A System Dynamics Analysis of Malaysian Healthcare Resources

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Abstract

Malaysian healthcare landscape is changing rapidly and facing drastic transformation in relation to drivers of change in the healthcare system. The objective of this study is to analyze the impact of healthcare resources interventions on accessibility and affordability of healthcare. The Malaysian Healthcare Resources Model (MHRM) is developed to provide a wide-ranging view of the complex interactions between demand and supply of healthcare resources and provide potential future scenarios of healthcare provision to achieve the country’s target. The scenario analysis’ findings suggest that increasing healthcare resources through medical workforce supply and productivity of hospital beds (bed turnover ratio) will assist to achieve healthcare accessibility and this in turn will improve the quality of healthcare along with moderate increase in budget allocation to public healthcare. Meanwhile, reducing the proportion of out-of-pocket expenditure is more valuable than having higher income in fostering healthcare affordability among Malaysians.

Keywords: System Dynamics, Healthcare Resources, Accessibility, Affordability

1. Introduction

Public health financing provided by the central government of one country acts as a crucial factor in improving health status through providing healthcare human resources and facilities such as doctors, nurses, bed capacity, hospitals, and so on. In contrast, the reverse is observed if money is spent privately from individuals’ out-of-pocket (OOP) on consuming healthcare. World Health Organization [1] described the risk and uncertainty of healthcare discouraged people from consuming preventive care, but they prefer to spend their OOP for curative care. Spending more OOP would reduce an individual’s disposable income in which bring about poverty in the society [2]. Hence, the policymakers of many countries have attempted to make sure the population lives healthier through raising the investment on healthcare which leads to the increase in public health expenditure around the world.

The objective of this study is to analyze the impact of healthcare resources interventions on accessibility and affordability of healthcare. The goal of this study is to answer the following research questions: (1) How does growing patient attendance at the government hospitals affect both public financed and non-public financed healthcare provision? 2) Under what conditions can the healthcare resources improve to achieve the accessibility and affordability of healthcare? In order to answer these research questions, a simulation model of demand and supply of Malaysian healthcare provision was constructed. Application of the system dynamics model provides a framework for understanding the feedback structure and the complex system of the components in healthcare resources.

The remainder of the paper is organized as follows. In the next section, the literature review is presented. Subsequently, Section 3 provides a description of system dynamics methodology and the Malaysian healthcare resources’ conceptual model. Section 4 presents the Malaysian Healthcare resources’ simulation model (MHRM). Section 5 shows the results of model testing while Section 6 discusses the results of the scenario analyses. Discussions of the various scenarios are explained in Section 7, and the conclusion of the paper along with remarks for future work are presented in Section 8.

2. Literature Review

Various types of methodologies have been used widely in healthcare resources analysis such as econometric method, questionnaire–based method and so on. Shortage of long time series data availability is one of the prior studies’ restrictions in using statistical analysis. For example, Xu et al. [2] argued that long term effects could not be observed due to the lack of panel time-series of data. Data quality is different by countries as well. Some countries have excellent data reporting systems, whereas other countries count on estimation approach to insert data gaps. In line with the study by Hassan et al. [3], long

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time series data constraints in using statistical technique is one of the limitations to obtaining a better estimation. Even so, various studies have adopted system dynamics methodology on healthcare issues over the years, mostly covering countries in developed regions and the countries concerned adopt a single healthcare system. Examples of the studies are healthcare affordability in Singapore by Ng et al. [4], the potential medical demand in China by Wang et al. [5], and modeling the sufficiency of doctors in Japan and Spain by Ishikawa et al. [6], Barber and López-Valcárcel [7] respectively.

To the best of our knowledge, no existing empirical research addresses the inclusion of individuals’ private healthcare spending in modeling demand and supply of healthcare resources using system dynamics. Yet, there is a lack of healthcare studies in Malaysia using system dynamics with regards to analyzing a general picture of the interconnection of healthcare resources components. The studies that have been conducted have discussed healthcare situation in general rather than evaluating the interrelationship between physical and financial resources thoroughly. An example is the research by Nurul et al. [8].

