

System Dynamics Model in Estimating Manpower Needs in Dental Public Health

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Abstract

System Dynamics Modeling, is the computerized model based on the conceptualized interactions of multiple factors within the study system. The present study applied the method of system dynamics modeling in estimation of man power need in dental public health from 1995 to 2015. The base line information derived from the National Oral Health Survey in 1984, 1989 and 1994. The results of projection suggested that the appropriate number of total dental personnel were 6,164 in 1995 and 11,970 in 2015, which led to the minimum dental personnel population ratio for dental services in Thai people of 1:9,636 in 1995 and 1: 5,813 in 2015. Three scenarios were developed for classifications of the roles of dentist and dental nurse according to the levels of simple tasks delegated to dental nurse. Proportion of requirement for dentists from the total dental personnel in 2015 decreased from 75% in the conventional scenario to 57% and 45% in the more progressive alternatives. The study indicates the possibility of oversupply of dental personnel in the future and the need for adjustment of the roles of dentist and dental nurse.

1. Introduction

The first, and perhaps the most difficult step in planning for public health personnel production and development is the estimation of man power needs in the future. Since the education and training process for personnel always takes a long time, as well as consumes substantial resources, an inaccurate estimation can cause the long term crisis of under or over supply of particular types of personnel, or their expected qualifications.

Since 1973, there are many studies in Thailand to estimate need for dental personnel with various approaches. So far, there are 3 national and 2 personal studies in this regard⁽¹⁻⁵⁾. However, their results showed obvious variations of estimation. Need for dentist per population ranged from 1: 4033 to 1: 15,727. While need for dental nurse were from 1:8900 to 1: 20,366⁽¹⁻⁶⁾. It is clear that there are high possibility of over or under estimations among those numbers.

The major difficulty of dental public health problem estimation is the complexity of related factors. Multi - factorial factors of dental problems such as socio-economic factors, natural history of oral diseases, service utilization system, distribution of dental personnel, as well as the population growth, affected the overall problems with their complex interactions. Each factor itself also has its own system of sub-factor interaction. Thus, an attempt to find explanation of the interactions among those factors and to search the problem solving method from the pattern of relationship within the whole system, should be an appropriate way for estimating man power according to dynamic situation of health problems⁽⁷⁾. System Dynamics Model, which provides this dynamic approach was

thus introduced to the present study in order to estimate man power needs in dental public health system in Thailand.

2. Objectives

To introduce the concepts of System Dynamics Modeling in estimation of man power needs in dental public health. The specific objectives are;

- 2.1 To study the framework of problems of insufficient dental services in Thailand.
- 2.2 To develop the System Dynamics Model of dental service utilization system in Thailand.
- 2.1 To develop an alternative model of dental service utilization and dental man power estimation in Thailand.

3. Basic definitions in this research

System Dynamics research is a rather new approach in the field of man power estimation. The crucial definitions for basic understanding are;

3.1 System Dynamics ⁽⁸⁾

“The method of studying a complex problem by explaining the structure of interactions among all the compositions as well as the behavior, or the change pattern of the system.”

3.2 Dynamic Problems ⁽⁸⁾

The problems that one addresses from the perspective of system, which dynamics have at least two features in common. First, they are *dynamic* : they involve quantities which change over time. They can be expressed in terms of graphs of variables over time.

Dental public health problems can be defined as dynamic problems according to their change pattern over time, as explained in Figure 1;

(Figure 1 here)

The second feature of problems to which the system dynamics perspective applies involves the notion of feedback. *Feedback* is the transmission and return of information. The emphasis, inherent in the word feedback itself, is on the return. This mechanism is similar to the function of thermostat to control the temperature of a refrigerator. Its main function is to feedback the existing temperature which is a part of the feedback system of the refrigerator.

The feedback system of dental public health problems can be demonstrated in Figure 2.

(Figure 2 here)

The feedback systems characteristically form loops of interconnection called loop of causes and effects or *Causal Loop* diagram.

