ORIGINAL ARTICLE

Modelling the Future Malaysian Clinician Dental Workforce using System Dynamics

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ABSTRACT

Introduction: The aim of this operational research workforce project was to build, and test, a clinical dental workforce model for Malaysia to address population need/demand with a view to informing health policy. **Methods:** A system dynamics (SD) model was developed to take account of population oral health needs and demands and dental workforce supply nationally from 2010 to 2040. This involved building two sub-models: population need/demand; and dental workforce supply, drawing on evidence from two previous studies (student survey and interviews of key-stakeholders) supported by government data. The two sub-models were integrated in relation to clinical time to explore potential of over- or under-supply of clinical hours; were latter converted to clinical workforce numbers. The SD model was tested and validated as an acceptable baseline model for Malaysia using existing workforce data. **Results:** A SD model was developed to model the need, supply and demand for dental care in two sectors from 2010 to 2040. There is a short-term need for an expanded dental workforce to meet the needs of the population but there is a potential oversupply of dentists and therapists from 2040, or earlier. The level of public demand for both primary and secondary dental care is expected to increase respectively from the year 2010 to 2040, varying in relation to demographic and health trends across public and private sectors. **Conclusion:** The study suggests there is are current requirements for an expanded dental workforce to serve the population needs/demand and potential for oversupply from 2040, or earlier.
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INTRODUCTION

There is a strong need for a health workforce with the right skills to respond to the needs and demands of the population (1). In this light, the World Health Organization [WHO] (2) asserts there is a great need for evidence-based planning to inform future health workforce requirements. This is particularly important to minimise negative implications of poor workforce planning (1) that may result in resource shortage, overproduction and poor distribution (3). Therefore, research to inform future planning helps to create a better model to meet the needs and demand of the future dental workforce thus addressing issues of undersupply and maldistribution that lead to improved access (4), as well as efficient use of resources (5).

There is a range of existing tools and resources commonly used to help policymakers to formulate and monitor the development of their workforce. Traditionally, human resource planning had been focused on attaining and sustaining "the right number of individuals, in the right place, with the right skills, at the right time" (6). However, it is strongly suggested that not enough attention has been given to recruiting a workforce with the right capacity and characteristics (2). Given that health systems are influenced by a range of drivers for change including population socio-demographic, economic, political, social and technological in which the complexity and dynamicity are increasing (7, 8), particularly in deciding future policy, operational research (OR) simulation methods are very useful to explore future developments. They can address the complexity of health systems by simulating various situations (9), which can vary in value, focus, perception of future, and application to policies, plans or practical programmes (10). The need to consider the past and planned production of the workforce when predicting future health needs and

delivery of dental services has been strongly advocated (2).

OR methods have not only been used in the medical field, but also in dental research in many countries, namely the Netherlands (11), England (12, 13), South Africa (14), Malaysia (15), Sri Lanka (16) and Lebanon (17). The most complex and widely discussed model in this area is the modelling work of Burgersdijk (11), which examined the supply and demand for services using five models and simulating work substitution ranging from dentists to hygienists, to consider team working. This model also accounted various predictors such as exogenous variables, including population profile, epidemiology status and demand level for services that were also important indicators being assessed in this paper.

This method which has the capability to integrate the behavioural components of workforce (5) has been a central point among individuals "who wish to use that model to understand, to change, to manage, and to control that part of reality" (18). Moreover, this approach has been considered as a theory-creating method given its model development process demonstrating several aspects for internal validity to create an original theory (19).

Within OR itself, there are various simulations types according to their distinct approach or operational strategy (20); in which Discrete Event Simulation (DES) and System Dynamic (SD) are the most popular and established operational simulation approaches used in OR (21). For this project an SD model which is built from both the quantitative and qualitative data (22) that best examines the relationship between supply, need and demand to the dental workforce is found to be more representative of the problem situation than a DES (21) which may traditionally be used to represent operational activity.

Failure in past and present health workforce planning is attributed to inappropriate selection of planning methods, inappropriate data sources (2), or the failure to capture all interrelated influential factors on health in the planning process (23). The primary reasons for the lack of healthcare workforces in some countries also include: low capacity of production (2), emigration of health workforce (24), demographic issues (25) and a poor mix of skills (2).

Like many countries, Malaysia is primarily focusing on the production of dentists by rapidly increasing the number of dental schools; however, there were increasing concerns about the long-term implications of these policies, particularly on how this expensively trained workforce will be utilised during the required period of compulsory service in the public sector. The rationale for this study is based on the current and potential drivers for change on health workforce and its implications, particularly in dentistry, and specifically for Malaysia, a middle-income country with high oral health needs. Given this, there is a need to identify those drivers and anticipate their potential implications. The aim of this OR workforce project was to build, and test, a clinical dental workforce model for Malaysia to address population need/demand, with a view to informing health policy.

