STOCHASTIC SIMULATION TO PROJECT SUPPLY OF THE KAZAKHSTAN GENERAL PRACTICE WORKFORCE TO 2030

Berik Koichubekov 1, Azamat Kharin 1, Marina Sorokina 1, Ilya Korshukov 1, Bauyrzhan Omarkulov 1, Temirlan Ukubayev 1

1 Department of Informatics and Biostatistics, Karaganda Medical University, 100000 Gogol st. 40, Karaganda, Kazakhstan

Corresponding author’s e-mail address: koychubekov@kgmu.kz

Keywords: system dynamics, sensitivity analysis, healthcare resources forecasting, public health

Abstract. Our aim was to explore the effect of the uncertainty of some parameters on total General Practitioner (GP) supply in Kazakhstan to 2030. System dynamics simulation was used to develop model for General Practitioner workforce forecasting. Sensitivity analysis (Monte Carlo method) was performed to account for changes in the number of GP as each and set of model parameters is varied. Three key input parameters were explored: retirement rate, attrition rate, recruitment rate. For each parameter relative sensitivity was calculated. Created model is the least sensitive to the parameter of the retirement rate, but is very sensitive to attrition rate. Staff turnover is one of the main problems of primary health care. The attrition rate parameter has great potential for controlling the flow of labor. The level of recruitment (other than new GPs) is another factor that has a significant impact on forecasting GPs. The sensitivity to this parameter is comparable to the sensitivity to the rate of depletion. We believe that measures taken to reduce dropouts will simultaneously increase recruitment. We also evaluated the effect of all three parameters simultaneously. If the most likely scenario is realized, then the proposal of a General Practitioner will almost completely cover the needs with a small deficit of 68 to 305 doctors. If the high limit or low limit scenarios in the labor market are implemented, Healthcare Ministry will face serious problems.

1. Introduction
Health human resource planning includes assessment of current situation, forecasting future demand and developing appropriate strategies to balance supply and demand for manpower. After determining the required number of health personnel to meet the needs of health services, it becomes possible to develop a strategy to maintain a balance between supply and demand of labor [2], [3].

In different countries different forecasting methods are used and each approach has its own strengths and weaknesses [4], [5], [6], [7], [8], [9], [10], [11]. Most of them do not have the ability to capture all key factors affecting demand and supply of health manpower. Usually they do not cover all
possible dynamic interactions between social, economic and environmental factors and are not able to generate possible scenarios in response to “what if” questions [12],[13],[14],[15],[16].

The cause of the uncertainty may also be incomplete data on the past and present. And, even when data about the past and present are reliable, it is often doubtful whether and how to extrapolate them to the future. Therefore, any assumption about the future has a chance of being wrong. For example, in 1998 an insufficient number of doctors in Canada was predicted for the next 25 years, based on the estimated reduction in the ratio of doctors to population by 31% [17]. However, if age and sexual needs were to be reduced by 1% per year, and the average productivity of doctors increased by 1% per year, the ratio of doctors and population would increase by 27% [18].

Deterministic sensitivity analysis and stochastic simulation are two commonly-used approaches to assessing uncertainty in forecasting models. In a deterministic sensitivity analysis, the input value of one variable changes, while the others remain unchanged. If a change in the input parameter leads to a significant change in the result, this proves that this variable is sensitive. The range of forecasts is determined by the limits of the input values of the sensitive variables. For example, you can use 3 estimates of the value - the minimum, maximum and most common value - for the input variables to get 3 corresponding forecasts: pessimistic, optimistic, and most probable [19].

In stochastic modeling (Monte Carlo method), the value of the input parameters changes in accordance with its probability distribution, and the forecast result will also be a random variable. This process is repeated many times and then the average value and variance of the forecast output can be estimated, and the forecast uncertainty can be quantified by calculating the confidence interval in which the true value is located. The probability distributions that have been used for stochastic simulation include the logistical-normal distribution, normal distribution and triangular distribution. Triangular distribution has some interesting features. It is determined by 3 parameters: the most likely value (mode), the minimum value and the maximum value. These values are used in conventional sensitivity analysis and can be understood easily by people without much statistical training [20].

