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Comparing health workforce forecasting approaches for healthcare planning: The case for ophthalmologists

John P. Ansah*[1], Victoria Koh[1], Dirk De Korne[1,2,3], Steffen Bayer[1], Chong Pan[2], Jayabaskar Thiyagarajan[2], David B. Matchar[1,4], Desmond Quek[5]

[1] Signature Program in Health Services and Systems Research, Duke-NUS Medical School, Singapore
[2] Singapore National Eye Centre, Singapore
[3] Institute of Health Policy & Management, Erasmus University Rotterdam, Rotterdam, Netherlands
[4] Department of Medicine, Duke University Medical Center, Durham, NC, USA
[5] Singapore Eye Research Institute, Singapore

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Abstract

Health workforce planning is essential in the provision of quality healthcare. Several approaches to planning are customarily used and advocated, each with unique underlying assumptions. Thus, a thorough understanding of each assumption is required in order to make an informed decision on the choice of forecasting approach to be used. For illustration, we compare results for eye care requirements in Singapore using three established workforce forecasting approaches – workforce-to-population-ratio, needs based approach, utilization based approach – and a proposed robust integrated approach to discuss the appropriateness of each approach under various scenarios. Four simulation models using the systems modeling methodology of system dynamics were developed for use in each approach. These models were initialized and simulated using the example of eye care workforce planning in Singapore, to project the number of ophthalmologists required up to the year 2040 under the four different approaches. We found that each approach projects a different number of ophthalmologists required over time. The needs based approach tends to project the largest number of required ophthalmologists, followed by integrated, utilization based and workforce-to-population ratio approaches in descending order. The four different approaches vary widely in their forecasted workforce requirements and reinforce the need to be discerning of the fundamental differences of each approach in order to choose the most appropriate one. Further, health workforce planning should also be approached in a comprehensive and integrated manner that accounts for developments in demographic and healthcare systems.

Key Words: Workforce projections, Ophthalmologists, System dynamics, Simulation modeling, Singapore

1. Introduction

Healthcare accounts for a large share of public expenditure in many countries.[1] 60-70 percent of healthcare expenditure is devoted to the health workforce. Health workforce numbers greatly affect population health, healthcare costs, operations of the healthcare system and access to healthcare.[2] In addition, the healthcare profession is characterized by long training routes. Multiple assessments and certifications that take years to complete are prerequisites for commencing work in the industry. Due to this training delay, there is a need for manpower planning so appropriate healthcare policies and training requirements can be put in place for the

*Correspondence: John P. Ansah; Email: john.ansah@duke-nus.edu.sg; Address: Signature Program in Health Services and Systems Research, Duke-NUS Medical School, Singapore.

efficient delivery of health services. Moreover, demographic changes have put a strain on the demand for human resources in healthcare. Demand for healthcare services is expected to rise substantially with an aging population as studies have shown that the prevalence of chronic ailments increases with age.[3] Another implication of this phenomenon is an aging healthcare workforce. Thus, recruitment policies have to be carefully tailored to meet future demands.[4]

Despite numerous concerns, health workforce forecasting has not been an easy task. The different types of health workforce forecasting approaches are not well-defined and can cause confusion during planning. The Organisation for Economic Co-operation and Development (OECD) broadly describes five main approaches;[5] the World Health Organisation (WHO) has four;[6] and other literature presents differently.[7–9] Several approaches, each with unique underlying assumptions, are customarily used and advocated. Among these, the workforce-to-population ratio, needs based, and utilization based approaches are the most prominent. While these assumptions exist to simplify the complex health workforce planning process, they have significant impact on forecasted results. Thus, a thorough understanding of the various assumptions is required before deciding on the use of any forecasting approach. We propose an integrated approach that explicitly considers factors such as changes in demographic and healthcare characteristics rather than replacing them with simplifying assumptions, thereby proving to be feasible and robust. This paper also compares projections from three conventional health workforce approaches – workforce-to-population ratio, needs based, utilization based – and the proposed integrated approach, as well as discuss when to use each approach, using future ophthalmologist requirements in Singapore as an illustration.

Health workforce forecasting approaches

The workforce-to-population ratio is a simplistic approach for determining the number of healthcare personnel required to serve a given population. The results can then be cross-referenced with benchmarks or expert opinions. Elements considered in this approach are typically demographic data such as population growth, and information on the workforce. Many studies have also made adjustments to account for factors such as utilization rates by age or gender and attrition rates of the health workforce.[10,11] In the workforce-to-population approach, the best ratio from a reference country or region with a slightly more developed healthcare sector than that to be investigated is assumed to be the benchmark.[12] For instance, in 2012, the number of ophthalmologists per million population is 112 in France, 81 in Germany, and 99 in Switzerland.[13] Despite its apparent advantage due to its speed and ease of application, this approach often does not consider factors such as productivity, utilization, and distribution of healthcare personnel, making interpretation of the results difficult. Therefore, the problem of unequal distribution of healthcare workforce is likely to persist even with the projected estimates.[12,14]