2.1 Originality

The abovementioned phenomena need an appropriate methodology that could demonstrate the dynamics of the healthcare resources and construct a comprehension of the interconnection of the key elements. The system dynamics approach is remarkably appropriate to investigate the circular connection events between variables under a complex system such as in healthcare system [9]. Accordingly, this study analyzed the interconnection between supply and demand for healthcare resources using the system dynamics approach. We included OOP spending in our demand and supply of healthcare resources as the OOP expenditure in Malaysia is quite high. Further, the paper presents various interventions in the supply side to meet growing demand in public hospitals.

3. Methodology

3.1 System Dynamics Modelling

In this section, we provide a brief background on the system dynamics modeling and subsequently, present our conceptual model. The evolution of system dynamics modeling (SDM) was pioneered by Jay Forrester in 1956. The system dynamics method is adopted to solve complex problems in a system and to diagnose the behavior of the system during a particular period.

In this study, we derived the main parameters involved in the model through detailed literature reviews of related materials. Consequently we built our conceptual model that connects the variables to each other. In order to quantify and elaborate on the conceptual model, the additional ability of stock and flow diagram (SFD) was developed to capture the stock and flow structure of the system. The following Table 1 displays the diagramming notations to represent the components of the stock and flow diagram in VENSIM. The stock variables are calculated through the integration of their flow variables with respect to discrete time (t). The state of the stock at time (T) can be mathematically expressed in Eq. (1):

$$\text{stock (T)} = \int_{t_0}^{T} (\text{inflows} - \text{outflows}) \, dt + \text{stock (t_0)} \quad (1)$$

Table 1 Diagramming notations of stock and flow

<table>
<thead>
<tr>
<th>Graphical Icons</th>
<th>Variables</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock or level</td>
<td>A variable which accumulates or depletes over time.</td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td>Arrow of flow into and out from the stock</td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>Controls the inflow and outflow that alter the quantitative value of stock over the course of time that drawn in the middle of flow</td>
<td></td>
</tr>
<tr>
<td>Cloud</td>
<td>Source and sink</td>
<td></td>
</tr>
<tr>
<td>Connector</td>
<td>The arrow connector represents the links between elements in the model system</td>
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</tbody>
</table>

3.2 Model Conceptualization

Figure 1 describes the generic conceptual model of Malaysian healthcare resources. Principally, the healthcare sector in Malaysia is similar to the German healthcare system, which operates a two-tier healthcare system consisting of both public and private healthcare sectors. The differences between both sectors are described below:

3.2.1 Roles of Public and Private Healthcare

Public healthcare service that is highly subsidized by the government is financed mainly through tax payments of affluent citizens who act as the main healthcare provider to the whole population, particularly to vulnerable groups such as the elderly and poor people. In contrast, profit-oriented private healthcare sector including high-class medical centres and private-owned healthcare businesses acts as the second choice of healthcare provider for most citizens.
of the citizens depending on their economic and health conditions. The sector is financed rigidly through fee-for-service basis.

3.2.2 Functions of Public and Private Healthcare

The government hospitals that are located in both urban and rural areas either charge a nominal fee or are free of charge to the citizens of the country. These hospitals are often overcrowded, leading to shortages of medical practitioners and stretching the hospital capacity and space with long waiting times. On the other hand, private medical centers that are mostly concentrated in urban and metropolitan areas offer more expensive curative and rehabilitative services. The sector provides better quality of services than public hospitals with highly equipped medical technologies, luxurious facilities and higher availability of general practitioners and medical specialists.

3.2.3 Relations between Public and Private Healthcare Sectors

All the private healthcare service providers are required to be licensed by the government (Ministry of Health). Mushrooming private healthcare businesses resulted from the government’s encouragement for them to play a crucial role in the country’s economy and healthcare system as it would help to reduce the burgeoning public health expenditure and the crowdedness of patient attendance at government hospitals. Besides, rapid growth of private insurance companies helps to release the burden of the citizens to cover the high cost of medical treatments in high-quality hospitals. However, the country is predicted to transform its healthcare financing system into a social insurance system as in most other countries, where the patients can utilize the services of any hospital, either public or private, as they wish.

