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System Dynamics Modelling for Workforce Planning: Case of Pharmacists

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Abstract

Pharmacists play a critical role in the healthcare system through medication management, patient counseling, chronic disease management, and ensuring the safe and effective use of medicines. However, the pharmacist workforce system in Thailand faces increasing challenges due to changing healthcare demands, an aging population, technological advancements, policy changes, and evolving labor market conditions. This study aimed to develop a thirty-year pharmacist workforce plan for Thailand using a system dynamics modeling approach covering five major professional areas: hospital pharmacy, retail pharmacy, consumer protection, education, and industry. The findings reveal that the simulation demonstrates the workforce imbalances significantly across professional areas. Hospital pharmacists experienced severe shortages during the early stages, while retail pharmacy showed the largest long-term workforce gap. In contrast, the consumer protection, education and industry area generally maintained a workforce surplus throughout the simulation period. These results indicate that workforce shortages are area-specific rather than system-wide and require differentiated policy responses. Future research should develop more detailed models in each area, particularly incorporating data on workforce mobility, job choices, retention, and employment behavior across different areas. These will enhance the effectiveness of the models as a tool for supporting policy decision-making at the national level.

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1. Introduction

Pharmacists are vital to the healthcare system as their roles include ensuring safe, effective medication use, bridging the gap between physicians and patients, and optimizing health outcomes through clinical, community, and hospitals. Key responsibilities include medication dispensing, counseling, chronic disease management, and drug therapy monitoring to enhance patient safety. After six-year study in pharmaceutical program and pass licensing exam, the graduates are ready to enter the workforce in different areas depending on their personal characteristics, preferences, skills, renumerations, expectation, and other factors.

The main workplace areas are hospitals, retails, consumer protection units, education, and industries. Hospital or clinical pharmacists focus on patient-specific medication therapy assessment while retail pharmacists provide accessible, community-based care in pharmacies. Consumer protection pharmacists work in Food & Drug Administration units or Provincial Public Health Office to ensure the safety for consumer. Education pharmacists are professors or researchers work in academic institutes while Industrial pharmacists involved in drug research, development, manufacturing, and marketing of medicines.

Human Resource Management (HRM) faces significant challenges when the demand for labor (need for employees) does not match the supply (available workforce). These imbalances create operational inefficiencies, higher costs, and reduced competitiveness, impacting both labor shortages and surpluses. The problems are worse for healthcare professional imbalances as the production process takes a long period of time and the shortages affect people's safety and well-being.

For pharmacist graduate, the main target workplace is private and government hospitals, however other areas are increasing their attractiveness. Hence, the forecasted demand for pharmacists in total may not reflect the actual need of professionals in different areas. The demand for one area may be surplus while others may face shortage. In addition, the dynamic shifts in today world driven by an intensifying aging population, the rapid evolution of digital health technology, the emergence of new and re-emerging infectious diseases, and the frequent policy changes of the government have big impact on the demand for each professional area differently.

At present, there is no research available on the workforce planning for pharmacists in Thailand, especially to take the differences between the actual situation and dynamic-shift scenario into consideration. Current researches are mainly on questionnaires survey, expert interview, or statistically forecasting techniques to forecast future workforces which are considered as static data. Very few researches use system dynamics which is a method for modeling and testing formal mathematical models and computer simulations of complex, nonlinear, and dynamic systems for planning pharmacist workforce.

The system dynamics can support the policymaking process in systems with increased structural and functional complexity [1]. Therefore, this research is aimed at planning pharmacist workforces for the next thirty years using system dynamics modelling. It covers the workforce plan for five major professional workplaces for pharmacists namely hospitals, retail pharmacies, consumer protection units, education, and Industries.

2. Literature Review

2.1. Method for Forecasting Manpower

Traditional pharmacist workforce planning in the past often relied on static quantitative estimation methods, such as by calculating the population-to-pharmacist ratio, estimating demand from healthcare service surveys, performing a qualitative analysis, or forecasting demand in individual fields [2–18]. These methods offered the advantage of being relatively simple for management application, but they were largely based on the assumption of linear workforce forecasting and substitution within the system. While static methods could estimate numbers, they failed to account for workforce imbalances within the system [19].

Therefore, recent research has turned to the system dynamics modeling, which can better reflect the relationship between supply, demand, personnel behavior, and latency occurring in the system. The model shows that changes in workforce are not solely a result of inflow or outflow but rather a combination of behavioral factors, and it can also assess the long-term effects of policies under various scenarios [20]. The context of workforce planning changing over time through the system dynamics modeling offers significant advantages over traditional forecasting methods because it can represent the workforce system as a stock (the number of personnel available in the system) and inflow–outflow (entering and exiting the system), reflecting the continuous accumulation and changes in workforce over the long term.

Furthermore, the model can explain the cause-and-effect relationship through a causal loop diagram, providing feedback loops, both reinforcing loops (R) and balancing loops (B), including the effects of workforce production latency to respond to changing policies on workforce demand [21]. These characteristics allow simulations to reflect the behavior of nonlinear systems and enable policy testing before implementation, unlike statistical or static estimation methods that typically only consider relationships at a specific point in time. Therefore, the system dynamics modeling can better describe long-term workforce imbalance structures. The literature review of methods used for manpower forecast in healthcare setting is shown in Table 1.

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Table 1. Literature review of methods used for manpower forecast in healthcare setting.