The needs based approach projects the health workforce requirements based on the current estimated healthcare needs of a population. Healthcare needs refer to the number of healthcare professionals or quantity of services required to provide optimal healthcare services to maintain a healthy population. Demographic characteristics such as the disease prevalence, age, gender, and education level of a population are fundamental to this approach.[8] This approach relies on the following assumptions: all healthcare needs will be met; economical methods to address the needs can be established; and healthcare resources are consumed according to relative levels of needs. The needs based approach presents a list of advantages. It has the ability to address the healthcare needs of the population using a combination of human resources for health and is also unaffected by current health service utilization. The approach is logical, comprehensible, and consistent with professional ethics. Hence, it can be employed as an advocacy tool. Nonetheless, it requires extensive epidemiological data, which is often unavailable. Also, this approach does not take into account the efficiency of the allocation of resources and requires regular updating of variables, for instance, the level of technology. Thus, projected staff and service targets may be unattainable.[12]

Utilization based approaches estimate the future healthcare workforce requirements using the current levels of services utilized by the population as a proxy for satisfied demand. Satisfied demand here refers to the levels of healthcare services a population will seek and have the ability to acquire at the current pricing within a certain timeframe. As with the needs based approach, the utilization based approach relies on demographic information such as disease prevalence, age, gender, and education level. In addition, utilization patterns of healthcare services and the market factors that influence these patterns are also taken into consideration.[8] The underlying assumptions of this approach are: current level, combination, and distribution of health services adequately meet the current demand for healthcare; age- and gender-specific requirements are held constant into the future; and demographic changes over time can be predicted based on prevailing trends.[15] The utilization based approach is useful in predicting economically feasible targets due to the assumption that there is little or no change in the population-specific utilization patterns.[12] Moreover, it is effective in studies of geographical variations, where utilization patterns are stratified. However, changes in future utilization patterns are not accounted for and can lead to skewed projections. In addition, information on the utilization and demand for healthcare services, especially in the private sector, is not always available. It must also be noted that the disparity between demand, utilization, and needs for services is not taken into consideration in this approach.[14]

We propose an integrated approach that estimates healthcare workforce requirements by projecting the healthcare needs or quantity of services required to provide optimal healthcare services to maintain a healthy population (needs based approach) and forecasting the likely current and future demand (utilization plus waiting list) of healthcare services among the population with healthcare needs, using demand data and expert opinions, taking into consideration expected demographic, health policy and technological changes. Demand herein refers to healthcare utilization combined with the time lapse between appointment booking and the actual patient visit (wait list). Similar to its constituent approaches, the integrated approach combines information on demographic characteristics such as disease prevalence, age, gender, education level, utilization of healthcare services, wait list of patients seeking healthcare and the market factors that influence usage. At the same time, other features such as financing, expansion of services and changing expectations of healthcare are also incorporated in the healthcare utilization estimates. While the assumptions of this approach are analogous to those of its constituent approaches, some differences exist due to the complementary nature of the two approaches. By considering those who require healthcare services and their care seeking behavior within the context of the health system and the likely expected future changes, we hope to mitigate the limitations of the individual approaches and better project future health workforce demands.

The first three are traditional approaches commonly used,[10, 16–21] while the latter is an approach proposed by the authors. A thorough comparison and evaluation are important because each approach introduces unique assumptions which have implications for the reliability of the forecast within the context of its application. Moreover, health workforce numbers have a major impact on population health, healthcare cost, and health outcomes.[2] Thus, understanding which approach to use given the characteristics of the healthcare system, population and time horizon of the forecast is vital.[22] This paper is built on an earlier study on health workforce projection using only a single approach that has been already published.[23] In this study, we further compare health workforce projection results using three distinct conventional forecasting approaches and a proposed integrated approach and discuss the differences and appropriateness of each approach. The appropriateness of each approach considering the characteristics of the healthcare system, population and time horizon over three time periods – short, medium and long – are discussed. The integrated approach was found to be the most versatile and suitable for health workforce planning.

2. Method

To compare the projections from the four health workforce forecasting approaches, four dynamic simulation models using the systems modeling methodology of system dynamics (SD) were developed based on a larger model described in detail elsewhere.[23] Using the example of eye care workforce planning in Singapore, the models were initialized and simulated. The previous model was built solely using the integrated approach, with the aim of forecasting the eye care workforce in Singapore, taking into account specific stakeholder concerns and considerations about changes in the eye care sector. SD models consist of an interconnecting set of differential and algebraic equations developed from a broad range of relevant empirical data.[24–26] The SD methodology depicts dynamic and detail complexity by focusing on causal relationships and dynamic feedback mechanism,[27] making it an appropriate method for understanding the forecasting approaches. The models are described in the following section.

Workforce-to-Population Model: Two inputs – total population and average population per workforce – are used to forecast workforce requirements under this approach. Using available data, average population per ophthalmologist was estimated and assumed to remain constant from the year 2012. Total ophthalmologists required for each year is then estimated by dividing the total population by the average population per ophthalmologist. The population from the year 2000 to 2040 under this approach was simulated using the model below (see Figure 1). The simple aggregate population model shows births, deaths and net migration as the three determinants of population change. Births are a function of average birth rate and the population, whereas deaths are a function of the population and life expectancy at birth. Net migration is herein determined by a constant fraction obtained by calibration. The population model is validated using publicly available national data.