4. Stock and Flow Diagram

The structure of each stock and flow sub-model was constructed based on the conceptual model described in the preceding section. The models were developed using Vensim PLE. The models adopted a simulation time range from 2000 to 2030 (31 years) since this is a considerably good timeframe for observing the effects of interventions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed turnover rate</td>
<td>0.37</td>
<td>%</td>
</tr>
<tr>
<td>Annual income per capita</td>
<td>10,800</td>
<td>Ringgit Malaysia</td>
</tr>
<tr>
<td>Admission rate</td>
<td>0.375</td>
<td>%</td>
</tr>
<tr>
<td>Percentage of discharge rate</td>
<td>0.65</td>
<td>%</td>
</tr>
<tr>
<td>Fatality rate</td>
<td>0.525</td>
<td>%</td>
</tr>
<tr>
<td>Percentage allocation of PHE</td>
<td>0.4125</td>
<td>%</td>
</tr>
<tr>
<td>Percentage of OOP health spending</td>
<td>0.3</td>
<td>%</td>
</tr>
<tr>
<td>Doctor quota</td>
<td>1570</td>
<td>People</td>
</tr>
<tr>
<td>Nurse quota</td>
<td>900</td>
<td>People</td>
</tr>
<tr>
<td>Time for recruiting doctor</td>
<td>1.5</td>
<td>Year</td>
</tr>
<tr>
<td>Time for recruiting nurse</td>
<td>2</td>
<td>Year</td>
</tr>
</tbody>
</table>

Note: PHE and OOP indicate public health expenditure and out-of-pocket expenditure

The initial values of input variables used in the model are based on the Malaysian Annual Health Fact Reports [10]. The data are publicly available and can be obtained through the Malaysian Ministry of Health website. We employed the year 2000 as a base year for the simulation model. Altogether, the Malaysian Healthcare Resources Model (MHRM) has been composed into four subsystem diagrams: healthcare demand, healthcare workforce supply, bed provision and financial resources sub-models. The list of key parameters used for the modeling are listed in Table 2.

4.1 Healthcare Demand Sub-model

Demand for public healthcare service is presumed to grow due to the increase in aging population, changes in socio-economic conditions, emergence of a variety of disease patterns, technological advances and many other factors. The increase in public health expenditure has prompted higher expectations from citizens for improvements in the highly subsidized government hospitals as a primary source of care and healthcare
services provided by the government. Figure 2 shows an overview of the demand sub-model from the population and the number of patients. This sub-model comprises three major stocks, namely total population, outpatients and inpatients that are indicated by three rectangular boxes. There are seven major flows among these stocks. Population growth variables are associated with the inflow of crude birth rate and outflow of the crude death rate. In Malaysia, the citizens generally seek treatments from general practitioners and these patients are known as outpatients. These outpatients will receive a prescription whether to walk-out or be admitted to the hospital for certain illnesses. Thus, the number of inpatients increase by the admission rate and decrease by the discharge rate and the death rate in the hospitals.

\[ \text{Doctor (nurse) recruitment} = \frac{\text{doctor (nurse)-patient capacity ratio}}{ \times \text{doctor (nurse) quota} \times \text{time for recruiting doctor (nurse)}} \]  \hspace{1cm} (2)

\[ \text{Doctor (nurse) retirement} = \frac{\text{Doctors (nurses)}}{\text{Doctor (nurse) retirement period}} \]  \hspace{1cm} (3)

\[ \text{Healthcare accessibility}^3 = \frac{\text{Doctors (nurses) bed availability}}{\text{Total population}} \]  \hspace{1cm} (4)

\[ \text{Quality of public healthcare} = \text{Healthcare accessibility} \times \text{percentage allocation of PHE} \]  \hspace{1cm} (5)

\[ \text{Bed occupancy rate} = \frac{\text{Inpatients}}{\text{Bed availability}} \]  \hspace{1cm} (6)

\[ \text{Healthy care accessibility is defined as when adequate supply of healthcare resources available be accessed by the citizens of one’s country. Gulliford et al. [12] defined healthcare accessibility as “when supply of healthcare resources available adequately, and population being able to access it”}. \]