Song and Ratwell tested the sensitivity of a simulation model designed to predict the demand for hospital beds and doctors in China [21]. They used two of these approaches. Their results showed the advantages of stochastic modeling over the deterministic approach. It is important that the stochastic forecast can be used for uncontrolled factors, such as changes in population.

Our aim was to use a stochastic simulation to project supply of General Practitioner workforce in Kazakhstan to 2030.

2. Materials and methods

Our model was based on the “stocks and flows” approach. System dynamics simulation was used to develop model for General Practitioner workforce forecasting. Our baseline year was 2018 and projections were made through to 2030 with an interval of two years. Data for the model were collected from various sources, which are presented in the Table 1.

| Table 1. Data source |
|----------------------|
| **Element** | **Value** | **Source** |
| New graduates per year (all medical universities in Kazakhstan) | 900 | Department of Science and Human Resources of the Healthcare Ministry |
| Recruitment rate | 10,3% (CI:9,7; 10,9) | Department of Science and Human Resources of the Healthcare Ministry |
| Exits from the health workforce due to retirement | 1,3% (CI:1,1; 1,5) | Department of Science and Human Resources of the Healthcare Ministry |
| Exits from the health workforce due to another reasons (attrition rate) | 14,5% (CI:13,8; 15,2) | Department of Science and Human Resources of the Healthcare Ministry |
| Average population per 1FTE GP | 1678 | Republican Center for Health Development |
| Birth rate in 2018 | 21,64 | Statistics Committee of Kazakhstan |
| Death rate in 2018 | 7,15 | Statistics Committee of Kazakhstan |
The model consists of two main components: sub-models of supply and demand. The sub-model of the supply consists of stock, inflow and outflow. The stock characterizes the current situation, the inflow includes new GP graduates and recruitment, and outflow - retirement, emigration and attrition.

The demand sub-model estimates the number of GPs required meet the public health needs.

| Immigration rate in 2018 | 0,86 | Statistics Committee of Kazakhstan |
|-------------------------|------|-----------------------------------|
| Emigration rate in 2018 | 2,09 | Statistics Committee of Kazakhstan |
| Average visit per person in 2018 | 2,5 | Republican Center for Health Development |
| Average patient visit per GP in 2018 | 4689 | Republican Center for Health Development |

Figure 1. SD model of GP forecasting

In the baseline we project the demand for healthcare workers assuming that the same level of service (defined as headcount density per population) is provided for an increasing population. Two inputs – total population and average population per workforce – are used to forecast workforce requirements under this approach. Using available data, average population per GP was estimated and assumed to remain constant from the year 2018 (it is estimated as 1678). Total GPs required for each year is then calculated by dividing the total population by the average population per GP. The total gap is derived from expansion demand and available supply.

Sensitivity analysis was performed to account for changes in the number of GP as each and set of model parameters is varied. The stochastic input variables were defined using triangular distributions (defined by the minimum, maximum and most likely values) in replacement of a single-point estimate input value. Monte Carlo simulation methods were used, with each run of the model involving 5000 iterations. In each iteration, a different value from within the defined range for the input variables was used. This produced output values that are value ranges rather than point estimates. Next, the median, minimum and maximum values at 95% confidence level for each run were used to show the credible interval. Three key input parameters were explored: retirement rate, attrition rate, recruitment rate.

Relative sensitivity can be calculated in accordance with $\Delta Y(t)/Y(t)$—which represents the change in the output variable and $\Delta X(t)/X(t)$—which represents the changing in key parameter. Thus, the formulation of relative sensitivity can be expressed as

$$S(t) = \frac{\Delta Y(t)/Y(t)}{\Delta X(t)/X(t)} \times 100\%$$
The sensitivity scale (weak sensitive ($\leq$30%), moderate sensitive (31-100%) and highly sensitive (>100%)) was used to determine the variables that caused a high level of instability.

3. RESULTS
In 2018, 10314 doctors were working in the primary healthcare (PHC) system of Kazakhstan, while according to the Healthcare Ministry of the Kazakhstan Republic, the deficit was 3%. Due to population growth, it is predicted that the demand for general practitioners will increase, according to our data, to 12681 by 2030 (Table). Even if medical universities of the country will keep the annual output as about 900 GPs, still there will be lack them.