Needs based Model: Under this approach, three input variables – people with eye diseases, average visit per person per year and average patient visit per ophthalmologist per year – were used to estimate workforce requirements (see Figure 2). Average patient visit per ophthalmologist per year was obtained from available data and assumed to remain unchanged from the year 2012 to 2040. Likewise, average visit per person with eye disease per year was obtained from data and assumed to remain unchanged over the simulation period. To project the number of people with eye diseases, a detailed dynamic population model was developed. Based on other published population models,[27–29] the population model shows a detailed aging process of the Singapore population disaggregated by single age cohorts (age 0-age 100 and older), gender, ethnicity (Chinese, Malays, Indians, Others), and educational attaintment (no formal education, primary, secondary and tertiary). The population model herein shows births, deaths and net migration as the three main determinants of population change. A detailed description of the population model can be found in the references as cited.[27–29] To project the number of people with eye disease, we applied the prevalence of eye diseases from the Singapore Epidemiology of Eye Diseases (SEED) study[30–32] for resident Singaporeans 40 years and older to the population model of resident Singaporeans. The prevalence of eye diseases was disaggregated by age, gender, ethnicity and educational attainment. The eye conditions included herein are cataracts, diabetic retinopathy (DR), glaucoma, age-related macular degeneration (AMD), myopia, refractive error (*Note 1: For the case mix administrative data from Singapore National Eye Centre [SNEC], refractive error refers to refractive error other than myopia*), epiretinal membrane (ERM), retinal vein occlusion (RVO), and other conditions (*Note 2: Other conditions include the SEED study categories of Amblyopia, Corneal conditions, PCO, Pterygium, Retinal scar, Retinal dystrophy, Optic disc, No obvious, Aphakia, Phthisis, Trauma, Squint and Others, an open category that includes all other eye diseases not classified into the previous 21 categories*). Since the needs based approach assumes that all individuals with care needs seek care, the number of people with eye diseases was multiplied by the average visit per person with eye diseases per year to obtain projected demand for eye care services. This was then divided by the average patient visit per ophthalmologist per year to project the number of ophthalmologists required.

Utilization based Approach Model: Under this approach, the number of expected patient visits was divided by the average patient visit per ophthalmologist per year to project the number of ophthalmologists required. Patient visits are herein determined by people with eye diseases, average visits per person per year and uptake rate. The utilization based approach model is similar to the needs based approach model and projects the prevalence of eye diseases among the population. In addition, it estimates the proportion of the population with eye diseases who are likely to seek eye care (uptake rate). The number of people with eye care needs is projected exactly as described in the needs based approach. The only difference between the needs based and the utilization based approach is that, while needs based approach assumes that all individuals with care needs will seek care, utilization based approach postulates that only a fraction of individuals with care needs will seek care due to various reasons.

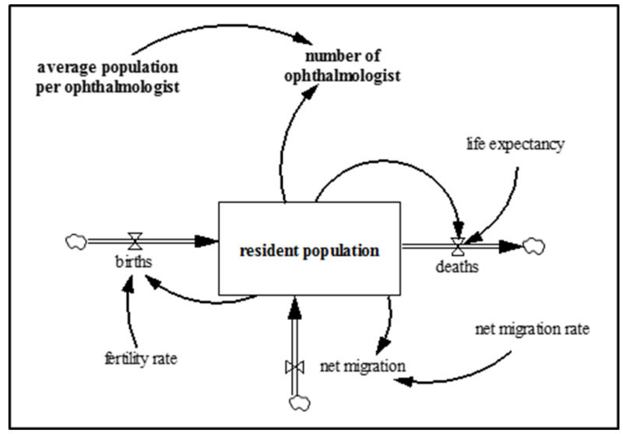

Figure 1. Workforce-to-population model

Integrated Approach Model: The integrated approach (see Figure 3), like the needs based and utilization based approaches, projects detailed estimates of the number of people with eye care needs on a population level. However, the population with eye care needs is herein divided into three groups – patients receiving eye care services, patients who have completed care (or receive step-down care) and unmet eye care needs. Similar to the population sub-model, these categories of patients with eye care needs are further disaggregated by age, gender, ethnicity, and education. To accurately account for mortality by age, the patients in care and the population that has completed care are aged over time.

The stock of patients in care increases as new patients from the stock of unmet eye care needs seek care for the first time and decreases by mortality and attrition of patient in care. Patients who completed treatment flow out from the patients in care stock to the completed care population stock. The non-surviving patients in each age cohort are removed by deaths, which is a reflection of age-specific mortality. For the purpose of this study, it was assumed that completion of treatment is applicable only to patients with these eye diseases – cataracts, myopia and refractive error – with an estimated treatment time of three, one and two years respectively. All other eye conditions specified herein are assumed to require lifelong care in the specialist eye centers. Mortality rates of patients in care are similar to that provided in life tables. Attrition of patients in care was estimated by dividing patients in care by average time in care. The stock of patients who have completed care (completed care population) increases by attrition of patients in care and decreases by death. Eye care demand was calculated from the number of patients in care and average visits per year.

The most important and vital difference between the the integrated approach and the utilization based approach is that the integrated approach is capable of accounting for changes in uptake rate among individuals with eye diseases due to changing educational attainment, particularly among the elderly population, and the inclusion of wait list in calculating demand for eye care services.

2.1 Model validation

Using the behavior test, simulated behavior was compared with time series data for selected variables: demand, and number of ophthalmologists employed. Results showed that the two were comparable, demonstrating the model's good fit with historical data. The model was also presented to stakeholders to verify its structure and assumptions regarding causal relationships. It was agreed that the model structure is sound and valid.