4.2 Healthcare Workforce Supply Sub-model

Meanwhile, two main components of healthcare workforce supply are considered in this study. The medical doctors and nurses sub-models have similar structures as illustrated in Figure 3. The medical doctor (nurse) stock is changed by the flow of recruitments added into doctors (nurses) cohort, and in turn, is depleted by layoffs and retirements. Increasing the supply of doctors (nurses) workforce has caused an increase in the doctor (nurse)-patient capacity ratio that equates to the division of the number of doctors (nurses) with the number of patients in public hospitals. The rise of both components in the healthcare workforce supply can lead to an increase in healthcare accessibility, which in turn will improve the quality of healthcare. The mathematical equation for healthcare workforce (nurses and doctors) sub-model are stated as:

\[ \text{Doctor (nurse) recruitment} = \frac{\text{doctor (nurse)-patient capacity ratio}}{ \times \text{doctor (nurse) quota} \times \text{time for recruiting doctor (nurse)}} \]  \hspace{1cm} (2)

\[ \text{Doctor (nurse) retirement} = \frac{\text{Doctors (nurses)}}{\text{Doctor (nurse) retirement period}} \]  \hspace{1cm} (3)

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\[ \text{Healthcare accessibility is defined as when adequate supply of healthcare resources available be accessed by the citizens of one’s country. Gulliford et al. [12] defined healthcare accessibility as “when supply of healthcare resources available adequately, and population being able to access it”}. \]
Gap of required and available capacity = Bed occupancy rate – bed availability

\( (7) \)

Accumulated bed capacity = Adjustment time of bed capacity x gap of required and available capacity x bed turnover rate

\( (8) \)

4.4 Financial Resources Sub-model

The number of patients in public hospitals has influenced the desired health expenditure which in turn increased the percentage allocation of public health expenditure (PHE) so as to close the gap with current public health spending availability. This sub-model indicates public health expenditure is boosted by investment inflow and drained by its depreciation, which leads to the increase in individual health spending.

This OOP payment will affect the affordability of the citizens’ healthcare particularly with regards to the vulnerable groups as shown in Figure 5. Therefore, the increase in OOP contributes to the growth in total private health expenditure, along with other sources of private funding such as private-owned clinics, health insurance companies and so on.

\[ \text{Increment} = \text{Decreasing in PHE} \times \text{percentage of OOP health spending} \times \text{time to adjust OOP} \]  
\( (12) \)

Health care affordability\(^4\) = \(\frac{\text{Annual income per capita}}{\text{OOP health expenditure}}\)

\( (13) \)

Increase in private health expenditure = Fraction of other private source of funding \(\times\) OOP health expenditure \(\times\) time to adjust

\( (15) \)

5. Model Testing

In the simulation scenario, we trained our model to reproduce similar results with the historical behaviors. Figure 6 depicts the result of structure validation between historical data [10] and simulation model over the period of 2000 to 2015 for public health expenditure as the funder of healthcare resources in Malaysia. From the Figure, it can be seen that trend line of the simulated model fit to the real behavior. Dotted and solid lines represent historical and simulated behaviors respectively. The numerical error analysis indicates the value of MAPE is considerably low and \(R^2\) values are more than 0.9 for all stock variables. This allows us to analyze the total error to affirm the model’s reliability.

\[ \text{Increment in PHE} = \text{Gap} \times \text{adjustment time to increase} \times \text{PHE} \times \text{percentage allocation of PHE} \]  
\( (9) \)

Desired PHE = \(\frac{\text{Number of patients}}{\text{Public health expenditure}}\)

\( (10) \)

Gap = Public Health Expenditure - desired PHE

\( (11) \)

\(^4\) Affordability healthcare means the population has ample income to pay for healthcare costs [13].
6. Results

Once the model has been validated through a statistical test to the main parameters, we ran several scenario analyses of supply side interventions over the course of 15 years from 2016 to 2030.