MATERIALS AND METHODS

Model Building: Model Hypothesis

This is a system dynamics (SD) modelling PhD project to explore the relationship between the population needs, the demand (which may differ from the needs) and supply for dental care from 2010 to 2040. In this regard, the clinician dental workforce namely the dentists (generalists or specialists) and therapists in both sectors (public and private) in Malaysia were observed and data obtained to inform the model.

Dental facilities have not been explicitly represented in this model as an assumption was made that the opening hours can be extended and the volume of facilities develop, at the same rate as currently, in parallel with the output rate of graduates.

Development of conceptual model/causal loop diagram (CLD)

At this initial stage of model-building, a conceptual model, incorporating a causal loop diagram (CLD) was developed; this was informed by previous literature and earlier findings on students' perspective (26, 27), and interviews with stakeholders to complement the sequential explanatory mixed-method study design (8) and inform the baseline scenario developed in Vensim PLE 6.4E software.

The conceptual model demonstrates the relationship between, and the complexity of, two sub-models: a need/demand model and a supply model as presented in Fig. 1. It comprises various interactions of sub-causal loop diagram (CLD) models that assess behaviours and feedback, including motivation and career expectations, and used/non-used clinical hours. In this sub-CLD model, students' expectations in relation to their future role (as generalists or specialists), sector of practice (public or private) and working pattern (part- or full-time) were modelled to inform the baseline model, taking into consideration the gender of the workforce (26, 27). The interactions of the sub-models coincide at the parameter to model the amount of 'used or non-used clinical hours' over time, indicating the existence of a potential for undersupply or oversupply of clinical hours.

Model behaviour and feedback

The components for students' motivation and career

expectations should be considered in a model-testing exercise to endorse a better accuracy of modelling results (5) and to reflect reality. In this sub-CLD model, students' expectation in terms of their future role (generalists or specialists), sector in which they practice (public or private) and working pattern (part- or full-time) were modelled to inform the baseline and alternative scenarios, taking into consideration student working preferences by gender (26, 27). Fig. 1 also presents the interaction and influences of this parameter on the overall CLD.

Several influential factors may impede the level of demand; thus, oral health improvement, by either increasing or decreasing the demand for clinical hours. This, therefore, that has implications for the used and non-used clinical hours respectively. For example, an increase in demand for clinical hours will then increase the clinical hours used and this is illustrated by "+".

Development of stock and flow diagram (SFD)

Formulation of each variable

At this stage, each parameter was quantified to assess and examine the model inter-relationship and behaviour. This stage included revisiting the CLD to add auxiliary parameters and to develop a formula to complement the assessment of the model behaviour; therefore, a holistic model that suits the local context was developed. The simplified version of overall SFD is presented in Fig. 2. Thereafter, a series of calibration and validation processes were performed throughout; including sensitivity analysis to ensure the model is designed appropriately and able to perform its purpose under extreme input of data.

Type of data needed for the stock and flow diagram [SFD]

Data were collected from published sources of the Ministry of Health Malaysia [MOH], the Department of Statistics Malaysia, the Ministry of Education Malaysia, the Ministry of Finance Malaysia, Malaysia Dental Council (MDC), Malaysia Dental Association (MDA), the World Data Atlas and the International Futures Centre at Paradee that provide historic data and trends. In addition, descriptive data from students' perspective in previous studies (26, 27) were used to complement the sequential explanatory mixed-method study design of this study to inform the baseline scenario developed in a Vensim PLE 6.4E software. Only relevant, accurate, and recent data were used to simulate the Malaysian population and dental workforce supply from 2010 to 2040.

Need/demand sub-model

Data were required to model the interactions of various parameters. This included the feedback loop under the need/demand model, integrated to produce the clinical hours demand across population age-bands, whereby increase in supply was predicted to result in increased demand for care as availability improved. The clinical hours of demand were therefore calculated, initiated by the size of the population (by age-band) that is needing or demanding care by types of treatment (primary or secondary care). The demand level for specific types of treatment is based on the trend of dental utilisation that varies by age-band which acts as a primary indicator to calculate the clinical hours' demand, rather than focusing on need, the latter being much higher than demand within this population.

