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SIMULATION MODEL FOR STUDYING IMPACT OF DEMOGRAPHIC, TEMPORAL, AND GEOGRAPHIC FACTORS ON HOSPITAL DEMAND

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ABSTRACT

This paper reports on the results of a study that aims to develop the hybrid simulation model for estimating the level and structure of the demand for healthcare services. Our research is performed for the Wrocław Region (WR), the main administrative area of Lower Silesia, the fourth largest province in Poland. An aging chain approach is implemented in the system dynamic model to forecast the number of individuals belonging to the respective age-gender cohorts over the next 20 years. The discrete event simulation model predicts the expected volume of emergency arrivals at the WR hospitals and explores the relations between demand and demographical, temporal and geographical aspects. The projections of long-term population evolutions are performed on the aggregated data and analysis is focused on pre-specified age-gender cohorts. The demographic groups are described using parameters such as birth and death rates, life expectancy, and migration descriptors. The historical data on hospital admissions are drawn from National Health Fund regional branch registry. Our findings have important implications for the future decisions on distributions of the resources on the regional level.

1 INTRODUCTION

A major challenge when dealing with healthcare management issues is to properly estimate the prospective demand for services. Information on the expected patients' arrivals to healthcare units is necessary when attempting to diagnose, correct, and improve the performance of the healthcare system. The initial assumptions on the predicted level of demand have to be made in order to evaluate the economic and/or clinical effectiveness of medical procedures, treatment therapies, and preventive and screening programs. Arrival patterns are usually defined based on the historical data or on-site observations. These analyses are, however, focused on the supply aspect of the particular healthcare unit, and they fail when the challenge is to estimate a population's needs at the regional level and/or for the longer time horizon. The overall objectives of the regional health policy planning have a much broader context that requires the inclusion of the random and uncertain factors, and consideration of the constant changes observed in the demographic and health structures of the population.

2 HYBRID SIMULATION MODEL

The main model consists of two connected sub-models (Figure 1), each developed using a different simulation method. The discrete event (DES) sub-model of the WR healthcare emergency system was built using Rockwell Automation Technologies' Arena Simulation software, version 15.0. The model generates batches of emergency patients on a daily basis according to month-dependent arrival patterns. The second model was constructed using ExtendSim 9 by Imagine That Inc. to simulate demographic changes of the

WR region. The sub-population model uses the system dynamics (SD) method and an aging chain approach to forecast the demographic changes that will be observed within the WR population over next 20 years. The age-gender cohort simulation is performed using the deterministic approach, and hence only one replication per simulation experiment is performed. The output values describing the quantitative status of all age-gender cohorts, as registered in the subsequent years, are exported and kept in the external databases. The population data is then imported to the DES model to perform stochastic simulation for generating patient arrivals to the WR healthcare system.

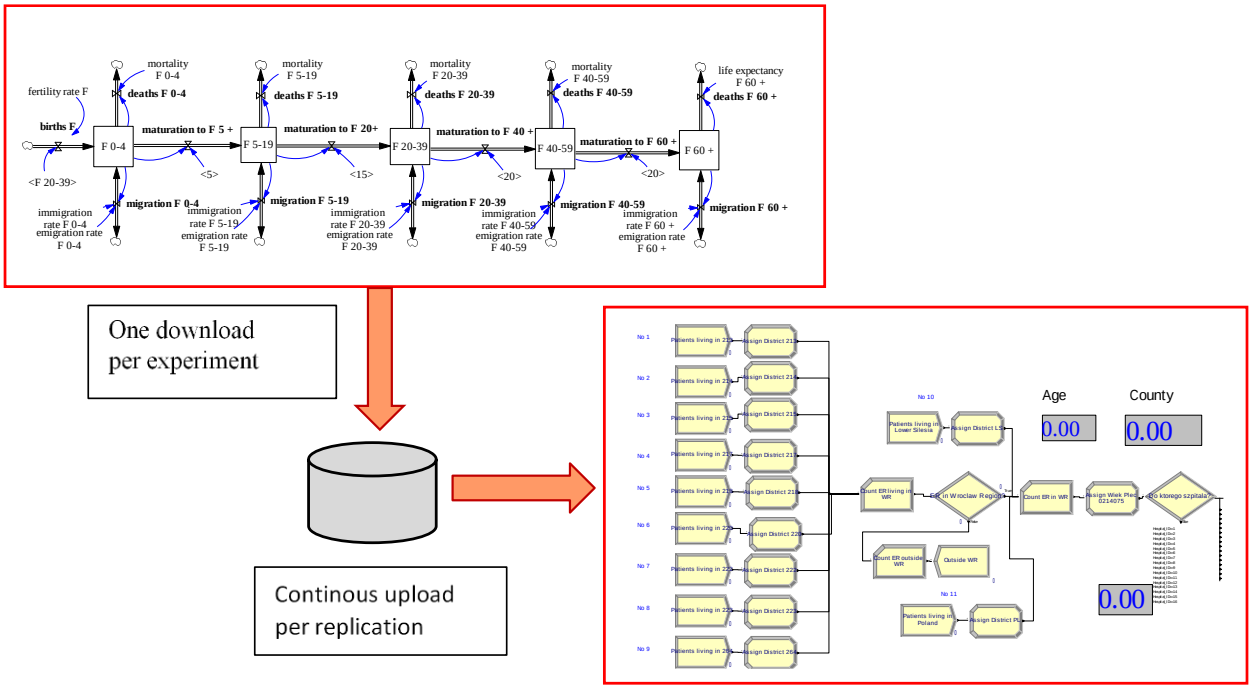

Figure1: Layout of the SD (upper) - DES (lower) model (fragments).