Figure 7 Baseline behavior of healthcare demand and supply of healthcare workforce

Figure 7 demonstrates the relationship between demand and supply of healthcare resources at baseline values. Healthcare demand is represented by the total number of patients attending the public hospitals. Meanwhile, health workforce supply is indicated by the number of medical officers and nurses available over the course of 31 years from 2000 to 2030. Further, Figure 8 depicts the relationship between the number of admissions to hospitals, the availability of beds and the utilization of beds. It can be seen that bed occupancy rate, which indicates the actual utilization of hospital facilities surpasses bed availability. This results from the steady increase in the number of patients admitted to the hospitals.

Figure 8 Baseline behavior of patient admission and supply capacity

Figure 9 Scenario analysis of doctor to population ratio

Figure 9 shows the three scenario tests on the changes in doctor quota by 15%, 20% and 25% increase from the baseline values. This study attempts to seek a doctor to population ratio as one of the government’s strategies in the Eleventh Malaysia Plan is to improve the doctor to population ratio to 1:400.

Figure 10 Scenario analysis of healthcare accessibility

Figure 10 represents the three types of scenario analysis (low, medium and high) on healthcare accessibility as shown in Table 3. Different levels of welfare and cost burdens borne by public healthcare provider are assumed. The target level has been set as the average increase in welfare and cost. The analysis attempts to identify in what conditions healthcare resources can improve healthcare accessibility. Through this scenario analysis, the quality of healthcare can be directly observed as shown in Figure 11 with different allocations of PHE.
Table 3 Scenario analysis of healthcare accessibility and quality of public healthcare

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Parameter Changes</th>
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<tbody>
<tr>
<td>Baseline</td>
<td>Doctor = 1570, Nurse=900, BTOR=0.37</td>
</tr>
<tr>
<td>Target (Medium)</td>
<td>25% increase 25% increase</td>
</tr>
<tr>
<td>Low</td>
<td>50% decrease 50% decrease</td>
</tr>
<tr>
<td>High</td>
<td>50% increase 50% increase</td>
</tr>
</tbody>
</table>

Figure 11 Scenario analysis of quality of healthcare

Figure 12 Scenario analysis of public health expenditure

Figures 12 and 13 display how the changes in percentage allocation of public health expenditure (as shown in Table 3) to improve healthcare accessibility would impact on public health expenditure and total medical demand. Total medical demand is represented by the total number of outpatients’ and inpatients’ attendance at government hospitals.

7. Discussion

The Malaysian healthcare resources simulation model (MHRM) was successfully developed with the aim to comprehend profoundly how an increasing population influences demand for public hospital resources, public health financing, and individuals’ health expenditure and how these elements are connected to each other dynamically. By 2040, Malaysia is predicted to become an aging population as the country’s above 65 years old population is projected to increase yearly. Undoubtedly,
these increasingly aging citizens will exert more pressure on public healthcare resources as the population relies heavily on government healthcare service due to its low cost of treatments. Therefore, this study strives to test several scenarios of healthcare resources to achieve healthcare accessibility and affordability as stated in the Eleventh Malaysia Plan.

By increasing the supply of doctors by 15%, 20% and 25%, Malaysia is expected to achieve its target to improve doctor-to-population ratio to 1:400 in 2023, 2021 and 2019 respectively as depicted in Figure 9. These are the points where the scenario lines of increasing the doctors’ quota have surpassed the target line. On the other hand, healthcare accessibility can be well achieved through increasing the supply of healthcare workforce, bed capacity ratio and proportion of public healthcare expenditure. Both doctors and nurses are vital as they have face-to-face interactions with the patients.