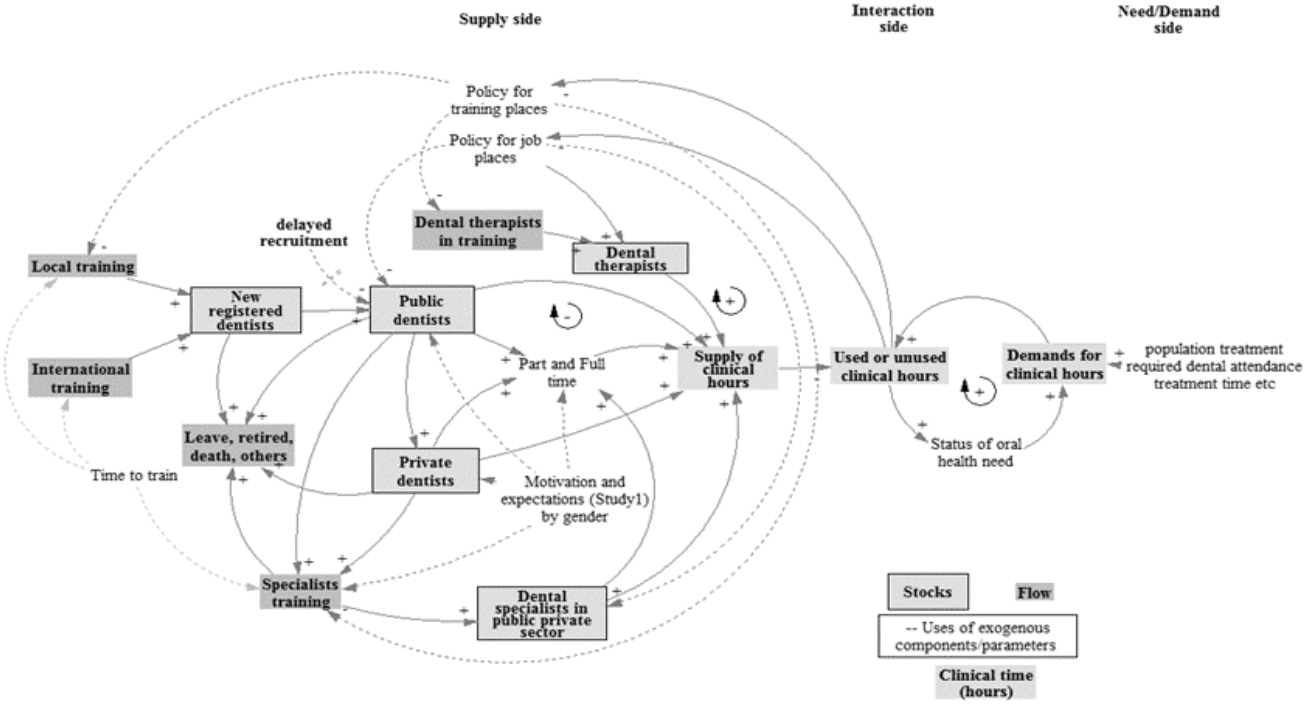

Figure 1: Conceptual model of causal loop diagram (CLD) of overall influences on Malaysian clinicians' dental workforce

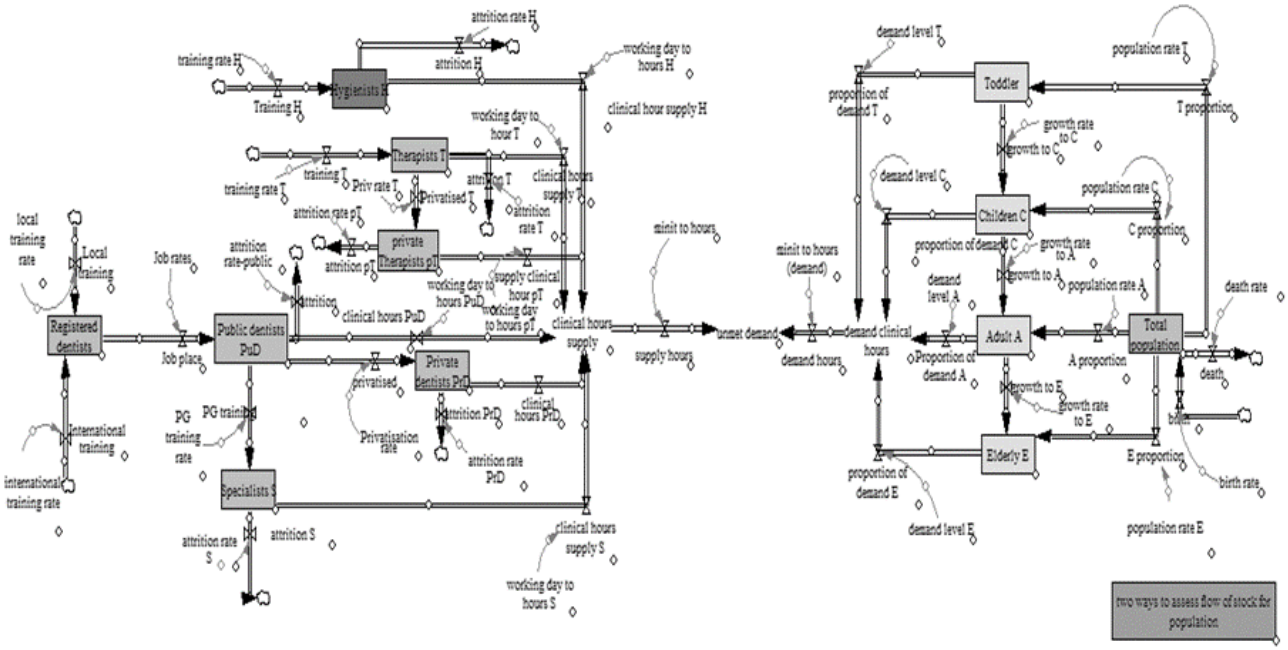

Figure 2: Stock and Flow Diagram (SFD) of overall influences on Malaysian clinicians' dental workforce in the Vensim Model