Author	Manpower	Methods for Forecast
[2–4]	Doctors	Linear regression, Needs-based, Time-series analysis
[5–7]	Nurses	Survey, Fuzzy logic, Time-series analysis
[8–10]	Physical therapists	Linear regression, Survey, Descriptive statistic, System dynamics
[11–13]	Lab technician	Survey, Workload-based
[14,15]	Dentists	Markov Chain, Needs-based
[16–18]	Pharmacists	Survey, Linear regression, System dynamics

2.2. Internal and External Factors Affecting the Number of Headcounts

Headcount, or the total number of employees in an organization, is influenced by a dynamic mix of internal and external factors. These factors drive recruitment, retention, and restructuring efforts. Internal factors are aspects of a business's operations that management is responsible for controlling such as strategy, organization culture, financial health, performance management, and compensation. External factors include labor market dynamics, legal and regulatory issue, technological changes, social and demographic trend, and new diseases. Internal and external factors affecting the number of headcounts from literature review is shown in Table 2.

Table 2. Internal and external factors affecting the number of headcounts from literature review.

Variable Name	Internal/External	References
Supply side		
Admission	Internal	[18,22,23]
Dropout rate	Internal	[1,18,24]
Graduate rate	Internal	[18,25]
Licensure pass rate	Internal	[18,25,28]
Exit rate	Internal	[1,18,24–27]
Demand side		
Workload	Internal	[1,21]
Population per pharmacist	External	[37]
Total population	External	[1,21,24,25]
Birth rate	External	[4]
Mortality rate	External	[4]
Elderly share	External	[28,29,32]
Internet access share	External	[31]
Health Online shopper share	External	[33]
Student–Faculty Ratio	External	[30]
Import pharmaceutical company	External	[34]
Marketing pharmacist reduction	External	[40]
Factory turnover	External	[38]
Pharmaceutical market growth	External	[39]
Pharmacist per retail pharmacy	External	[35]
Expansion retail pharmacy store	External	[36]

3. Methodology

System dynamics (SD) is used for workforce forecasting because it models complex, long-term talent flows using feedback loops that traditional static methods miss. It enables "what-if" simulation to understand how policies impact future labor supply and demand, rather than just predicting numbers. For pharmacist workforce planning, it is complex interdependencies and has "what-if" scenarios integrating internal and external factors in which system dynamics is particularly effective. The steps of methodology are shown in Figure 1.

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In this study, the system dynamics modeling was used to analyze the long-term supply-demand imbalance of the pharmacy workforce in Thailand under a context of multiple fields linking each other through a shared supply pool. The study design began with a systematic literature review, focusing on synthesizing knowledge to identify problem structures, key factors, and concepts related to workforce dynamics. Furthermore, the study invited a group of experts from diverse pharmaceutical fields to collaboratively develop a causal system structure to design a Causal Loop Diagram (CLD) for describing the relationships between key variables. This structure was then transformed into a Stock-Flow Diagram (SFD) for quantitative modeling and simulating possible future policy scenarios. All models were developed using Vensim PLE Plus Version 10.3.2 (Ventana Systems, Inc.).

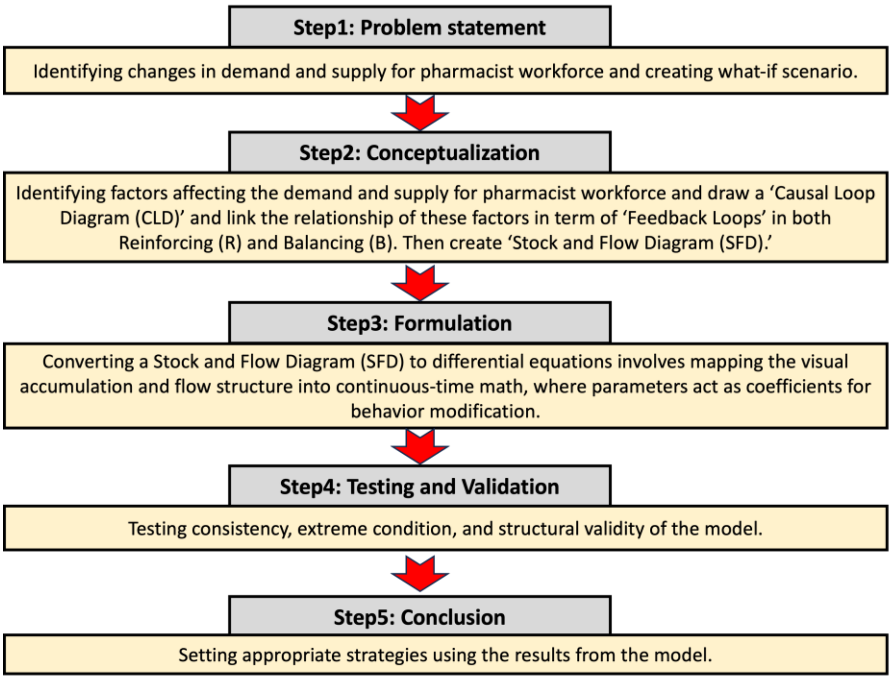

Figure 1. Steps of methodology.