3.3 Formal model

Perhaps the most visible feature of the system dynamics approach

is its use of formal, quantitative computer models . The term “model” stands for a representation, essentially a simplification, of some slice of reality. A system dynamics model is a laboratory tool. It allows repeated experimentation with the system. Testing assumptions or altering management policies . The purpose is to gain understanding. So that the problem to which the model is addressed may be solved or minimized.

3.4 The time horizon

The time horizon , or time frame , is the period of time over which the problem plays itself out. It is the length of simulated time over which one will eventually run a dynamic model.

The time frame of the present study is 20 years, between 1995 - 2015 .

3.5 The Reference Mode

Graphing important variables , and inhering graphs of other significantly related variables, produces the problem focus for a system dynamics study.

The major reference mode of this research is the graph from the analysis from the National Oral Health Survey in 1984, 1989 and 1994 ⁽⁹⁻¹¹⁾ .

4. Methodology

:System dynamics approach to dental public health problems and dental delivery care system in Thailand

The system dynamics approach to complex problem focuses on feedback processes. It takes the philosophical position that feedback structures are responsible for the changes we experience over time. The premise is that dynamic behavior is a consequence of system structure.

There are roughly seven stages in approaching a problem from the system dynamics perspective. The process begins and ends with understanding of a system and its problems , so it form a loop , not a linear progression. Figure 3 shows overview of the system dynamics modeling approach.

(Figure 3 here)

4.1 Developing the causal loop and flow diagram of dental public health problems.

This stage is the “*problem identification and definition*”, including “*system conceptualization*”. The major interest is the problem, not the system. The problem here is the under supply of need for dental services. There are two sides of flow diagram in Figure 4. Loop 1 shows dental problems from oral diseases and oral health behavior that cause the need for services. Loop 2 is related to the cause of problem from the service utilization system, involving number of dental personnel and their proportional roles in health promotion, prevention and treatment.

(Figure 4 here)

In Loop 1, dental problems increase from various factors, such as the increasing number of population, the change of socio-economic status of people, or

recurrent rate of oral diseases. On the other hand, the problems decrease from the impacts of disease prevention and treatment. As the actual provided services is less than the needs, the model can show the dynamicity of the problems according to this discrepancy over time.

Loop 2 composed of 2 critical factors or activities affecting the decrease of dental public health problems. First is dental treatments which have direct impact to reduce dental problems. Second is the health promotion and disease prevention activities affecting the incidence of diseases. These two factors are weighted and prioritized according to the government policy, which consequently influence the policy of man power development.

From the main Causal Loop in Figure 4, the present study developed further Causal Loop of sub-system of each main factors, the Reference Code from the data from the National Oral Health Survey in 1984, 1989 and 1994, as well as the Causal Loop of population change and dental man power production system of Thailand from 1995 to 2015.

4.2 Model formulation and analysis of model behavior

This stage is to transform the Causal Loop into “*Dynamo Flow Diagram*”, which is the computerized flow diagram developed by DYNAMO language⁽¹²⁾. The purpose is to develop an arithmetic model to explain relationship among factors in the Feedback or Causal Loop. Therefore, the computer can calculate the results within a time unit and show the results in numbers or graphic illustrations. The program can perform the repeated experimentation for decision analysis by transforming some major parameters to testify different assumptions of the system behavior.

4.3 Research information

The present research utilized the data from the National Oral Health Surveys in 1984, 1989 and 1994 to estimate the need for service of dental treatments and trends from 1995 to 2015 as follows (Figure 5);

- 1) Trends of dental treatment need
- 2) Prediction of change rate (hours per year or hours/person/year)
- 3) Prediction of need for man power
- 4) Prediction of impacts from dental health promotion and disease prevention

4.4 System of problem and demand for dental personnel

The analysis of structure, together with epidemiological data by system dynamics modeling approach produced the systematic interactions of problems, need and demand for services, need for dental personnel, and all the crucial influencing factors of systematic change in Thailand. This set of relationship, or *the system of problem and demand in dental personnel*, was demonstrated in Figure 6, as a dynamics system upon the time frame from 1995 to 2015.