Moreover, the demand for dental services varies according to the sector (public or private) and workforce (generalists, specialists and therapists) preference. The total volume of the population requiring specific dental treatment is multiplied by the treatment time for the purpose of converting it into clinical hours.

Supply sub-model

Data required to assess several interactions of various sub-CLD under the supply model was integrated to produce clinical hours supply across clinician dental workforce. The calculation of the clinical hours' supply was initiated by the total volume of therapists, generalists and specialists providing dental care (primary or secondary) to patients in two sectors (public and private) in clinical time (hours). Conversion of the total volume of the dental workforce into total clinical hours supply is undertaken by multiplying the workforce volume by total working hours in a year (working time equivalent [WTE]).

Potential working patterns (full- and part-time) by gender were informed by the current policy. Students' perspective (from the previous studies) was also integrated (26, 27). In this model, the main approach used to model the Malaysian workforce supply was by identifying historical and trends data namely employment rate, attrition, migration, study leave and others from 2010 onwards and extrapolating them in the short-term to 2015 and then comparing the findings with current workforce data, as part of the model validation and calibration exercise. This showed model validity and relevance.

Conversion of Malaysians' working days to clinical hours supply

The number of working days for an individual member of the dental workforce per year was calculated, based on the difference between the total volume of working days and the annual leave taken. Clinical hours of supply were based on an eight-hour day. Both the total supply and demand of clinical hours from these two main models were compared in order to investigate the following features:

a. The level of clinical hours used and un-used

The difference in clinical hours between the 'supply' and 'demand' determines the gap in clinical hours, suggesting the existence of 'used' or 'non-used' clinical hours; thus, indicating whether there is potential for under or oversupply of clinical hours.

b. The volume needed for respective workforce type

The gap in clinical hours between the two sub-models was examined. The total clinical hours supply required was transformed into workforce requirements in relation to whole time equivalent staff (WTE) to provide the workforce volume needed. The model outputs provided an indication of the future volume of care needed and the workforce requirements across sectors (generalist vs specialist and private vs state).

RESULTS

A SD model was developed to model the need, supply and demand for dental care in two sectors from 2010 to 2040. The SD modelling in this project highlights the relationship of need/demand and supply for care building on national data and evidence from two earlier

studies to simulate the Malaysian context and suggests there is the potential for a balance between supply and need/demand projections for both dentists and therapists to 2040 and 2035 respectively. The findings, however, indicate the potential for oversupply of generalists in both sectors as early as 2035 and the potential for undersupply for all specialists throughout the simulation period.

Development of stock and flow diagram (SFD)

Each parameter was quantified to assess and examine the model inter-relationship and behaviour. A series of calibration and validation processes was performed which included sensitivity analysis to provide a spread of output values to determine the optimal data input.

Model-refining and validation

The next stage of the SD model involved refining the model structure and behaviour through calibration and validation. Given this model was developed and informed by earlier findings (26, 27), populated by evidence from the health sector, under a research team with knowledge of the Malaysian system, workforce modelling and public health expertise on shaping the dental workforce to meet population needs, the structure and behaviour of the model are suggested to be logical and valid for the Malaysian context.

Additionally, the model was tested with extreme values of the parameter inputs to ensure it was fit for purpose. Several assumptions and hypothesis were used to challenge the system rather than following one particular client idea as a way to further validate the structure of this SD model (28), as suitable at state level. Validation of the behaviour of the SD model was also performed on both the sub-models; particularly on (i) average trend of international graduates' outputs; (ii) total volumes of the dentists; and (iii) public-private sector distribution.

The average trend of 'international graduates' outputs

Data on past trends in international graduates returning to Malaysia suggest that this parameter is dynamic and unpredictable, therefore it was considered as the most sensitive parameter in the model, one that required further testing and adjustment. Based on the past 10-year trend, there were on average of 44 additional students graduating per year. Therefore, the SD model tested this assumption and the output illustrated a sharp increase in the volume of Malaysians graduating overseas to 1,411 graduates in 2040. The model output, however, was considered to be excessive, given the rapid growth of schools that offer more places to study locally. Therefore, two alternative assumptions were tested to examine what happened if the rate is cut by 50% (n=22) and 75% (n=11) from the initial volume of the international graduates (n=44) in order to provide a spread of output values to be examined. The first value of 22 graduates produces a much more stable and realistic output compared with the other alternative and original value. Accordingly, the trend of an additional 22 students graduating annually was then selected and used in the supply model.