4. Findings

4.1. Changes and Uncertainty

The changes and uncertainty affect the demand and supply of pharmacist workforces. Even without significant changes, the demand is changed due to the growth of demographic population and the supply is changed based on the number of academic program offerings. The changes and uncertainties and their impacts on the pharmacist workforce in different area is shown in Table 3. Therefore, this study employed a structural experimentation approach within the system dynamics modeling by defining two scenarios: the workforce forecast for the 'base-case scenario' and 'change scenario' to assess the long-term impact on the pharmacist workforce. The simulation covered a 30-year period from 2025 to 2055 and used the same model structure across all scenarios. Only time-dependent parameters were adjusted to allow for clear causal comparisons of outcomes, enabling the analysis of the dynamics of supply–demand interaction, labor absorption, and branch-level imbalance under different policy contexts.

The base-case scenario model reflected system trends under existing conditions, without additional policy interventions. The supply side was determined by the number of students enrolled and constraints on public sector jobs, while the demand side in each area was driven by area-specific structural factors, reflecting behavior without altering the system structure.

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The change scenario simulated the effects of policy interventions and factors influencing changes in the number of pharmaceutical personnel by adjusting parameters over a defined time period under the same structure as those of base-case scenario. On the supply side, production capacity and employment were increased through policies to expand student enrollments and increase public sector positions as well as the launch of new PharmD curriculums.

On the demand side, it covered all five areas with different drivers: (1) the hospital pharmacist area driven by the expanded access to clinical services, the new regulations on one pharmacist for one Subdistrict Health Promoting Hospital (SHPH), and the aging society; (2) the retail pharmacy area driven by the new regulation requirement for a full-time pharmacist in every pharmacy; the Anywhere Healthcare with One ID Card policy and the aging society; (3) the consumer protection pharmacist area driven the growth of online purchases of health products; (4) the education area driven by the adjustment in the student-to-faculty ratio; and (5) the industry area driven by changes in production standards and drug procurement models. Defining the scenario in this way allowed for a systematic assessment of the impact of policies on workforce, employment, and changes in workforce gaps in each area.

Table 3. Changes and uncertainties and their impacts on the workforce.

Professional Area	Changes and Uncertainties Driven	Impact on Demand
Hospital	One pharmacist for one Subdistrict Health Promoting Hospitals (SHPH) Aging population Expansion of clinical roles	↑
Pharmacy	Anywhere Healthcare with One ID Card policy Full-time pharmacist in all retail pharmacies Aging population	↑
Consumer protection	Online ecommerce New product development	↑
Education	Student-Faculty ratio	↑
Industry	Technology and automation Production standard	↓

4.2. Conceptualization

4.2.1. Causal Loop Diagram Development

In this study, a Causal Loop Diagram (CLD) was developed to explain the imbalance in the pharmacist workforce in Thailand. Conceptually, the workforce system was a structure that links the workforce supply, gap, and demand. Under a shared supply pool, the relationship between variables was defined by positive and negative signs to show the direction of causal effects and to identify both reinforcing and balancing feedback loops that reflect the long-term behavior of the system. This CLD was developed from a synthesis of past research and expert opinions to serve as a concept for constructing a Stock-Flow Diagram (SFD) in the next step.

On the supply side, the system was determined by the workforce production process, including the capabilities of educational institutions, the number of graduates, and licensing examinations, which together determined the number of pharmacists entering the labor market and strengthened the country's workforce base in the long term (B1). However, limitations on the rate of job openings in the public sector caused some workforce to flow into the private sector, leading to competition for personnel recruitment between the two sections (B2). On the demand side, this CLD reflected that the demand for pharmacists was not increasing in the same direction but was driven by different policies and structural factors in each area (R1).

The relationship between demand and supply affected the workforce gap, which was defined as the central mechanism of system adjustment. When demand exceeded supply, there was pressure on employment to bridge the workforce gap. Therefore, this CLD demonstrates that Thailand's pharmacy workforce system is a dynamic, loop interconnected system and a cause-and-effect structure supporting the development of quantitative models in the next step, as shown in Figure 2.

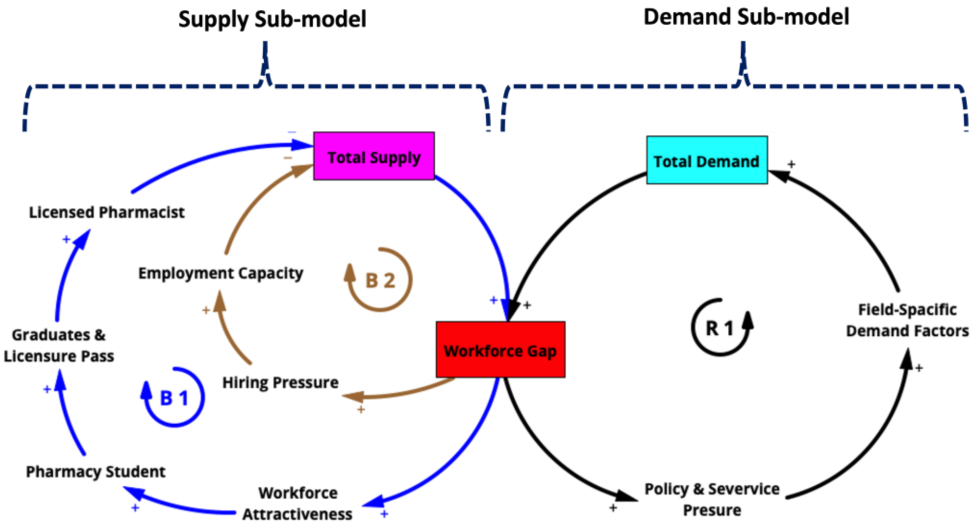

Figure 2. Causal Loop Diagram of the pharmacist workforce in Thailand.