2.2 Data

Demographic data used in the population module were obtained from the Singapore Department of Statistics (SDS).[33] The population module was calibrated using time series data on the resident Singapore population from SDS. Age-specific prevalence estimates from the SEED study[30–32] were used. Administrative data on patient visits were provided by the Ministry of Health (MOH). The SNEC provided administrative patient visits case mix data, disaggregated by age, eye disease, and data on ophthalmologists work schedule used to estimate the proportion of time spent on clinical work, research, teaching, and administration duties. The number of ophthalmologists in Singapore was obtained from Singapore Medical Council (SMC) annual reports from 2003 to 2013.[34] Table 1 shows a list of the various data sources and model input parameters.

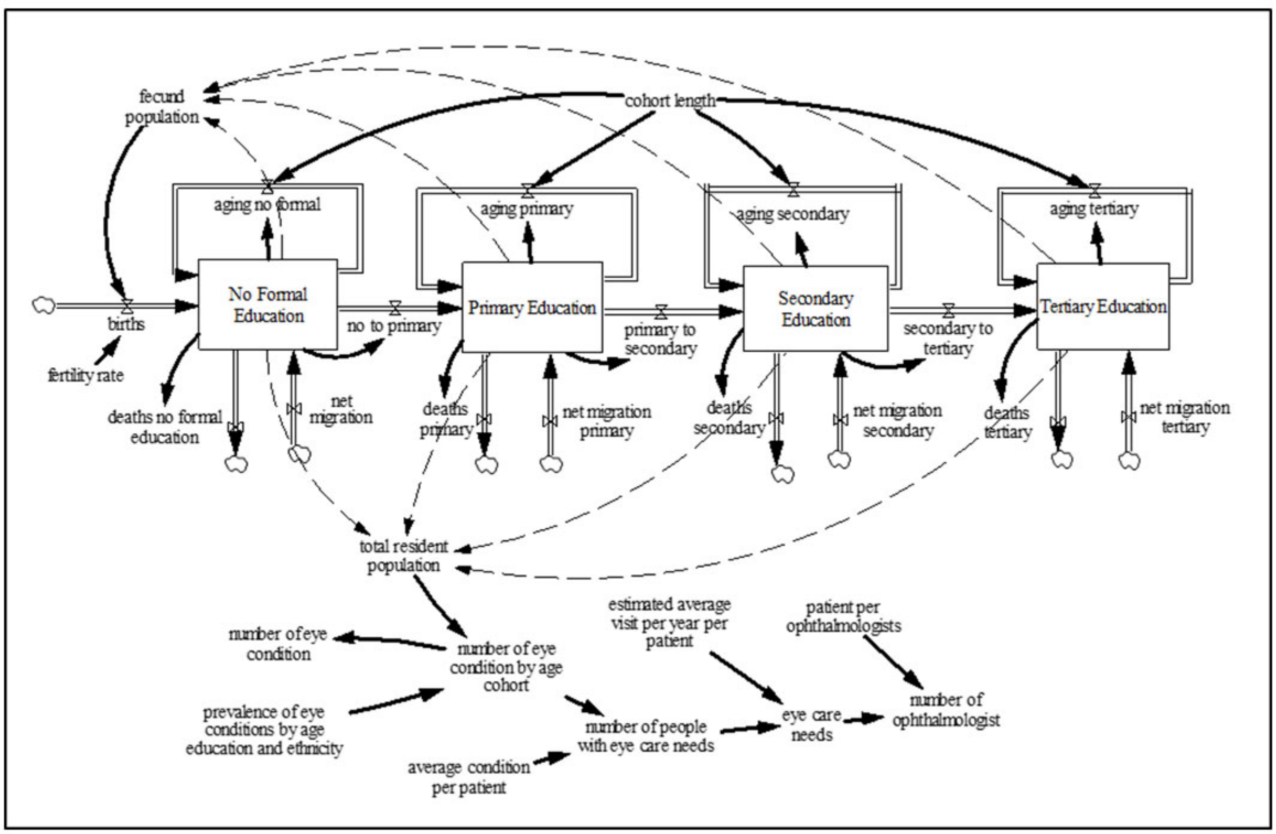

Figure 2. Needs based approach model

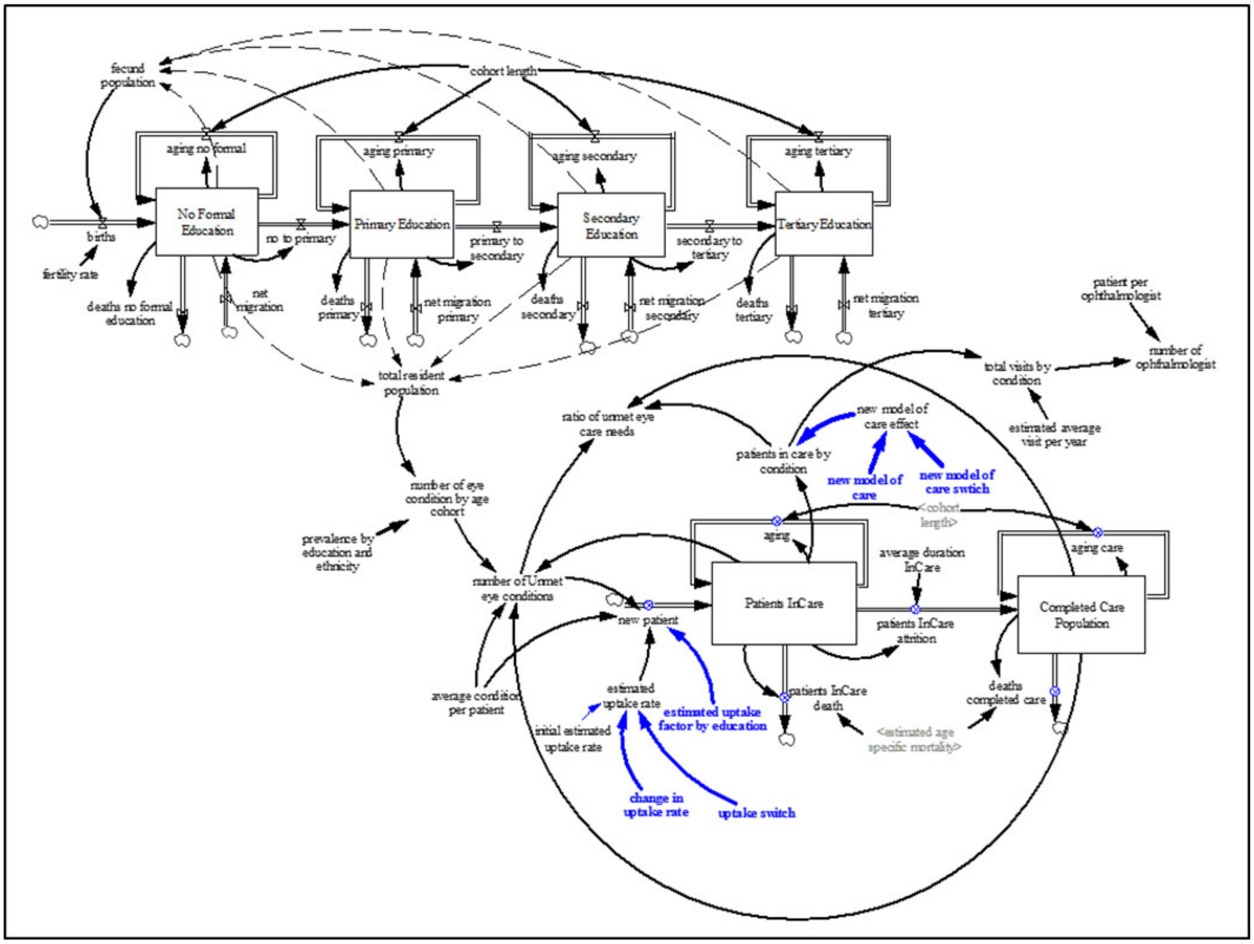

Figure 3. Integrated approach model

2.3 Sensitivity analysis

Sensitivity analysis was performed to account for changes in the outcome variable as a set of model parameters under each approach is varied. Using two-way sensitivity analysis,[35] the value for these sets of parameters were varied by $\pm 25\%$, and a uniform distribution for each parameter range was assumed (see Table 2). The model was run 1,000 times for each set of parameters under each approach. Each run drew a parameter value from a uniform distribution. We report 95% sensitivity bounds (2.5 percentile to 97.5 percentile) of the results from the Markov chain Monte Carlo (MCMC)[36] simulations.