In other words, the dynamics system in Figure 6 is the expanded illustration of the fundamental system in Figure 4. It incorporated the epidemiological data in Figure 5 to construct a complete *Causal Diagram* to be further formulated into a *Mathematical model*.

4.5 Model formulation, simulation and model testing

As mentioned in 4.2 and 4.3, the mathematical model was simulated by repeated computerized process to test the structure and sensitivity of the model. Behavior of major factors in the model were studied and confirmed by adjusting related parameters. These experimental were repeated until the systemic model showed its acceptable validity and reliability.

5. Results

The developed system dynamics model provided various synthesized information such as;

- Population structure by age groups during 1995 - 2015
- Need for dental treatments: total and specific treatment type
- Trend of dental problems by year
- Manpower need: total and specific service type
- Current personnel production

5.1 Supply projection

According to the present production plan in Thailand, dentist : population ratio will be change from 1: 11,944 in 1995 to 1: 6,890 in 2015, dental nurse : population ratio will be from 1: 43,452 to 1: 9,369 (Table 1). Thus, dental personnel (dentist and dental nurse) population ratio will be improved from 1: 9,369 in 1995 to 1: 3,905 in the next twenty years.

(Table 1 here)

5.2 Requirement projection

According to the actual situation and trend of dental health problems in Thailand, the average time to serve the need for dental service in Thailand (AV TN) will decrease from 180.9 minutes/person in 1995 to 136.5 minutes/person in 2015 (Table 2). This means that there will be the decrease of approximately 25 percent of overall dental public health problems, in term of time spending for service, during the next two decades,

(Table 2 here)

If we want to serve all the **need for dental treatments within 1 year** (PERS YR), the total number of dental personnel required will be 129,800 in 1995 or 114,700 in 2015. However, in case it is possible to produce such a great number of dental personnel in Thailand, all accumulated dental treatment needed will be totally served within 1 year. Thus for the next coming year, the dental treatment needed will be reduced only to incidence and re-treatment cases. This will consequently cause unemployment of dental personnel from the next year, or surplus numbers (SUR PERS) of 123,000 in 1996 and 102,600 in 2016. (Table 2)

The appropriate number of dental personnel suggested from the system dynamics model were presented as PERS NO in Table 2, which were 6,164 in 1995 and 11,970 in 2015. The recommended dental personnel population ratio (PERS: POP) were 1: 9,636 in 1995 and 1: 5,813 in 2015.

This estimated number of dental personnel needed was calculated based on the number that should theoretically maintain the present oral health status of Thai people to

the year 2015. It should be noted that the underlined assumption of the acceptability of the current dental health status of Thais comes from its comparison to World Health Organization's goal by the year 2000. Two standard oral health indicators are compared i.e. the dental caries status in 12 year-old children and number of functional teeth in 35-44 year-old adults. While WHO goal for the dental caries status measured by the number of decayed, missing and filled teeth (DMFT) in 12-year-old children is set at 3 teeth per person by the year 2000⁽¹³⁾, the actual figure for Thai children was as low as 1.6 teeth per person in 1994⁽¹¹⁾. The second indicator is the percentage of 35-44 year-old people who have at least 20 functional teeth. While the acceptable WHO figure was 50% by the year 2000, the figures for Thai adult (35-44 years-old) was 91.9% in 1994⁽¹¹⁾.

Thus the estimated dental health personnel proposed in this study would correspond to the minimal demand for dental health services including the services to maintain present dental health status plus demand from recurrent and incidence of dental health problems.

In addition to the indication of the minimum number of dental personnel to maintain the present oral health status of Thai people through 2015, the suggested numbers of dentist and dental nurse were proposed based on their different roles in dental services. The whole dental services were classified into complicate, general and simple services (Figure 7). However, there is no conclusive agreement about the border line of "the simple services" which should be delegated to dental nurse. The present study set up 3 scenarios in drawing this line

The three scenarios range from the conservative one with least roles for dental nurse to the progressive one with highest roles for dental nurse. The requirement of dentists and dental nurses in each scenarios were estimated as shown in table 3. It is clear from table 3 that the proportion of dentists goes from 75% in the conservative scenario down to 57.6% and 45.2% in the compromise and progressive scenarios, respectively.