4.2.2. Stock-and-Flow Model Formulation

In this study, the stock-flow diagram (SFD) model was developed to describe the dynamics of the pharmacist workforce system in Thailand under a structure that links supply, demand, and workforce gaps at the same-system level. The model's structure was divided into three main components: workforce supply subsystem, workforce demand subsystem, and workforce gap subsystem, all of which were linked through employment and absorption mechanisms.

On the supply side of this model, the process began with pharmacy students who have completed their studies, passed the licensing exam, and become licensed pharmacists before being distributed into the public and private sectors according to the constraints of the labor market. At the same time, the model also incorporated the dynamics of those waiting for employment, those leaving the labor market, and those re-entering the system to reflect continuous long-term changes in the workforce, rather than viewing supply as just the number of graduates each year.

On the demand side, the demand for pharmacist workforce arose from different structural factors in each area: the use of healthcare services, the transfer of Subdistrict Health Promoting Hospitals, and the aging society in the hospital area, the expansion of online healthcare businesses in the consumer protection area, the increase in pharmacies and public health requirements that mandate every pharmacy to have a regular pharmacist in the retail pharmacy area, the changes in the structure of the pharmaceutical industry and drug marketing patterns in the industry area, and the expansion of pharmacy students that necessitate consideration of teaching standards and the faculty-to-student ratio in the education area, all of which were linked to the variable "Total demand" and compared to the variable "Total supply" to calculate the workforce gap in the system.

In addition, in this model, variables "Unused workforce" and "Absorption gap" were developed to explain the phenomenon where some workforce has the potential to work but cannot actually enter the employment system, allowing the model to simultaneously reflect the shortage, distribution of the workforce, and structural limitations of the pharmacist labor system through the feedback and time delay mechanisms of the System Dynamics modeling, as shown in Figure 3.

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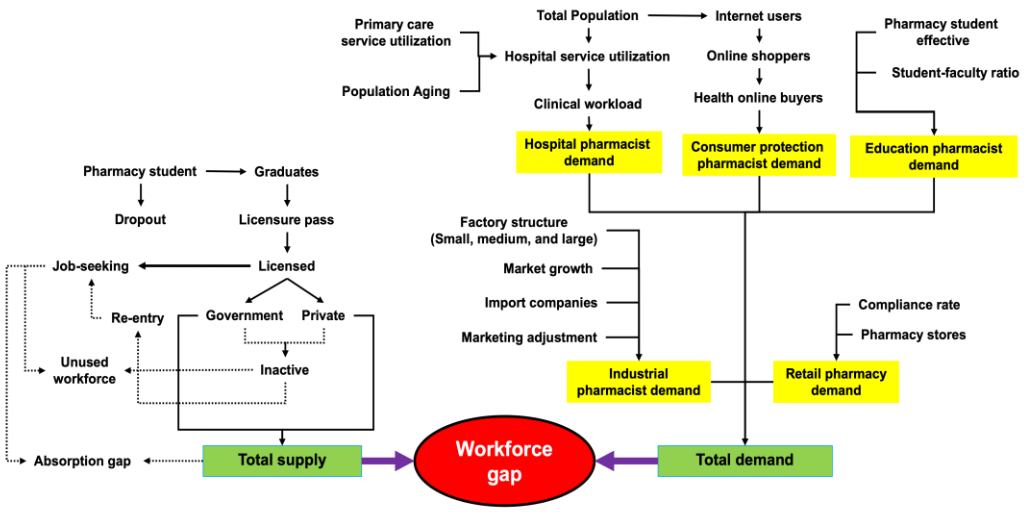

Figure 3. Conceptual model for pharmacist workforce dynamics system in Thailand.

4.3. Model Parameters and Equations

Model parameters were defined to reflect key mechanisms of the Thai pharmacist workforce system on the supply, demand, and labor market sides. All parameters were derived from a systematic literature review, secondary data from government, private, and professional agencies, and structural data from relevant healthcare systems and industries. Supply-side parameters were designed to align with the dynamic structure and changes in the pharmacist workforce production system over time. Meanwhile, demand-side parameters were determined by specific structural parameters of each area, ensuring the model realistically reflects the different drivers of each area.

In addition to structural parameters, the model incorporated system dynamic parameters to reflect long-term system changes. Under the system dynamics modelling, these parameters not only function as statistical constants but also determine system behavior through feedback and time delay mechanisms, affecting the accumulation and changes in workforce over time. This parameterization allows the model to systematically describe shortages, incomplete employment, and distribution of workforce gaps between professional areas as well as enables the model to be used in policy trials and long-term situational analyses relevant to the real-world context of Thailand's healthcare systems.

4.4. Model Validation

The model was validated by unit consistency testing, which was performed to check that the units of all variables had meaning consistent with the variable definitions and were consistent throughout the model, including the correctness of the units in all equations. The test results showed no unit errors, indicating that the quantitative structure of the model had internal consistency and could be physically interpreted in relation to the real system. An extreme condition testing was used to examine the behavior of the model under parameters at extreme limits, such as very high, very low, or zero values, to assess whether the model still yielded reasonable results and did not produce unrealistic behavior. Furthermore, structural validity was also assessed through a review by a group of experts from each relevant area. The experts said that the model's structure appropriately reflected the mechanisms of the pharmacist workforce system in a real-world context. Therefore, it was concluded that the model passed validation in both its structure and behavior under various conditions.