3. Results

Table 3 compares the number of ophthalmologists required projected by the workforce-to-population ratio, needs based, utilization based, and integrated approaches. In 2010, the projected number of ophthalmologists are 101 (95% sensitivity bounds i.e. 2.5 percentile to 97.5 percentile: 77-125), 645 (389-1,044), 102 (57-179) and 103 (65-171) using the workforce-to-population, needs based, utilization based and integrated approaches respectively. By 2040, under the workforce-to-population ratio approach, the projected number is 183 (140-226); while that for needs based approach is 1,465 (883-2,373), and 231 (129-406) for the utilization based approach. Lastly, 406 (251-674) ophthalmologists are projected to be required by 2040 under the integrated approach.

When using the workforce-to-population ratio approach, the projected number of ophthalmologists required to provide adequate care for patients with eye diseases shows an 81 percent increase from 2010 to 2040. Under the needs based approach, ophthalmologists required from 2010 to 2040 will increase by 127%, representing 8.00 times the number projected for the workforce-to-population ratio approach. With the utilization based approach, the projected required ophthalmologists increase by 127% from 2010 to 2040, which is 1.26 times as many as that of the workforce-to-population ratio approach. Lastly, for the integrated approach, the required number of ophthalmologists is projected to increase 293% from 2010 to 2040, which is 2.22 times as many as that of the workforce-to-population ratio approach.