Table 2. Impact of uncertainty in key model inputs on the projected supply of GP

| Key parameter         | 2020         | 2022         | 2024         | 2026         | 2028         | 2030         |
|-----------------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Number of GP (median [95CI]) |
| Retirement            | 10778 [10738-10817] | 11185 [11107-11262] | 11542 [11433-11653] | 11856 [11714-11992] | 12127 [11962-12299] | 12370 [12176-12563] |
| Attrition             | 10940 [10800-11081]  | 11501 [11227-11769]  | 11966 [11606-12408]  | 12442 [11943-12976]  | 12840 [12223-13483]  | 13197 [12477-13947]  |
| Recruitment           | 10841 [10643-11037]  | 11307 [11227-11769]  | 11710 [11606-12408]  | 12077 [11943-12976]  | 12399 [12223-13483]  | 12681 [12477-13947]  |
| Set of parameters     | 10880 [10558-11203]  | 11375 [10927-11691]  | 11826 [10963-12699]  | 12219 [11165-13435]  | 12574 [11282-14041]  | 12889 [11428-14574]  |
| Projected demand      | 11181         | 11538         | 11907         | 12287         | 12679         | 13084         |

Firstly, we explored the effect of retirement rates on total GP supply. The figure shows how the uncertainty in the retirement rate parameter affects the gap between projected demand and supply. In general, changes in the number of retiring doctors cannot cover the GP deficit. In 2020, the deficiency can be from 364 to 443 with a deviation from the median value of about 1%. According to the forecast, by 2024 the median of the deficit will decrease to 365 GP, however the maximum mean absolute deviation is 30% and shortage of the number of GP observed may vary between 254 and 474 for a 95% CI.

After 2024 the GP workforce demand will be projected to reach 13 084 by 2030 — a net gain of just 1177 doctors in 6 years. At the same time, deficit growth is projected to increase from 365 (95% CI: 254; 474) to 714 (95% CI: 521; 908) GP. Variations in the retirement rate in the range of 1.1-1.5% keep the maximum mean absolute deviation in the gap forecast at about 30%.

Figure 2. Influence of uncertainty in retirement rate (A) and attrition rate (B) to the gap between demand and supply. Positive values of gap corresponds to GP shortage.
The trend of GP gap under the varied attrition rate are shown in Figure 2. The model was based on an uncertainty in attrition rate of 13.8-15.2% with the most likely value of 14.5%. Moreover, the forecast can develop in two scenarios. In the case of the implementation of the upper limit of this range (high limit), the gap between supply and demand will remain - the deficit in different years will be from 301 to 607 GPs. If the attrition rate takes a median value, then already in 2024 there will be an excess of 89 GPs in the PHC system. Under this scenario, in subsequent years will be observed an accelerated growth of supply level, which will exceed the sufficiency level by 155 in 2026, by 161 in 2028 and by 113 GPs in 2030.

Similar trends are predicted at the low limit value of attrition rate. In this case, the predicted number of GPs will not only cover all PHC needs, but also significantly exceed them - the surplus will be 2% in 2022, 4.2% in 2024, 5.6% in 2026, 6.3% in 2028 and 6.6 % in 2030. If events will follow this scenario in 2030, demand will be 13084 GP, and supply - 13947 GP, i.e. with a difference of 863 doctors.

The effect of a changed pattern for recruitment rate intake is presented in Figure 3. In the case of the most likely recruitment rate scenario it will be projected the lag of supply from demand, which will lead to a shortage from 197 to 403 in different years. In addition, if a low limit scenario is implemented by 2030, the shortage of specialists can reach 1365 GP.

![Figure 3. Influence of uncertainty in recruitment rate to the gap between demand and supply. Positive values of gap corresponds to GP shortage.](image)

In contrast, a high recruitment rate will result in a significantly larger supply level over sufficient level. Those, there is a small chance that the number of doctors will increase and exceed the needs, which are determined by the population. In this scenario, this excess can range from 153 GP in 2022 to 627 GP in 2030.

4. DISCUSSION
In 2018, Kazakhstan accept a program for the development of PHC. According to this program, PHC should become the central element in the system of providing medical services in the republic. Special attention is paid to the national healthcare resources (HCR) development policy. One of its tasks is to develop new approaches to planning and forecasting HCR.