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4.5. Result

4.5.1. Supply-Demand Ratio

The supply-demand ratio has been used as a key performance indicator for the model. The ratio is less than 1 which means the supply is less than the demand. It is found that in 2025 the ratio is close to 1 in the beginning, but once the time passes, the ratio is fluctuated based on what will be happening during those years. In 2027, the ratio is sharply dropped to 0.76 as the policies of "one pharmacist for one SHPH" and "one full-time pharmacist for one retail pharmacy" has been in effect. These means that it demands a lot more pharmacists to work. In order to completely fulfil the policies, at least 8,000 pharmacists are needed for all SHPHs in the country and about 10,000 pharmacists are needed to cover full-time positions at all retail pharmacies. The ratios are getting better once the supply is increased to meet the demand. However, the increase of supply cannot do all in one time as there are limited resources and facilities, the maximum student-faculty ratio, and more importantly, the six-year duration of PharmD. In 2031, the ratio looks better and at the end of the forecasting period, the ratio will be 0.98. The forecasted supply-demand ratio during 2025-2055 for the base-case and change scenarios is illustrated in Figure 4.

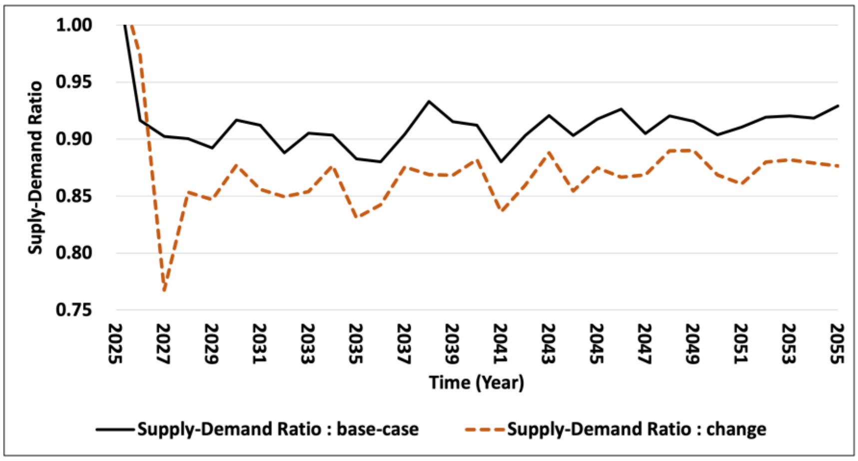

Figure 4. Forecasted supply-demand ratio during 2025-2055.

4.5.2. Workforce Gap

From the simulation, the total supply and the total demand for 2025-2055 for the base-case and change scenarios is shown in Figure 5.

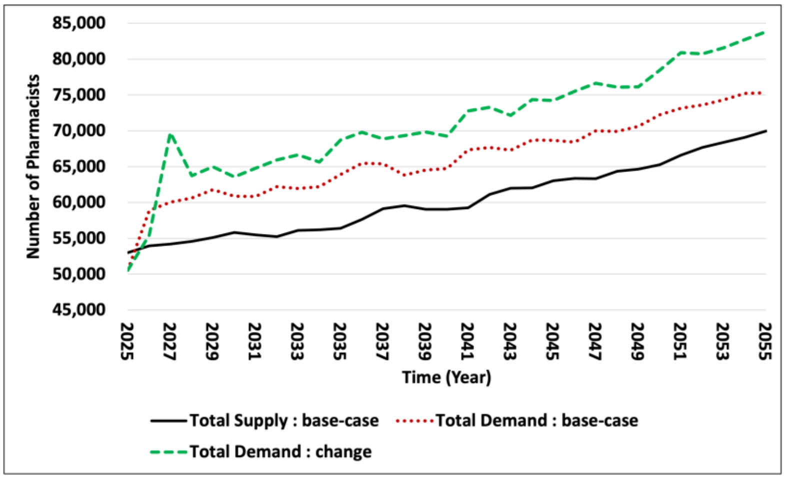

Figure 5. Total supply and total demand for 2025-2055 for the base-case and change scenarios.

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On the supply side, the current number of pharmacists is 53,003. Overall, the total supply has been increased gradually over the years as the policy to increase number of pharmacists in healthcare system and the new curriculum has been launched. In the base-case scenario, the total demand has increased based on the population growth and the aging society. In case of the change scenario, the total demand has sharply increased in order to respond to the new policies. Hence, the workforce gap is getting wider at the beginning of the simulation period and it is gradually narrowed down after the supply has increased.

4.5.3. Separated Demand by Professional Areas

The total demand may not accurately reflect the actual challenges in human resource management, as demand may increase in certain areas while decreasing in others, resulting in no significant change in the overall demand. This research simulated and forecasted the demand for each professional area in order to see the details.

Demand for Hospital Pharmacists

From the analysis, the workforces in the hospital area shows a structural imbalance in the workforce system during the early stages of the simulation, with a rapidly widening gap under changing factors and policies. For the change scenario, the workforce gap spiked to approximately 12,000 people from the beginning of 2027, compared to 2,139 people in the based-case scenario. This reflected the impact of expanded access to healthcare services, the increasing elderly population, and importantly, the implementation of the policy of one pharmacist per one primary care unit namely SHPH, leading to a dramatic increase in demand and a rapid increase in both the volume and complexity of the work. From this result, it could be said that the system could not meet the workforce demand in the short term.