Table 1. Data sources

Parameter	Value	Unit	Source
Workforce Population Ratio:			
Life expectancy	Time series [2000-2014]	Dimensionless/year	Singapore Department of Statistics
Fertility rate*	Time series [2000-2014]	Dimensionless/year	Singapore Department of Statistics
Net migration rate&	0.014	Dimensionless/year	Model Calibration
Population per ophthalmologist	28,670	Person/doctor	Singapore Medical Council
Initial population	3,273,360	Person	Singapore Department of Statistics
Needs based approach:			
Cohort length£	1		-
Age-specific mortality rate‡	Time series [2000-2014]	Dimensionless/year	Singapore Department of Statistics
Average condition per patient§	1.7	Dimensionless/year	SEED Study
Visits per ophthalmologist†	4,951	Visit/doctor	Ministry of Health Singapore
Utilization based approach:			
Uptake rate	0.157	Dimensionless/year	Model Calibration
Integrated approach:			
Average duration in care			
Cataracts	3	Year	Expert Opinion
Myopia	1	Year	Expert Opinion
Refractive Error	2	Year	Expert Opinion
Initial estimated uptake factor	0.075	Dimensionless/year	Model Calibration
Estimated uptake factor by education			
No education	0.6	Dimensionless/year	Estimates from literature
Primary education	0.759	Dimensionless/year	Estimates from literature
Secondary education	1.03	Dimensionless/year	Estimates from literature
Tertiary education	2	Dimensionless/year	Estimates from literature
Change in uptake rate	0.005		

Note. The same parameters*, & from the workforce-to-population ratio and parameters £, ‡, §, † from the needs based model were also included in both the utilization based model and the integrated approach model.

In 2020 (see Figure 4), the projected required ophthalmologist estimates suggest that the needs based approach estimate is significantly different from that of the workforce-to-population ratio, utilization based and integrated approaches. On the other hand, when using the utilization based approach, there is a 58% chance that the projected number of ophthalmologists will fall within the estimate from the workforce-to-population ratio, considering the uncertainties around the projection. The likelihood that the projected number of ophthalmologists using the utilization based approach will fall within that projected by the integrated approach is 81%. The projected number of ophthalmologists from the integrated approach has a 37% chance of being similar to the workforce-to-population ratio.

In 2040 (see Figure 5), there is 44% chance that the number of ophthalmologists projected by utilization based approach will fall within that projected by the workforce-to-population ratio, taking into account the uncertainties around the projection. The needs based approach estimate is entirely different from all three other approaches. In comparing the integrated approach to the utilization based approach, there is a 38% chance of obtaining similar projected numbers.