Our prediction model for primary care general practitioners number was based on SD methodology and computer simulation modeling technique for framing, understanding and discussing complex issues and problems. These approach has been used in a variety of contexts, including human resources planning, to gain an understanding of a system with complex dynamic and nonlinear interacting variables [23].
We analyzed base scenario, under that to forecast workforce requirements two input parameters — total population and average population per workforce – are used. The projected labor supply, in turn, also depends on a number of parameters, three of which were considered by us as sources of uncertainty.

The model in this study was used in experiments that simulated policy interventions, all of which would have effects on medical supply by virtue of changes to some of the parameters. In the intervention trials, by changing three key parameters, we could see and analyze changes to the effects on the number of GP. We tried to identify those to whom the model is most sensitive and evaluate the consequences of their variability for the HCR state, since this is important for the formation of human resources policy. For that the experiment results were compared to the demand of GP that was defined using two input parameters – total population and average population per workforce.

Table 3. Parameters relative sensitivity

| Year  | 2020 | 2022 | 2024 | 2026 | 2028 | 2030 |
|-------|------|------|------|------|------|------|
| retirement | 2%   | 5%   | 6%   | 8%   | 9%   | 10%  |
| attrition    | 27%  | 49%  | 67%  | 83%  | 100% | 113% |
| recruitment  | 31%  | 58%  | 79%  | 100% | 115% | 130% |

As our results showed, the created model is the least sensitive to the retirement rate parameter. Relative sensitivity S (t) in the forecast period varies from 1% to 10%. Changing this parameter within the confidence interval will not allow to bridge the gap between supply and demand. Currently, about 7% of retirement age doctors work in the PHC system. Silver, M.P. et al. note that over the last 40 years, across multiple jurisdictions, a pattern has emerged whereby a disproportionate number of physicians continue to practice beyond the traditional retirement age of approximately 65 years old [24]. However, in Kazakhstan it is hardly possible to increase their share, because in the PHC there is an active process of replacing therapists and pediatricians of the Soviet period with general practitioners with other competencies.

The size of a country’s health workforce is affected by both inflows and outflows, and it is essential that these labor market dynamics be well understood if countries are capable to formulate effective workforce policies and strategies. Attrition - defined broadly as exits from the workforce, which can be due to emigration, voluntary exits (e.g. to other sectors of employment), illness, death - is an important element of outflows from the labor market and something that governments can directly influence by implementing strategies for health worker motivation and retention.

To address the shortage of health workers and plan effectively for the future, more attention needs to be paid to staff turnover. The departure of doctors to other sectors of the economy leads to a large loss of public funds spent on education and training of health workers [25]. The resulting lack of personnel contributes to an increase in workload and worsening working conditions for other doctors, which, in turn, contributes to a decrease in the quality of medical care and a deterioration in the effectiveness of healthcare [26]. Withdrawal from the workforce significantly affects the predicted supply of health workers and makes depletion one of the key components of workforce forecasting models [27].

Our proposed model is very sensitive to this parameter - S (t) ranged from 27% in 2020 to 113% in 2030. Given the current attrition rate, scenarios of both a GP deficit (high limit scenario) and a supply excess (most likely and low limit scenario) are possible. Staff turnover is one of the main problems of primary health care. The main reasons are the lack of motivational incentives to work, low wages and insufficient social protection of workers. The situation is quite serious with the involvement and retention of personnel in rural areas. Attrition rate parameter has great potential for regulating the flow of labor. Currently, a number of measures are being developed and implemented in the republic to improve the system of motivation, stimulation of the work of medical workers, which include:
- the introduction of social, financial and material incentives to support health workers at the local level with appropriate sources of funding, the provision of social support measures for health workers, especially young rural specialists;
- the introduction at the level of medical organizations of differentiated remuneration based on the final results of work;
- development of mechanisms of non-material motivation (providing training opportunities at the expense of the employer, ensuring continuous career and professional growth, maintaining a favorable organizational culture, safety and convenience of jobs);
- creating safe working conditions to maintain the health and safety of health care providers [28].