The total volume of dentists

Modelling the total volume of dentists was based on past trends of both the inflow and outflow. The initial output for 2015 was then compared with the actual data reported by the MDC for the same year. The table shows the initial output from Vensim was lower than expected at 5,896 compared with the actual trend (6,410).
However, following adjustment activities outlined above, the difference was reduced model shows a difference of 585 which gives a new modelling output for 2015 of 6,481 which only exceeds the actual trend by 71 (6,481 - 6,410). The output therefore was considered valid and acceptable, and can be used in the subsequent modelling activities.

The distribution between public and private generalists

This section presents the distribution of dentists across the sectors using a privatisation rate. Recent trends show a dynamicity of the privatisation rate fluctuating between 9% and 5% calculated since 2012 and 2005 respectively. However, in this study, 5% was used, based on the past 10-year trend in which the public sector remained dominant throughout the simulation period to reflect the reality of the current situation of the sector's distribution in the country. The rate is relatively stable for this long simulation period based on the assumption that compulsory service continues as in the present. Given potential changes in policy, however, it was important to explore the implications of different rates in relation to private sector dominance.

The model suggests the public sector is expected to remain dominant until 2040 if the privatisation rate is 7% and below. However, if the privatisation rate reaches 9% and above, then the private sector becomes dominant. These values and their potential outputs will be used to inform scenario testing.

Model outputs

Need/demand sub-model

The level of demand for both primary and secondary dental care is expected to increase by over 130% and 51% respectively from the year 2010 to almost 38.8 million and 11.2 million hours respectively by 2040; a rate that varies by age-band in relation to demographic and health trends across public and private sectors. Toddler, preschool, adults and elderly age-groups are presenting an increased demand due to demographic growth, whilst a decline is presented amongst primary and secondary school children, which has implications for both workforce and sector preferences.

Consequently, the demand for all generalists and specialists in both sectors is also expected to increase over time, whilst the demand for therapists might decline over time. The greater demands particularly for the public sector and generalists (primary care) are based on current patient preferences and oral health needs. Given this, the model suggests that generalists and specialists will delegate the majority of their clinical hours or work proportion to the adult and elderly by 2040; whereas therapists will be shifting their focus to the pre-school and toddler programme whilst maintaining their main coverage at primary and secondary school.

Supply sub-model

Supply projections indicate that increasing the volume of dentists and therapists by a factor of ten and two respectively in 2040 will lead to potential of overcapacity of dentists nationally in the year 2040. Whilst the volume of general dentists is likely to increase ten-fold, specialists are expected to increase only five-fold, thus, resulting in the proportion of specialists dropping from 25% in 2010 to 12% in 2040. Fig. 3 shows an increase in the clinical hours' supply of dentists and therapists by eight and 1.8 times respectively to 5.3 and 6.6 million hours by 2040.

By sector, Fig. 4 illustrates an increase in clinical hours supply for all elements of the workforces in parallel with increasing volume of the workforce. The public and private generalists increase from 2010 to 2040 was estimated to be in the region of thirteen and eight times increase respectively, whereas public and private specialists showed a more modest increase of approximately four times for both, by 2040.

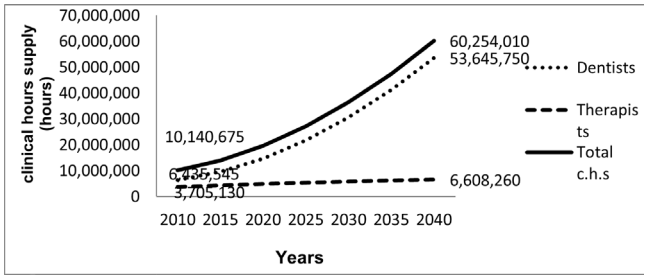

Figure 3: Forecasting the total clinical hours supply for all workforce type, dentists, and therapists, 2010-2040

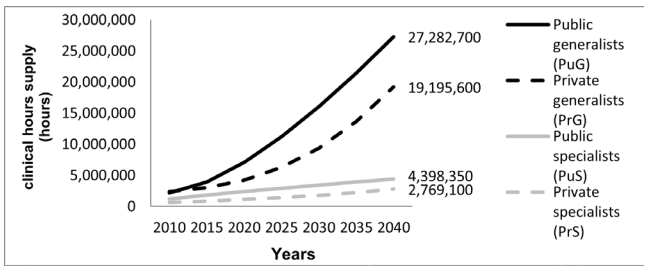

Figure 4: Forecasting the total clinical hours supply for generalists and specialists in two sectors, 2010-2040

Comparison between need/demand and supply models

The evidence for a potential oversupply is based on the comparison between the need/demand projection and supply projection in relation to clinical hours (Fig. 5). The model contained a feedback system or loop, whereby demand increased in relation to supply. The modelling results indicate there is a current need for an expanded dental workforce to meet the needs of the population. However, the model suggests a potential for oversupply of total dentists from 2040.