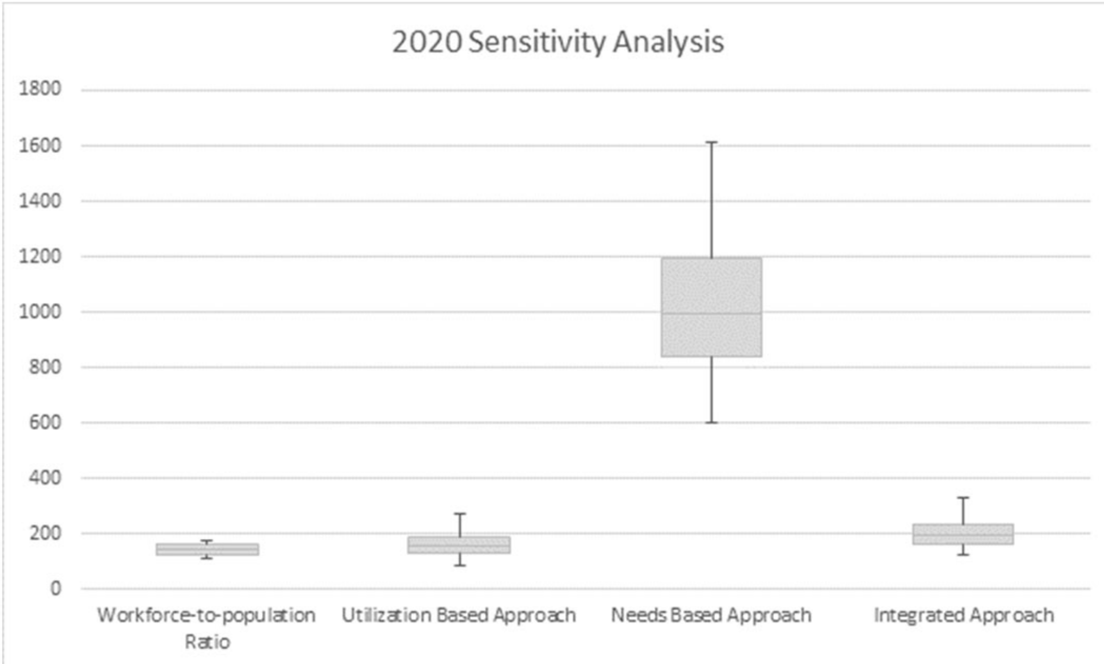

Figure 4. Box plot of sensitivity analysis for the year 2020

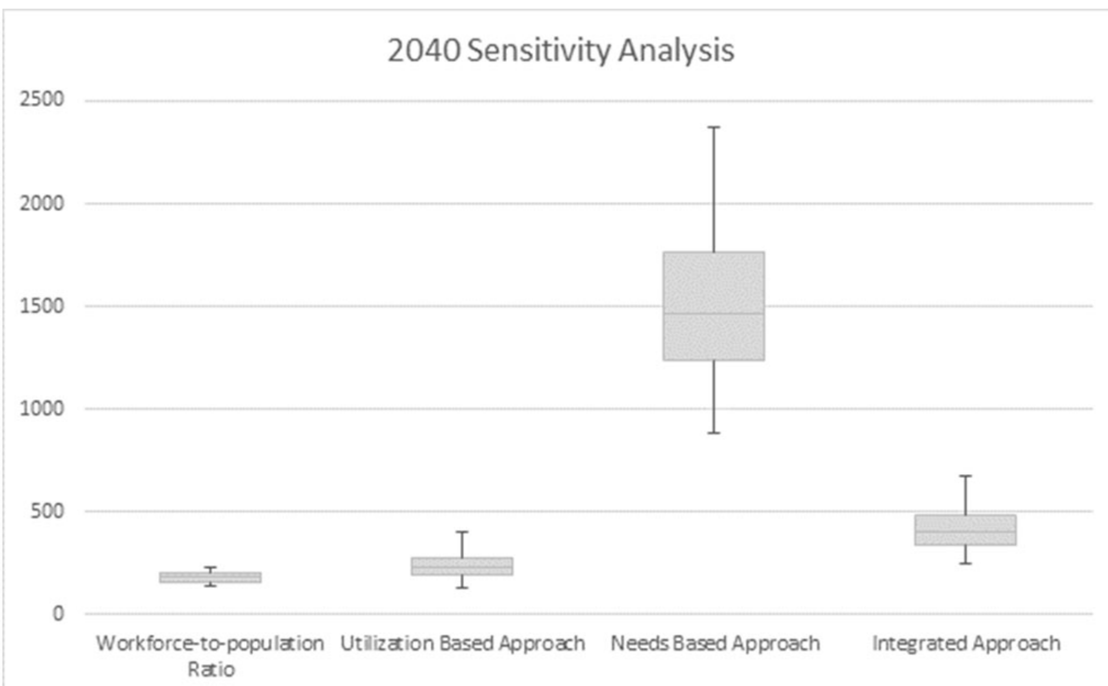

Figure 5. Box plot of sensitivity analysis for the year 2040

4. DISCUSSION

In comparing the projected number of ophthalmologists required under the different approaches, we found that each approach projects a different number of ophthalmologists required over time. The needs based approach tends to project the largest number of required ophthalmologists, followed by integrated, utilization based and workforce-to-population ratio approaches in descending order. The likelihood of projecting similar numbers under the approaches differ in the short and long term. In the short term, our results suggest that there is a high likelihood that utilization based and integrated approaches may project similar results; however, needs based approach estimates were found to be significantly different from all the other estimates. In the long term, our results suggest that the likelihood of projecting a similar number of ophthalmologists between workforce-to-population ratio and utilization based approaches, as well as utilization based and integrated approaches decrease. A summary of the strengths and weaknesses of the four approaches is shown in Table 4.

Table 2. Model parameter values and ranges for sensitivity analysis

Parameter	Value	Range	Unit	Distribution
Workforce Population Ratio:				
Population per ophthalmologist	28,670	21,502-35,837	Person/doctor	Uniform
Utilization based approach:				
Visits per ophthalmologist	4,951	3,713-6,188	Visit/doctor	Uniform
Uptake rate	0.157	0.118-0.196	Dimensionless/year	Uniform
Average visit per patient per year	2.46	1.845-3.075	Visit/patient/year	Uniform
Average eye condition per patient	1.7	1.257-2.125	Dimensionless/year	Uniform
Needs based approach:				
Visits per ophthalmologist	4,951	3,713-6,188	Visit/doctor	Uniform
Average visit per patient per year	2.46	1.845-3.075	Vist/patient/year	Uniform
Average eye condition per patient	1.7	1.257-2.125	Dimensionless/year	Uniform
Integrated based approach:				
Visits per ophthalmologist	4,951	3,713-6,188	Visit/doctor	Uniform
Uptake factor by education				
No education	0.6	0.51-0.86	Dimensionless/year	Uniform
Primary	0.759	0.56-0.93	Dimensionless/year	Uniform
Secondary	1.03	0.77-1.28	Dimensionless/year	Uniform
Tertiary	2	1.5-2.5	Dimensionless/year	Uniform
Average visit per patient per year	2.46	1.845-3.075	Vist/patient/year	Uniform
Average eye condition per patient	1.7	1.257-2.125	Dimensionless/year	Uniform

The increase in ophthalmologist requirements by 2040, under the workforce-to-population ratio approach, is mainly a result of an increase in population size; while that for the needs based and utilization based approaches include population aging. The change in requirement for ophthalmologists under the integrated approach is due in part to an increasing population and aging, which is associated with increased prevalence of eye diseases and increased use of eye care services due to a combination of factors such as higher educational attainment, expected increase in screening, subsidies and availability of healthcare services.

The finding that health workforce forecasting under the four approaches considered is likely to produce both significant differences and similarities over time implies that future health workforce forecast is reliant on the choice of forecasting approach. The appropriateness of the forecasting approach used depends on the changing characteristics of the population to be served, the timeframe of the forecast, how factors influencing utilization of care are expected to change over time, healthcare financing and how the productivity of the workforce is likely to change.

First, the demographic characteristics of a population to be served and its possible changes over time should be identified. In general, a growing population is expected to demand more healthcare services. However, the increase in demand between young and aging populations will differ. A young population is expected to be relatively healthy with disease burdens unlikely to change drastically, resulting only in a proportionate increase for healthcare services. On the contrary, the prevalence of chronic conditions in an aging population is expected to increase, resulting in a more than proportionate increase in the demand for healthcare services.[37] This has implications for the number of healthcare professionals required to maintain a healthy population. In addition, a demographic distribution such as gender and ethnicity must also be taken into consideration as disease prevalence have been shown to differ among these categories.[38–40] The workforce-to-population ratio simply projects a ratio that does not account for changes in demographic characteristics, thereby yielding a significantly underestimated workforce requirement. Thus, when changes in demographic characteristics are expected, the other three approaches – needs based, utilization based, and integrated – may be more appropriate because these approaches account for changes in demographic characteristics.