The results confirm that extending the service supply will lead to better healthcare accessibility. On the other hand, the analysis also identified that an increase in bed turnover ratio will result in an increase in the availability of beds for admitted patients. This improvement certainly will improve the quality of service in public hospitals along with burgeoning financial resources compared to merely increasing the welfare capacity. Based on the analyses shown in Figures 10 and 11, the medium scenario is set as a target since it is an appropriate condition for the country to achieve its goal that is a moderate increase in healthcare provision at a moderate increase in budget allocation. Over-spending of government budget on healthcare will lead to unstoppable increase of the citizens’ reliance on government hospitals that will cause unresolved undersupply of healthcare provision.

Apart from accessibility of healthcare, this study also attempts to analyze healthcare affordability as part of achieving universal coverage. Currently, Malaysians’ OOP expenditures are predominantly derived from the private sector as the government only charges the bare minimum amount for medical services at private health centres. The behavior of Malaysians spending directly for healthcare and medical services could result in a financial meltdown. Presently, Malaysians contribute 35% of OOP through payments made out of their own pockets despite the government’s heavily subsidized universal healthcare system [14].

Decreasing the OOP is much more valuable to the citizens rather than earning better incomes. The result of the scenario on healthcare affordability demonstrates that even when the annual income per capita is set at low and medium, lowering OOP by 20% will improve health affordability to levels similar to the baseline and high income values respectively in the future. Consequently, most of the high-income earners who have to pay more for healthcare are expected to turn to public healthcare resources in the future rather than continuing to consume the services of private hospitals, which are much more expensive. As shown in Figure 14, the behaviors of all scenarios tend to converge and achieve a catch-up effect. This behavior is similar to the idea of economic growth theory of convergence in that a backward country, initially having a low income will tend to grow faster than a high-income country in the long-run. The analysis of health affordability relies on the level of income of the citizens. As income increases, people can afford to access better healthcare.

Corresponding to that theory, Figure 14 illustrates that the citizens who have considerably moderate initial income and moderate healthcare affordability at present time will tend to grow to the same levels with high income level and thus achieve similar level of healthcare affordability in the future. This situation might be true for Malaysia: as the country aspires to achieve its Vision 2020 to become a high-income country in 2020, the income per capita is expected to increase. Therefore, the citizens are expected to afford better healthcare in the future in line with increasing level of income.

Furthermore, a country with an OOP rate exceeding 15-20% will face a higher risk of financial catastrophe, where people will get ill and then they do not have enough money to bear the medical bills. In order to surveil the progress of Asia Pacific Region, WHO Health Financing Strategy [15] had proposed one of the targets namely, OOP health expenditure should not be over 30% to 40% of total health expenditure [16]. Therefore, lowering OOP health funding rate to below 30% by increasing the funding in public health budget will mitigate the barriers faced by the citizens particularly the low to average income group to attain healthcare affordability.

8. Conclusion

The study of the financing of healthcare is crucial as it is an important component in a healthcare system that would help to reduce the financial risks of individuals and thus improve their health outcomes. Most of the emerging economies are confronting several common challenges to achieving universal healthcare coverage. For instance, financial and non-financial constraints such as inadequate capacity and health workers and last but not least is the ongoing epidemiological transition such as infectious diseases and increasing non-communicable diseases. Financial risk protection prevents sick individuals and their families from being pushed into poverty as they doubt either to pay for health services or to spend on other goods from their own pockets.

The development of the Malaysian healthcare resources model (MHRM) is to comprehend and explore the effects of healthcare resources in achieving universal coverage. The model enables us to visualise the interactions between demand and supply of healthcare resources. This would assist healthcare management to understand resource capacity and the bottleneck of the healthcare system and thus make a decision to improve the healthcare service. The results of this study are expected to provide important information on how policymakers should formulate the availability of healthcare resources for planning their limited resources.
Expecting supply of healthcare to address future health challenges is a pivotal but complex task for policy makers.

We believe that the proposed conceptual framework and system dynamics simulation can be improved in the future through the following considerations: (1) analyzing how public health expenditure are spent to other healthcare resources (2) disaggregating the population cohorts, (3) expanding the current model of private healthcare sector and further analyzing of this sector as it is growing to play a more important role in the healthcare system as well.

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References