After that, although the gap decreased from its peak, it remained high at approximately 5,000–6,000 people throughout the simulation period, indicating a structural shortage that could not be rebalanced in the short term. Comparing the two scenarios, the change scenario resulted in service expansion exceeding the ability to produce sufficient workforce for this area, reflecting the high sensitivity of this area to policy changes, as shown in Figure 6a.

Demand for Pharmacists Work in Retail Pharmacies

According to the simulation results, the retail pharmacy sector exhibited a continuously widening long-term workforce gap, primarily driven by the implementation of the policy requiring one full-time pharmacist per pharmacy to enhance primary care services. Consequently, the rate of demand growth exceeded the normal rate of workforce expansion. The workforce gap is approximately 4,771 people in 2030. For the change scenario, it expanded rapidly towards the end of the simulation, reaching approximately 16,427 people in 2055, reflecting a sustained long-term demand expansion.

Although the increase was not as dramatic as that observed in the hospital sector, the steady upward trend reflected policy changes aimed at expanding service accessibility by enhancing the role of pharmacists in community pharmacies in accordance with regulatory requirements. Overall, this sector demonstrated the highest long-term growth rate in workforce demand and was among the major contributors to the continuously increasing workforce imbalance within the system, alongside the hospital pharmacy sector, as shown in Figure 6b.

Demand for Pharmacists Work in Consumer Protection

According to the simulation, the consumer protection area exhibited a relatively stable workforce gap, resulting in a narrower range of variation compared with other areas. Throughout the simulation period, the workforce gap remained between approximately 1,200 and 1,600 personnel. By 2030, the gap was estimated at approximately 1,251 personnel under the change

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scenario, compared with 1,580 personnel under the based-case scenario. These findings indicate that workforce demand in this area was driven primarily by the steadily increasing regulatory workload rather than by the rapid expansion observed in areas associated with direct healthcare service provision.

However, in 2055 under the change scenario, the gap was projected to slightly decrease compared to the current scenario, reaching approximately 1,303 people from 1,647 people. This indicated that policy played a role in controlling or slowing the increase in workload in this area to some extent, without causing high volatility like other areas. It could be said that this area was a regulated demand system with low flexibility but high stability and was not the primary workforce group contributing to the overall imbalance in the pharmacist workforce system, as shown in Figure 6c.

Demand for Pharmacists Work in Education

The education pharmacy area, primarily comprised of faculty members in the faculties of pharmacy, exhibited a unique characteristic: a medium- to long-term structural transition from a shortage to an oversupply of workforce. Initially, the system was unable to meet the workforce demand. For example, in 2030 the gap was approximately 1,294 people under the change scenario, reflecting the demand for teaching personnel remaining high in the initial phase. However, this trend was not sustained and declined rapidly in the subsequent period, demonstrating that the expansion of workforce within the system occurred faster than the actual demand.

Subsequently, in the medium to long term, the workforce gap showed a positive sign. According to the simulation, by 2055 the gap was approximately 275 people under the change scenario, reflecting a faster expansion of the capacity to produce educational personnel than the actual demand in the system. This showed an accumulation of sufficient workforce within the system to meet the demand. At the same time, the differences between scenarios followed a similar pattern, suggesting that policy had only a minor impact on the gap compared to the production of personnel. Overall, this area exhibited a supply-driven imbalance, which clearly differed from other areas driven by demand, as shown in Figure 6d.

Demand for Pharmacists Work in Industries

According to the simulation, the industry area was characterized by a long-term transition from a slight shortage to an oversupply of the workforce. The early stages of the simulation showed a shortage of personnel in this area before a clear trend changed in the early part of the simulation under the change scenario. This reflected that the demand for workforce in this area did not expand in line with the number of people entering the system, but it was determined by market dynamics and changes in business models rather than direct policy factors. As a result, the workforce demand continued to decline in the long term.

Overall, this area exhibited a market-driven and efficiency-driven imbalance, clearly different from areas driven by demand or supply, and might represent a structural change in the future pharmaceutical labor market, which may be replaced by automation or evolving competition in the pharmaceutical business, as shown in Figure 6e.

The simulation results of the workforces for each area during 2025-2055 is shown in Table 4. The comparison of demand growth in the change scenario is illustrated in Figure 7.

Table 4. Simulation results of the workforce demand for each area during 2025-2055.

Professional Area	2025	2035	2045	2055
Hospital	17,114	23,309	23,229	23,291
Retail pharmacy	11,256	19,468	26,466	36,097
Consumer protection	1,695	3,451	3,594	3,070
Education	1,220	1,664	1,353	1,122
Industry	19,268	20,658	19,567	20,263

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Total demand	50,553	68,715	74,223	83,817