All these measures are also aimed at reducing staff turnover and ensuring the most complete provision of PHC with human resources.

Recruitment rate is another factor that has a significant impact on the forecasting of GPs. It does not include people who have just completed their studies (new GP). Among recruited workers are those who have changed their place of residence or, for some reason, have moved from one health care facility to another. It can also be doctors who have completed military service, who have quit maternity leave, who have moved from adjacent fields of medicine or have once left medical practice and have decided to return. According to our data, the share of such persons is 10.3% (CI: 9.7; 10.9). Sensitivity S(t) to this parameter is comparable to sensitivity to attrition rate (see table 3). We believe that measures taken to reduce attrition will simultaneously increase recruitment.

Sensitivity analysis also allows identifying the significant parameters that you can focus on in order to reduce uncertainty and increase the reliability of the system. Figure 4 shows the effect of interaction of three researched parameters on output variable (GP).

Figure 4. Uncertainty in GP supply forecasting

If the most probable scenario is realized, then the GP proposal will almost completely cover the needs with a small deficit of 68 to 305 doctors. The upper and lower lines on the graph show unlikely, but also possible forecast scenarios. If they are implemented on the labor market, serious problems may arise in front of the healthcare ministry.

Since our model is based on data from past years, the question is about the accuracy of the initial parameters specified in it. Unfortunately, Kazakhstan is at the initial stage of creating a professional
registry of human resources for health. Workforce information can be found in the reporting forms of Ministry of Health: “Medical organization Report”, “Report on medical resource”, as well as in the database “Personnel”, on the portal of the Republican e-health center, in the department of science and human resources of Ministry of Health, in employment departments of medical universities. None of these sources is comprehensive. For example, we calculated three key parameters and their confidence intervals based on data from the last four years for the lack of information on earlier period. This led to a wide CI and significant forecast uncertainty. The advantage of system dynamics in its flexibility, with the accumulation of new data, it is possible to correct the key parameters of the model, which will increase its reliability.

5. CONCLUSION
In this paper there was considered baseline projection of GP assuming that the same level of service (defined as headcount density per population) is provided for an increasing population. And we assessed impact of three parameters for sub-models of supply. At the same time, another key parameter - new graduates - remained unchanged. This was due to the fact that for the next three years the government keep the number of grants provided for training in medical specialties unchanged, and further plans have not yet been determined.

The reform carried out in the republic aims to change the structure of primary health care, to redistribute the functions of providing medical care between a general practitioner, psychologist, social worker and nurse. In addition, a reduction in the burden per doctor is expected from the current 2000 population to 1500 population. The population growth that has been observed in the republic in recent years can lead to a change in the age composition and epidemiological situation. All this makes it necessary to consider other approaches to forecasting human resources in primary care, to assess the influence of other factors on the accuracy of models, which we plan in the near future.