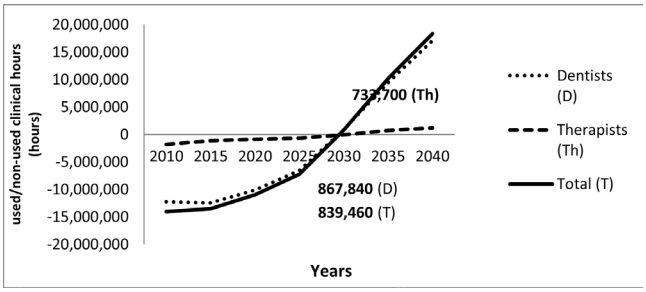

Figure 5: Forecasting the used and non-used clinical hours demand for total workforce type, dentists and therapists, 2010-2040 (current demand level)

The output data indicate an oversupply of generalist dentists, as early as 2035 in both the public and private sectors, with potential undersupply of specialists throughout the simulation period (Table I). Forecasting the workforce to population ratio also presented in Table II.

These findings provide a strong basis for on-going modelling of the Malaysian dental workforce in which alternative scenarios may be examined and integrated into the model in order to best use dental professionals within the service if the production continues at the current rate.

DISCUSSION

This OR modelling which used a SD approach in considering the future oral and dental workforce drew on expert knowledge, literature, surveys that explicitly model the demand versus the supply to explore their behaviours over time and national data. It represented dentists remaining focused on adults whilst therapists play an important role in delivering care for schoolchildren. This model involved developing and integrating the two sub-models of need/demand and supply.

The need/demand sub-model integrated demographic trends (population growth and ageing), oral health trends (informed by epidemiological surveys) and the level of demand for care (patients' preference for the sector and type of care) by population age-bands that led to the production of the clinical hours' demand across age-bands. The supply sub-model studied the Malaysian clinical dental potential over or undersupply

Table I: Forecasting the workforce volume needed for all clinician dental workforce across sectors, 2010-2040

	Output	2010	2015	2020	2025	2030	2035	2040
General dentists	Public generalists	-3,739	-3,702	-6,703	-4,885	-2,097	**+1,080**	**+3,948**
General dentists	Private generalists	-322	-450	-1,435	-1,121	-382	**+768**	**+2,065**
Specialists	Public specialists	-2,414	-2,258	-3,348	-3,179	-2,731	-2,128	-1,928
Specialists	Private specialists	-552	-546	-824	-787	-660	-477	-346
Total Dentists		-7,027	-6,956	-12,310	-9,972	-5,870	-757	**+3,739**
	Therapists (public)	-1,290	-1,011	-654	-432	-19	**+492**	**+817**

Used/non-used clinical hours **divided by** %WTE of workforce type
Oversupply is indicated by volumes in **bold** and with **positive (+)** sign

Table II: Forecasting the workforce to population ratio, 2010-2040

Output	2010	2015	2020	2025	2030	2035	2040
Generalists	9,297	6,494	4,250	2,856	2,011	1,471	1,209
Specialists	37,032	24,955	19,325	15,720	13,088	10,973	9,609
Therapists	3,611	3,020	2,673	2,428	2,221	1,979	1,810
Total dentists	7,431	5,186	3,540	2,527	1,901	1,297	1,224

Based on total population **divided by** the volumes of workforce 1 workforce: no. of population

of the clinical hours which were later converted to clinical workforce capacity, the findings of which will be discussed further in the subsequent sections, along with its sub-models.

The model output confirms there is a current need for an expanded dental workforce to meet the needs and demands of the population. However, given the parameters of the study examined, there is potential for oversupply from 2040 or earlier so there are growing concerns amongst stakeholders on how this expensively trained dental workforce will be absorbed and utilised. It could be argued, pre-pandemic, that the potential oversupply might be reached earlier considering this modelling study has adjusted the demand level for adults and elderly people conservatively; however, it is predicated that increased supply leading to increased demand (29).

The concern of oversupply was critically important given this issue is currently debated amongst stakeholders for several reasons. First, following the recent rapid increase in dental graduates and the implementation of the moratorium, the potential oversupply is still occurring. Second, there is no such control on the number of students who study abroad. Third, potential oversupply leads to the underutilisation of clinical hours, which has financial implications for government, given most students in the public sector are funded by the state. Fourth, and finally, there is the potential for loss of expertise if there is migration of the dental workforce and dentists change to other professions or transition into aesthetic care as is occurring in other countries. Following the modelling output as well, the potential crisis of dentist oversupply warrants the dental moratorium continuing; together with monitoring the volume of international graduates to manage the outputs to the dental market. An initial step to register specialists should also be taken, following the free movement of foreign specialists once local legislation is approved to enable monitoring and empower action if required.