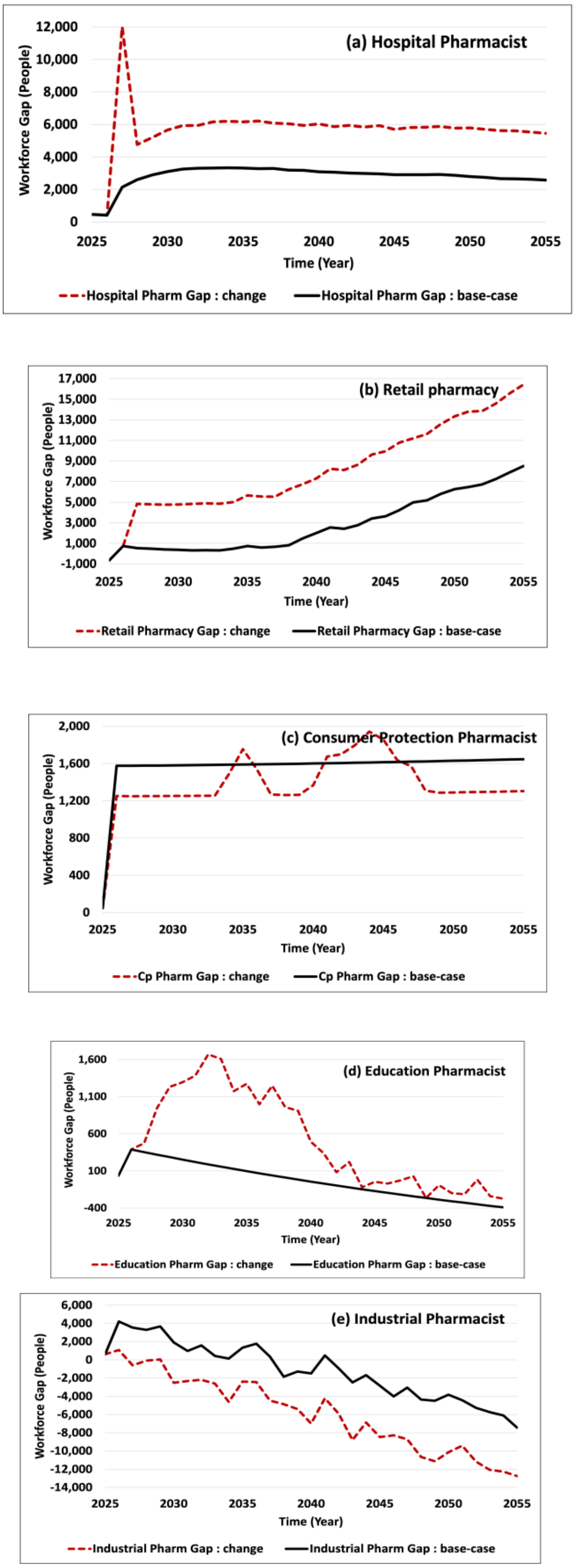

Figure 6. Pharmacist workforce gap in a) Hospital pharmacist, b) Retail pharmacies, c) Consumer protection pharmacist, d) Education pharmacist, and e) Industrial pharmacist under base-case and change scenarios (2025-2055).

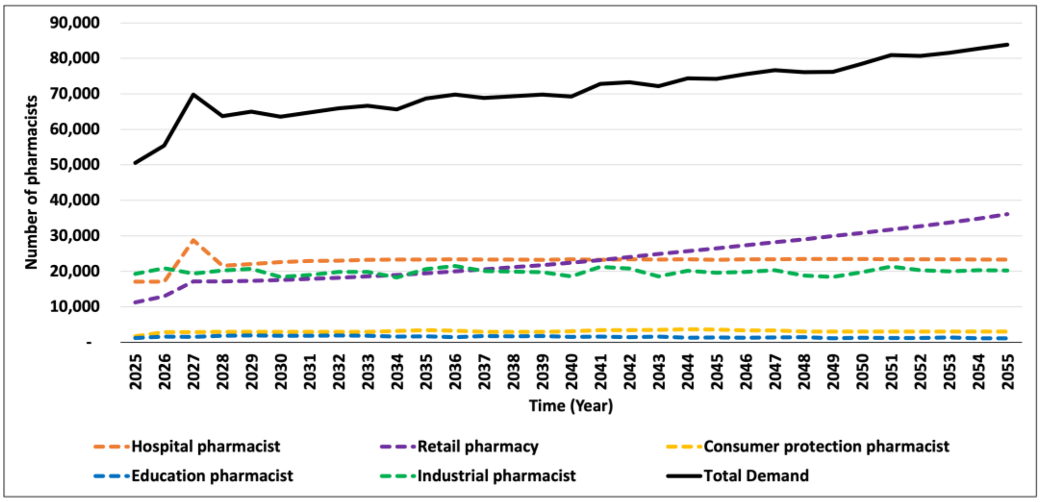

Figure 7. Comparison of demand growth in the change scenario.

5. Discussion

This study demonstrated that the pharmacist workforce issue in Thailand could not be attributed solely to a workforce shortage, but rather to an imbalance among workforce supply, demand, and employment mechanisms within the same system. Although the supply-to-demand ratio was relatively balanced during the initial stage of the simulation, it declined markedly after 2026 and did not return to equilibrium over the forecast period. This trend suggested that workforce demand was increasing more rapidly than the system's capacity to transform the available workforce into active employment, particularly under the change scenario, which accelerated service accessibility and intensified the workload within the healthcare system.

Regarding the labor market, the findings revealed substantial structural limitations, particularly the existence of an available workforce that was unable to consistently enter the employment system. In addition, the numbers of individuals waiting for employment, exiting the labor market, and remaining underutilized continued to increase. These results suggest that a quantitatively sufficient workforce does not necessarily translate into effective employment across all areas. Therefore, the mechanisms governing the recruitment and absorption of pharmaceutical personnel represent a critical component of the workforce problem and should be addressed in parallel with workforce production rather than considered separately.