References
[1] Smits M, Slenter V, Geurts J: Proceedings of the 23rdBled eConference ‘eTrust: Implications for the Individual, Enterprises and Society’. Improving manpower planning in health care. Edited by: Puchiar A. 2010, Bled eConference, 144-154.
[2] Committee, A.H.W.A., Nursing Workforce Planning In Australia - A Guide To The Process And Methods Used by the Australian Health Workforce Committee. 2004, AHWAC: Sydney, http://www.healthworkforce.health.nsw.gov.au/amwac/pdf/nurse_plan_20041.pdf
[3] Birch, S., Health human resource planning for the new millennium: inputs in the production of health, illness, and recovery in populations. Can J Nursing Res, 2002. 33: p. 109-114
[4] Hall, T.h., Why plan human resources for health? Hum Resour Dev, 1998. 2: p. 77-86
[5] Barer, M. and G. Stoddart, Toward integrated medical resource policies for Canada, in Report to the Federal/ Provincial/Territorial Conference of Deputy Ministers of Health. 1991, McMaster University: Ontario, Canada
[6] Dussault, G.B., J. Sermeus, W. Padaiga, Z., Assessing future health workforce needs-Investing in Europe’s health workforce of tomorrow: Scope for innovation and collaboration. 2010, European Observatory on Health Systems and Policies: Geneva
[7] Forte, G.J., U.S physician workforce forecasting: a tale of two states. Cahiers de Sociologie et de Demographie Medicales, 2006. 46(2): p. 123-148.
[8] Lavis, J.N. and S. Birch, The answer is ..., now what was the question? Applying alternative approaches to estimating nurse requirements. Can J Nurs Adm, 1997. 10(1): p. 24-44
[9] Roberfroid, D.L., Ch. Stordeur, S., Physician supply forecast: better than peering in a crystal ball. Hum Resour Health, 2009. 7(10).
[10] Schofield, D., I. Mcrae, and R. Shrestha. Modelling demand for medical services in Australia. In International Medical Workforce Conference. 2008. Edinburgh, Scotland: the Royal Colledge of Surgeons
[11] Schofield, D., R. Shrestha, and E. Callander, Access to general practitioner services among underserved Australians: a microsimulation study. Hum Resour Health, 2012. 10(1).
[12] O’Brien-Pallas, L., et al., Health human resource planning in home care: How to approach it - That is the question. Healthc Pap, 2000. 1(4): p. 53-59.
[13] Organization., W.H., Models and Tools for Health Sima Rafiei, Sina Abdollahzade, Fariba Hashemi Workforce Planning and Projections. 2010, Human Resources for Health Observer, World Health Organization: Geneva
[14] Scott, A., et al., Alternative approaches to health workforce planning. 2011, School of Population Health, National Health Workforce Taskforce, University of Queensland: Australia.
[15] Solutions., D.C.f.H., Better health care worker demand projections: A twenty first century approach. 2013, Bipartisan Policy Center.
[16] The Complexities of National Health Care Workforce Planning. 2011, Bipartisan Policy Center
[17] Buske L: Projected physician supply. CMAJ 1998, 158:1584
[18] Birch S, Kephart G, Tomblin-Murphy G, O’Brien-Pallas L, Alder R, MacKenzie A: Health human resources planning and the production of health: Development of an analytical framework for needs-based health human resources planning Ontario: McMaster University; 2007
[19] Ship, P.J. Health personnel projections, The methods and their uses, studies on country experiences. WHO/EDUC/ 89.198. Division of Health Manpower Development, WHO, Geneva. 1989
[20] Joyce C, McNeil J, Stoelwinder J: More doctors, but not enough: Australian medical workforce supply 2001–2012. Med J Aust 2006, 184:441-446
[21] Song F, Rathwell T: Stochastic simulation and sensitivity analysis: estimating future demand for health resources in China,World Health Stat Q 1994, 47:149-156
[22] Medical Training Review Panel. Seventh Report. Canberra: Commonwealth Department of Health and Ageing, 2003. Available at: http://www.health.gov.au/internet/wcms/Publishing.nsf/Content/health-workforce-education-mtrp7thr.htm (accessed Mar 2006).
[23] Australian Bureau of Statistics. Population projections, Australia, 2002–2101. Canberra: ABS, 2003.
[24] Silver, M.P., Hamilton, A.D., Biswas, A. et al. A systematic review of physician retirement planning. Hum Resour Health 14, 67 (2016). https://doi.org/10.1186/s12960-016-0166-z
[25] Kollar E, Buyx A. Ethics and policy of medical brain drain: a review. Swiss Med Wkly. 2013;143:w13845
[26] Serour GI. Healthcare workers and the brain drain. Int J Gynaecol Obstet. 2009;106:175–8
[27] Ono T, Lafortune G, Schoenstein M. “Health Workforce Planning in OECD Countries: A review of 26 projection models from 18 countries”. OECD Health Working Papers. 2013. No. 62, OECD Publishing, Paris. 2013
[28] Republican Center for Healthcare Development [Internet]. Nur-Sultan: The Association; [cited 2020 Jun 07]. National Healthcare Personnel Management Policy. Available from: http://www.rcrz.kz/files/nauka/%d0%9d%d0%b0%d1%86%d0%b8%d0%be%d0%bd%d0%b0%d0%bb%d1%8c%d0%bd%d0%b8%d1%8f%20%d0%b0%bb%d0%b8%d1%82%d0%b8%d0%ba%d0%b2%d0%b5%d0%bd%d0%b8%d1%8f%20%d0%9a%d0%a0%d0%97.pdf