Need/demand sub-model

The need/demand model based on historical patterns and trends and future population projections maintains the full demand level for schoolchildren and slowly increased the demand for toddler and pre-school care which tends to be lower than schoolchildren in countries with established care (30). The demand level for working age adults and elderly in this country based on a feedback loop supply demonstrated lower than given international comparisons (31). This model also maintained the public preference for use of the public and private sectors and therefore the workforce implications across the simulation period. Changes, particularly in the population sector of preference for seeking treatment, which is possible, will have implications for the model outputs.

The outputs of the need/demand model suggest clinical hours demand from the total population for both primary and secondary care by the year 2040 was

found to increase following the growing volume of total population, especially for primary care. Notably, changes in demographic and dental disease patterns strongly influenced the level of dental demand which varied by age-bands. Increasing clinical hours' demand was found in four bands, namely toddlers, pre-schoolers, adults and elderly people.

Conversely, declining need/demand for clinical hours is shown by schoolchildren, both in primary school and secondary school. This decline was mainly influenced by a predicted significant decrease in dental caries and demographic changes whereby the proportion of school children in the total population will fall (32, 33). Consequently, a low volume of oral health need/demand for clinical hours was simulated in the SD model for this age-group. At present, this situation also occurs in other countries globally (34, 35). Moreover, the dental school programmes under the MOH were successfully conducted and covered almost 100% of primary and secondary schoolchildren (36). More than 95% of primary and secondary schools are government schools (37). Demand from these groups is based on the assumptions that coverage of school children within the state system continues. In light of this there may be an oversupply of dental therapists by 2040; this necessitates further action to tackle the volume, scope and/or patient base of dental therapists trained (38). Conversely, toddlers and pre-schoolers showed increasing clinical hours demand although their proportion across population was decreasing. Improved health activities and programmes by health providers every year increased service uptake as demonstrated by previous trends (36).

The significant increase in the demand nationally amongst other age groups and overall was attributed to population growth and ageing most notably affecting adult and elderly people (33) with a high prevalence of dental diseases that might require long and complex treatment, and re-treatment (39). In treating both the adult and elderly groups, the workforce should be planned and executed carefully as their demand level almost reaches the same level as oral health need, especially for secondary care. Rather than producing a high volume of specialists, preparation of future workforce with a geriatric component in the undergraduate curriculum should also be considered to address the greatest need of these groups for primary care. Nevertheless, although Malaysia currently had a higher rate of specialisation than many countries, sufficient funds and places for specialist training are required to maintain specialist expertise and address this growing need/demand for secondary/tertiary dental care in the country. Alternatives include developing dentists with enhanced skills (40), and where possible using dental team skill mix such as hygienist as a cost-effective approach (41). Dental schools might therefore be supported financially in reducing the undergraduate student intake and increasing post-graduate training to support population need in support of sustainability.

Nevertheless, demand is relatively difficult to determine. The percentage and type of staff that the system needs are complex as is the information required to calculate the optimal volume of workforce needed (42). Several factors influence demand: changes in technology, government policy, legislation/regulation, migration of staff members, and the economic climate (7). These factors may alter the future workforce requirement between now and the date of forecast.

The findings of this study support the MOH in foreseeing the potential indication of increasing utilisation rates among the Malaysian population and improving health conditions (43). The rates will also increase dramatically following the outlined recent trends and policies.

Supply sub-model

The supply model basically maintains the similar proportion of gender distribution between workforce and their working pattern; however, the proportions of generalists and specialists are changing depending on the training rate suggesting changes in the proportion might change the model output.

Rapid growth in the number of dental schools following government policy and trade liberalisation in education was the main reason for the increased volume of total dentists and their total clinical hours supply in both the public sector and private sector by the year 2040. The same increasing trend was seen for generalists and specialists across both sectors. Meanwhile, the volume of therapists was also expected to increase but at a constant rate.

The increase of total dentists in the country was not parallel and was slightly above 11% from their total clinical hours' supply, suggesting lower clinical hours supply compared to their forecasted volume. As observed in other countries, the reasons were the bounded policy for public practitioners in Malaysia and the preferred working pattern of the female workforce (44); they prefer to work at reduced capacity (27).

Our preliminary study surveying the emerging Malaysian dental workforce (final year dental students) (27), demonstrated high levels of professional commitment and seeking to achieve a stable work-life balance in the profession. The majority of the respondents reported being inclined to work full-time; meanwhile, those who preferred to work part-time chose a maximum of four working days in a week (26, 27); this also reflects their approach to achieve quality of life. There is increasing recognition in the global literature that the younger generation of dentists prefer a flexible and relaxing working environment (45). Alternatives to the present policy of full-time working should be examined in further

research, given the potential surplus of clinical hours' supply, particularly in the public sector. This approach was hindered by the slightly lower clinical hours supply for therapists compared to their total volume.