5.3 Comparison between supply and requirement

Table4 and Figure 8 Show the figures compare between supply projection and three scenarios of requirement projection. It shows that which ever scenarios is chosen, there will always be surplus of both dentists and dental nurses in the next twenty years.

6. Discussions and Conclusion

The estimation of manpower requirement by the system dynamics model is performed by indicating the problems and their causal factors to form a systemic model of problem. The factors in the model then freely interact each others corresponding to the indicated relationships. Those systemic interactions develop the system behavior which can explain the complex problems and the required improvements to solve those problems. The outstanding advantage of the system dynamics model is that its parameters can be adjusted by policy makers according to changing situation or to create visualized alternatives in planning.

The estimation of dental personnel from the present research showed the lowest number of personnel required in comparison of the previous studies in Thailand⁽¹⁻⁵⁾. The difference partly originated from some different assumptions of the studies. However, one of the prime distinction between system dynamics model and the conventional cohort estimations is that the system dynamics estimation did not calculate the total number of personnel in order to eliminate all the problems within each particular year as the main

outcome. This approach took the surplus number of personnel if all the needs were served within that year into consideration. If the long term goal of dental health service can be clearly defined, we can estimate the manpower needed accurately. However we assume that the current dental health status of Thai people is quite well and we estimate the personnel needed to keep this dental health status in the next 20 years. Therefore, the final suggested results from the model should be considered to be more appropriate as well as more realistic.

The critical findings of the present study indicate the possibility of oversupply of dental health personnel in the next two decades (Table 4). **We thus propose that there should be no attempt to increase the production rate of dental health personnel beyond the present situation.**

In term of proportion between dentist and dental nurse, 3 alternatives were demonstrated in Table 3-5. The first mode., which is similar to the conventional justification nowadays (Table 3) showed as height proportion of dentist as three quarters of the total dental personnel in 2015. This is the most expensive model and might be rationally considered inappropriate to the situation of a developing country as Thailand. The next 2 models delegated more simple tasks to dental nurse and could reduce the proportion of dentist from total dental personnel in 2015 to 57.6% and 45.2% respectively. In comparison to general proportion of medical personnel or any other professional and para-personned ratio, of which more tasks were rationally delegated to the para-personned than to the professional, the third model should be regarded as the most appropriate.

The results indicated the importance of justification of the roles to various dental personnel. Dental specialist should be responsible to the complicate tasks which is beyond the qualification of graduated dentist. While the simple dental services have to be delegated to dental nurse and possibly to health worker. Without the reasonable change of the present roles of dental personnel, the human resources will not be maximally utilized to efficiency improve the oral health of Thai people. The consideration of this kind of change needs moss discussions among dental profession, health administrators. As will as consumer groups.

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References:

1. Yuktanant I.: **Dental public health problems in Thailand**, Thesis, Bangkok, National Defense College, 1972-1973. (*Thai*)
2. Tumkhosit U.: **Estimation of need for dental personnel**, Bangkok, Department of Health, Ministry of Public Health , 1979. (*Thai, unpublished paper*)
3. Dental division, Department of Health, **Dental man power development to achieve oral health for all by the year 2000**, Bangkok: Veteran Press, 1986. (*Thai*)