Table 3. Sensitivity analysis results of required ophthalmologists

Approach	Base Year	Projected						% change from 2010-2040
	2010	2015	2020	2025	2030	2035	2040	
Workforce-to-Population ratio	101 [77-125]	136 [105-169]	145 [111-179]	153 [118-190]	163 [125-201]	173 [132-213]	183 [140-226]	81%
Needs based	645 [389-1,044]	849 [512-1,376]	995 [600-1,613]	1,136 [685-1,841]	1,267 [764-2,054]	1,379 [832-2,235]	1,465 [883-2,373]	127%
Utilization based	102 [57-179]	134 [75-235]	157 [87-276]	179 [100-315]	200 [111-351]	218 [121-382]	231 [129-406]	127%
Integrated	103 [65-171]	144 [90-241]	197 [122-330]	256 [158-428]	315 [193-524]	366 [226-607]	406 [251-674]	293%

Table 4. Overview of approaches

Approaches	Advantages	Limitations
Workforce-to-population ratio	Easy to implement Does not require extensive data	Unable to resolve unequal distribution of health workforce Does not provide insight into utilization pattern
Utilization-based	Predictions are economically feasible Effective in studying utilization stratified by geographical variations	Changes in future utilization patterns unaccounted Requires extensive data Disparity between demand, utilization and needs for services is not considered
Needs-based	Ability to address the healthcare needs of the population Unaffected by changes in service utilization	Requires extensive epidemiological data No consideration of practicalities of supply Little attention to factors influencing care seeking behavior
Integrated Approach	Accounts for changes in epidemiological needs, care seeking behavior, and other potential changes that will affect healthcare demand	Requires extensive data

The duration over which the workforce requirement is projected is also an important consideration as the parameters considered in the projection of healthcare demand are subject to changes over time. In short, timeframes where changes to the factors are not expected, the relatively simple workforce-to-population ratio approach may be used.

Healthcare utilization is dependent on a variety of factors. The socioeconomic factors that influence healthcare utilization have been well documented.[41,42] Higher educational attainment is expected to positively influence health care utilization patterns. Studies have shown that those with better education have increased expectations of their health status and thus are likely to have increased preventive visits.[43,44] An increasingly educated population is also likely to be more affluent suggesting an increased ability to afford healthcare services.[45] If utilization is expected to change over time, the integrated approach will be the most suitable approach for projecting future requirements for health workforce.

Another important factor to consider when selecting a suitable forecasting approach is the mode of healthcare financing within a population. Whether healthcare is supplied by free market mechanisms, public provision or insurance coverage affects utilization rates and in turn health workforce requirements. Since socioeconomic status is one of the determinants of healthcare utilization, the utilization based or integrated approaches may be more suited for health workforce forecasting in a healthcare system primarily funded by out-of-pocket payment. On the other hand, the needs based approaches may be more suitable for forecasting in a universal healthcare system or one with compulsory social insurance as it aids in the identification of the minimum number of healthcare professionals required to attend to the health needs of everyone in a population.[46]

Lastly, the productivity of the health workforce is influenced by a myriad of factors such as technology, care organization and new models of care. Any increase or reduction in workforce productivity will significantly affect the projection numbers and therefore cannot be neglected. The increasing use of sophisticated technology in healthcare has been shown to increase productivity, reducing the need for manpower. However, it must be noted that whilst the use of technology often serves to increase productivity, the opposite effect might result as machine operation may require constant supervision or manual input. In addition, the manner in which healthcare is organized can have an effect on the health workforce productivity. In chronic eye care, an increasing number of activities (e.g. fundus photography and management of diabetic retinopathy patients or intraocular pressure management in glaucoma patients) could potentially be performed by non-doctors (e.g. optometrist and ophthalmic technicians). Thus there is a need to optimize the combination of skills necessary, or skill mix, to deliver healthcare efficiently to a population.

5. Conclusions

This paper compares four different approaches for forecasting health workforce requirements over a period of forty years. A novel approach integrating the needs based and utilization based approaches was also proposed. By considering both the demand for eye care services and its utilization patterns, the limitations of the traditional approaches can be mitigated. The integrated approach was found to be suitable for analyzing health workforce requirements over short to long timeframes due to its dynamic nature.

A variety of factors such as educational attainment and changing demographics have an impact on the demand for healthcare services and thus have to be considered when projecting health workforce requirements. As each approach is fundamentally different, policy makers must be aware of the various considerations that must be accounted for when planning to select a suitable approach for projection.

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Authors' contributions

JA, DK, DM and DQ conceived of the study, participated in its design and supervised the data analysis. JA and VK drafted the manuscript. JA performed the statistical analysis. DK, SB, CP, JT, DM, VK and DQ revised the manuscript, provided conceptual support and critical evaluation. All authors read and approved the final manuscript.

Conflicts of Interest Disclosure

The authors declare that they have no competing interests.

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