The findings also indicated a potential increase in the total volume of specialists at lower rate compared to the generalists, due to limited funding and places for post-graduate training (46). The increased volume was mainly attributed to the constant annual rate of specialisation in the country and the recent policy of trade liberalisation that allows free movement of foreign specialists into the country (47). Accordingly, the proportion of specialists to the total volume of dentists was expected to decrease from 25% in the year 2010 to 12% by 2040.

As demonstrated in several studies, specialists, particularly in the private sector contribute fewer clinical hours supply compared to the generalists because they have already achieved financial stability and preferred to have flexible and reduced working capacity (27). Specialists in educational institutions also contributed to the clinical hours supply of specialists. In this model, they were assumed to provide a similar working duration as those in the MOH although their main role was teaching and education. Nevertheless, this group may complement the gaps in hours projected due to their capacity to work part-time in the private sector and the impact of trade liberalisation in the country (47).

The supply projection was also based on the understanding that the flow of general dentists from the public to private sector was due to the policy of compulsory service that required new graduates to work initially in the public sector (48). Total clinical hours supply of public practitioners was much higher than in the private sector although the increment rate for the former is lower by volume compared to the latter as the result of privatisation. Accordingly, public practitioners remain dominant throughout the simulation period under this current trend. Any changes or termination of the compulsory service policy will affect the projected distribution and expectations of both the profession and patients.

Comparison of demand and supply forecast

Simulation of discussed trends in the two sub-models produced outputs that were subsequently compared. The workforce supply was indicated to have sufficient balance to meet the need/demand of the population. Policies and professional expectations however contribute to potential oversupply of dentists and therapists by the year 2040 and 2035 respectively.

The oversupply of dentists was attributed to unused clinical hours due to the increased volume of dental graduates, whereas the oversupply of therapists was caused by decreasing incidences and prevalence of dental disease among the children that received their services. The current low rate of production of specialists was a limiting feature in the model and led to the high demand for specialists throughout the simulation period. The dental facilities that act as mediator for all the above interactions were not included and tested in this model; they were assumed to grow in parallel with the pace of dental demand which will be dependent upon the economic health of the country and the willingness of patients to pay for care in the private sector. This model therefore provides the basis for the future research on scenario modelling.

Strengths and limitations

This modelling study has a number of strengths. First, the workforce modelling was performed at national level where the projections examined and tested the dynamic interactions of clinician dental workforce related to patient utilisation across both primary care and secondary care and sectors of dentistry. Second it integrated different levels of need/demand across different age-bands of the population that had been translated into clinical hours' demand, which is something few countries have achieved in their modelling project. Third, the model included both the private sector and the public sector and in doing so addressed notable gaps in two recent modelling studies that were conducted for the Malaysian dental workforce (15). Fourth, this model used a systematic dynamic approach to simulate broad and more complex problems and involved collaboration between operational research experts' team at the School of Mathematics, Cardiff University and the academicians at King's College London.

Some limitations of this study need to be addressed. First, the parameters used in the model have a certain level of uncertainty, notably specialisation, privatisation and working patterns. The researchers observed that this may influence the accuracy of the modelling outcome (49). Uncertainty in parameters is very common in health systems (6), however, calibration and validation exercises were performed to provide correction to overcome this issue. In this study, determining the accurate data required for models: need, supply, and demand also imposed some challenges. Second, epidemiological surveys among school children only reported the dental needs and care requirements for the key ages 6, 12, and 16 years old. Hence, extrapolation activities as being practiced in projection works by many institutions such as the Organisation for Economic Cooperation and Development (OECD), Asia Pacific economies (50) and Malaysia in determining the demand of care (43) was undertaken. This typically ignores the potential differences in treatment need of other ages within the same age-band. Although it is accepted that the data used to project demands among school children may not be ideal, the forecasted volume, however, was considered to be within the accepted range for local context and no countries have complete data on their population.

CONCLUSION

To conclude, this research involving a case study of Malaysia, a middle-income country, with high oral health needs and rapid growth in dental education, suggests there is currently the requirement for an expanded dental workforce to serve the needs of the population. However, it also highlights the potential for oversupply from 2040, or earlier, together with growing concerns amongst stakeholders on how this expensively trained dental workforce will be absorbed, and utilised, in meeting the current and future need/ demand of the Malaysian population, especially in the highly subsidised public healthcare system. This model provides evidence for the benefit of the Malaysian nation and its main use is to inform decision making rather than predict or forecast change. Their level of acceptance may vary given the different priorities and directions of various dental organisations that exist in the country, recognising that by its very nature such a 'futures study' will influence change.

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