitment+DH_recruitment +US_recruitment))*12
FT_proportion	GRAPH(TIME) (0.00, 0.33), (1.50, 0.335), (3.00, 0.36), (4.50, 0.375), (6.00, 0.395), (7.50, 0.425), (9.00, 0.445), (10.5, 0.47), (12.0, 0.505), (13.5, 0.525), (15.0, 0.54)
Total_Demand_hours	GRAPH(TIME) (0.00, 3.6e+006), (1.50, 3.7e+006), (3.00, 3.7e+006), (4.50, 3.8e+006), (6.00, 3.8e+006), (7.50, 3.9e+006), (9.00, 4e+006), (10.5, 4e+006), (12.0, 4.1e+006), (13.5, 4.2e+006), (15.0, 4.2e+006)

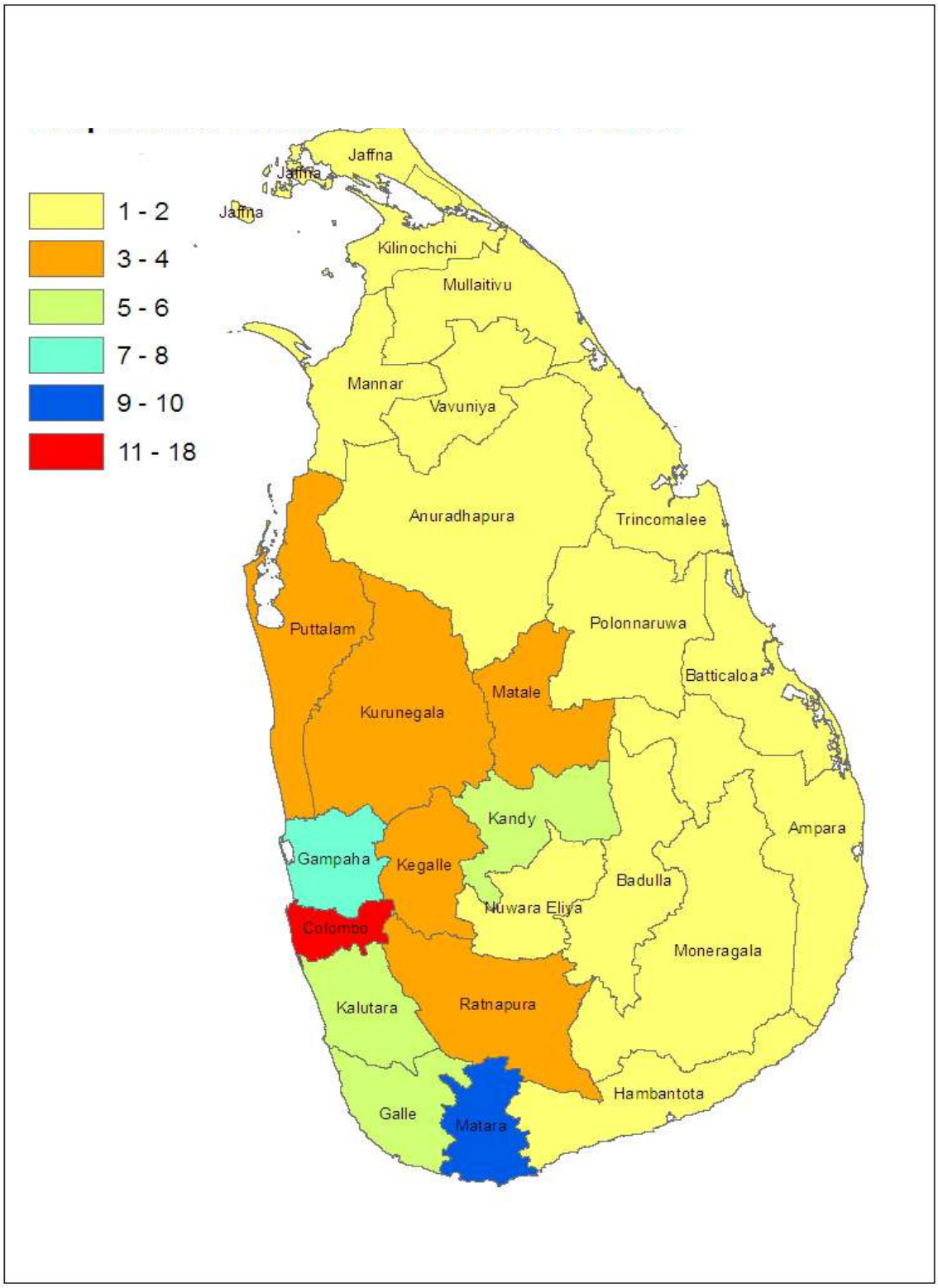
A8. Distribution of full-time private dental clinics, by district



A9. Distribution of part-time private dental clinics, by district



A10. Distribution of unqualified practitioners, by district



A11. Population of Sri Lanka, by district

Source: census data 2006 -Department of Census and Statistics Sri Lanka