4. Proceeding of the conference **Dental personnel in dental public health system in Thailand**, Khonkaen: Faculty of Dentistry, KhonKaen University, 1993. *(Thai)*
5. Udompanich S: **The development of delivery care model in dental public health at district level**, PhD thesis, Bangkok: Mahidol University, 1990. *(Thai)*
6. Health Systems Research Institute, Bureau of Health Policy and Plan, Praboromrajchanok Institute, **Health manpower requirement for Thailand in the next two decades**, Research report, Bangkok : Health Systems Research Institute, 1997. *(Thai)*
7. Feungchantra S. **Policy analysis by System Dynamics**. In Feungchantra S and Sirisampan T (eds): *Technique and strategy in policy analysis*, Bangkok: Chulalongkorn Press, 1984.
8. Richardson, GP. and Pugh III, AL , **Introduction to system dynamics modeling with DYNAMO**. Cambridge: MIT, 1981.
9. Dental health division, Department of health, **Report of the second national oral health survey**, Bangkok: Dental Health Division, 1984. *(Thai, unpublished paper)*
10. Dental health division, Department of health, **Report of the third national oral health survey**, 1989, Bangkok: Veteran Press, 1990. *(Thai)*
11. Dental health division, Department of health, **Report of the fourth national oral health survey**, 1994, Bangkok: Veteran Press, Bangkok, 1995. *(Thai)*
12. Roberts N, Anderson DF, Deal RM, Garet MS and Shaffer WA , **Introduction to computer simulation: A system dynamics modeling approach**, Portland, Oregon : Productivity Press, 1994.
13. Leopold T et.al. **The world Health organization goals for oral health** a progress report, *Community Dental Health* 1991:8, 245-251
14. Office of the Permanent Secretary of the Ministry of University affair, **Report on increase production of dental graduates by Ministry of University Affair to the Government, Bangkok**: Chulalongkorn University Press, 1989

1. CPITN (Community Periodontal Index for Treatment Need) index is used to determine the treatment need for periodontal disease., when :

CPI2 = need for scaling

CPI3 = need for root planing

CPI4 = need for periodontal surgery

2. DMFT index is used for determining the treatment need for Dental Caries, when :

D = decay tooth with the need for filling/or root canal treatment/
extraction

M = missing tooth with the need for prosthesis

F = Filled tooth; needs to be refilled in case of recurrent caries

3. Others means the treatment needs for other diseases and conditions such as orthodontic treatment, maxillo-facial surgery, occlusal adjustment, etc.

Table 3 Condition for three scenarios of dental services responsibility by dental nurses and projected dental manpower requirement

Condition

Responsibility	Scenario 1 (Conservative)	Scenario 2 (Compromise)	Scenario 3 (Progressive)
Scaling. (CPI-2)	60%	100%	100%
Put and fissure sealant	50%	50%	50%
Simple tooth extraction	50%	50%	50%
One surface filling	50%	80%	80%
Two surface filling	-	-	50%
Pulpotomy in Children	-	-	20%

Projection

Year	Dentist	Dental nurse	Dentist	Dental nurse	Dentist	Dental Nurse	Total
1995	4771	1393	3840	2324	2956	3208	6164
2000	5047	1504	3949	2602	3221	3330	6551
2005	7606	1677	6470	2796	5668	3604	9282
2010	9296	2414	7686	4024	6505	5205	11710
2015	8924	3046	6892	5078	5410	6560	11970

Table 4 Supply - requirement comparison for dental health personnel

Dental personnel	1995	2000	year 2005	2010	2015
Dentist					
supply	4,973	6,187	7,441	8,840	10,100
requirement					
scenario 1	4,771	5,047	7,606	9,296	8,924
+/-	+202	+1,140	-165	-1,456	+1,176
scenario 2	3,840	3,949	6,470	7,686	6,892
+/-	+1,133	+2,238	+971	+1,154	+3,208
scenario 3	2,956	3,221	5,668	6,505	5,410
+/-	+2,017	+2,966	+1,773	+2,335	+4,690
Dental nurse					
supply	1,367	2,744	4,651	6,301	7,718
requirement					
scenario 1	1,393	1,504	1,677	2,414	3,046
+/-	-26	+1,240	+2,974	+3,887	+4,672
scenario 2	2,324	2,602	2,796	4,024	5,078
+/-	-957	-142	+1,855	+2,277	+2,640
scenario 3	3,208	3,330	3,604	5,205	6,560
+/-	-1,841	-586	+1,047	+1,096	+1,158
Total					
supply	6,340	8932	12090	15140	17820
requirement					
scenario 1, 2, 3	6,164	6,551	9,282	11,710	11,970
+/-	+176	+2,381	+2,808	+3,430	+5,850

+ = surplus
 - = deficient