3 RESULTS

As expected, population aging results in a noticeable increase in the numbers of patients arriving at the WR hospitals (Figure 2). The observation of percentage changes of demand between 2011 and 2020, in relation to the level registered in 2011, shows that the intensity of demand will increase between 2011 and 2016, then it is predicted to remain around the same level up to a year 2018, however between 2018 and 2020 the number of arrivals will increase by as much as 1.52% compared to 2011. It means that more than 3000 visits will be registered in the WR hospitals in 2020 relative to the year 2011.

A detailed analysis of demand generated by individuals requiring hospital care shows that there are noticeable differences in the number of arrivals that the particular hospitals will have to face in the next few years (Figure 3). Although, between 2011 and 2020, the WR population is predicted to grow by 4.57% and the numbers of patients arriving at the WR hospitals will increase by about 1.52%, some hospitals will have to deal with the substantial growth in the number of arriving patients, while others will experience only a modest increase.

The predicted changes in the volume and age-gender structure of the population inhabiting the WR will have a differential impact on the temporal distribution of the healthcare demand (Figure 3). Although the same rising trends are observed for each calendar month, their intensities are different. The highest increase, as measured by the number of arrivals in 2020 compared to the number of patients in 2011, is observed in March (2.18%) and August (2.17%) and the lowest in April (0.78%).

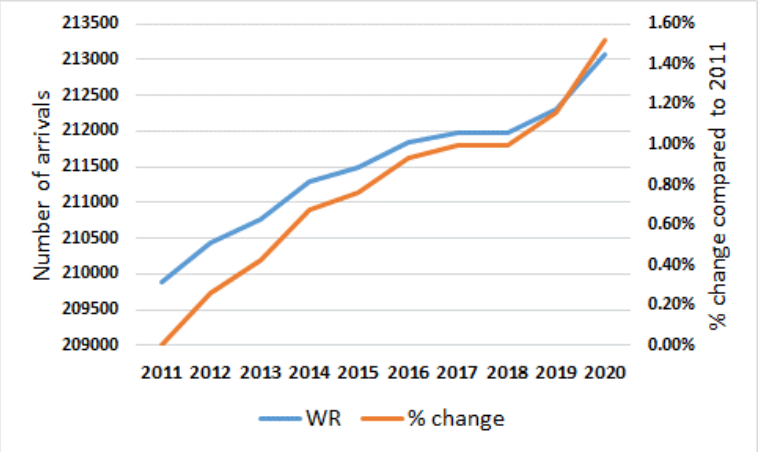

Figure 2: Predicted number of patients arriving at hospitals between 2011 and 2020 as a result of the simulated demographic changes.

Month	2020	Hospital	2020
January	2.01%	No 1	1.88%
February	1.28%	No 2	2.54%
March	2.18%	No 3	1.89%
April	0.78%	No 4	1.61%
May	1.36%	No 5	1.12%
June	1.26%	No 6	0.53%
July	1.58%	No 7	1.98%
August	2.17%	No 8	1.80%
September	1.99%	No 9	0.79%
October	1.67%	No 10	1.78%
November	0.97%	No 11	0.71%
December	1.05%	No 12	2.52%
		No 13	1.47%
		No 14	2.47%
		No 15	1.21%
		No 16	1.16%
		No 17	2.12%

Figure 3: Percentage changes in the number of individuals arriving to the WR hospitals in 2020 compared to 2011.

4 CONCLUSIONS

Planning the supply of healthcare services at the regional level requires an accurate projection of future needs of the population inhabiting the area. The majority of healthcare decision support models focus on the past demand and the current levels of utilization, however, such an approach does not guarantee a proper resource planning and the optimal coverage of people's needs in the future. The available supply might not meet the expected demand for services. Due to the aging phenomenon, the health policy planning requires better information and more reliable forecasts. Therefore, the approach linking the demand projections with the forecast demographic changes might be helpful in leveling up the inequalities in accessing hospital services in the short and long horizon. This might, in turn, improve the equity of access to health services across the region and adjust the future regional budget to the changing needs of slowly but constantly evolving age-gender cohorts.

The present work aims to contribute to filling this gap by proposing a unique approach based on two connected simulation models: the system dynamics model to forecast the demographic changes of the WR population and the discrete model to generate the emergency demand. The simulation showed a clear impact of the ongoing demographic trends on the volume and the temporal and geographical distribution of healthcare demand. We have also demonstrated that the complementary use of two simulation methods adds a new value to the process of predicting the future needs by considering a range of characteristics that describe both the population and the region. Furthermore, the demand for healthcare services is strongly driven by uncertain factors, and some of these factors are closely related to on-going changes in age-gender population profiles. We believe that our findings have important implications for the future distributions of the resources on the regional level.

ACKNOWLEDGMENTS

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