When considering each area individually, the workforce issue was characterized by an imbalance between workforce supply and demand. The hospital pharmacy area experienced workforce shortages during the early stages of the simulation, potentially driven by policies aimed at expanding access to healthcare services, the impacts of an aging society, and changes in the management structure of SHPHs. Meanwhile, the retail pharmacy area exhibited the largest long-term workforce gap, reflecting the continued expansion of the pharmacy business sector and stricter regulatory requirements for maintaining pharmacists on staff. In contrast, the industry pharmacy area generally demonstrated a sufficient workforce supply throughout the simulation period, consistent with evolving pharmaceutical marketing models and the diminishing role of pharmaceutical sales representatives within modern procurement systems. These findings suggest that workforce imbalances did not occur uniformly across all professional areas, but rather involved continuous workforce movement and redistribution among professional areas.

An increase in demand in some areas may coincide with a surplus of workforce in others, where the system is not flexible enough to adjust the movement of workforce across areass. This finding has significant implications for workforce planning knowledge because it demonstrates that estimating the total workforce size can lead to misinterpretations if the mechanisms for labor absorption and structural differences between professional areas are neglected.

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This study suggests that resolving the pharmacist workforce problem cannot depend solely on increasing the number of graduates. Instead, workforce planning should adopt a more targeted approach that emphasizes areas with high short-term demand. Policy measures should prioritize expanding the system's capacity to absorb workforce in high-workload areas, particularly the hospital pharmacy area. Over the longer term, systematic strategies should also be developed to address the growing workforce demand in the retail pharmacy area. At the same time, mechanisms should be established to monitor and manage areas with potential workforce surpluses, such as the industry pharmacy area, in order to minimize underutilization of human resources and improve overall system efficiency.

This study also contributes academically through the development of a system dynamics model that integrates workforce supply, demand, and labor market mechanisms within a unified structure. This approach differs from previous studies, which have often focused on only a single dimension of the workforce issue. In particular, the model incorporates labor market dynamics concepts, including the absorption gap, job-seeking workforce, and inactive workforce, to provide a more comprehensive explanation of workforce imbalances. Consequently, the findings demonstrate that workforce shortages are not caused solely by an inadequate number of personnel, but also by inefficiencies in the system's ability to absorb available workers into the actual labor market. Furthermore, the application of a demand modeling framework across five distinct areas clearly captures the structural differences in workforce demand among areas, offering a perspective that has been relatively limited in previous pharmaceutical workforce research.

In addition, this study used a scenario-based simulation to demonstrate the dynamics of the system with a heterogeneous workforce imbalance that differs across different areas over the long term (2025–2055), such as structural shortages in the hospital pharmacy area, accumulated demand in the retail pharmacy area, and oversupply in the education and industry pharmacy areas. These conditions are not visible in typical aggregate analysis, significantly addressing a gap in the literature on pharmacist workforce planning in the context of developing countries.

6. Conclusions

Changes and uncertainty in the healthcare landscape, including rapid technological advancements, evolving clinical roles, deviation of government policies, and fluctuating supply chain issues, are profoundly affecting both the demand and supply of the pharmacist workforce. In term of demand side, the changes have resulted in a shortage in one area and over demand in other areas. For supply side, it is known that the six-year curriculum is compulsory for producing a licensing pharmacist. This means that in case that the number of student admission changes today, the number of pharmacist graduates will be reflected in the next six years. In general, the demand for pharmacists expected to grow by roughly 5.6% a year, creating over 17,000 new positions nationwide, while the supply of new graduates fails to keep pace. Therefore, it is needed to explore how the demand and supply will be in the next thirty years, so that the implement measures can be made in time.

This study clearly demonstrates that Thailand's pharmacist workforce problem is not merely a quantitative shortage but a structural imbalance resulting from a mismatch between supply, demand, and workforce absorption mechanism within the same system. Even when the system has a certain level of available workforce, this workforce is not consistently converted into employed workforce, resulting in a widening workforce gap throughout the forecast period. This finding indicates that estimating workforce solely from the total number can lead to misinterpretations. The workforce gap should be viewed as a systemic outcome rather than simply a direct quantitative shortage.

According to the results for each area, workforce imbalances were not uniform across all areas but were concentrated and fluctuate over time. The hospital pharmacy area was a significant catalyst for early-stage shortages, while the retail pharmacy area experienced the largest long-term gap. Conversely, the industry pharmacy area tended to have a continuous workforce surplus, reflecting that the pharmacy workforce system does not face the same shortage across the system but rather a area-specific imbalance requiring different response measures tailored to its specific structure. Therefore, this study suggests that future pharmacist workforce planning should prioritize policies on workforce recruitment and allocation across areas, aligning with the complex dynamics within the system, in addition to simply focusing on increasing the number of pharmacists to meet market demands, which will ensure the system can sustainably respond to changing needs.

7. Limitations and Future Research

This study has several limitations that should be considered when interpreting the findings. First, the model relies on secondary data sources and proxy variables for certain parameters, which may not fully capture variations in real-world contexts across all areas. Second, the model structure necessarily simplifies real-world systems in order to support long-term behavioral simulation, resulting in the incomplete incorporation of several behavioral factors, including job satisfaction, motivation for area selection, workforce mobility between areas, and other operational constraints, as endogenous variables within the system. Third, the simulation results should be interpreted as a tool for illustrating trends and the systemic effects of policies rather than as precise quantitative forecasts.

Future research should develop more detailed models in each area, particularly incorporating data on workforce mobility, job choices, retention, and employment behavior across different areas. Furthermore, the analysis should be expanded to test more specific policy measures, such as mechanisms for labor absorption in various areas, incentive measures for workforce distribution, and management approaches for areas that already have sufficient workforce. This will enhance the effectiveness of the models as a tool for supporting policy decision-making at the national level.

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