

## **Research topic and the reasons for choosing it**

The number of the services provided within the public healthcare system does not cover the demand arriving to the healthcare units. This inconsistency is due to inadequate resources intended for the financing of the healthcare services, but it is also due to the improper resource allocation, both in relation to the place and to the time of the service delivery. The appropriate distribution of the financial and material resources determines to the great extent the effectiveness of the healthcare system performance. Therefore, the accurate prediction of the population demand for the healthcare services can contribute to the improvement of the quality of the decisions taken on the different management levels.

The estimation of the future level of the demand for healthcare services is crucial when dealing with the majority of the management problems in the healthcare systems. The process of analyzing and modeling the healthcare demand is present, for example, when diagnosing and improving the performance of the healthcare system in order to formulate the overall diagnosis and to test the improvements; in studying the cost-effectiveness and/or the clinical effectiveness (in terms of mortality or morbidity changes) of medical procedures, medical treatments associated with clinical pathways, and prevention strategies or contemporary health trends; in supporting the decision makers to carry out the capacity planning process at the local, regional or national level.

The dominant approach to model the demand for healthcare services is to forecast how the demand changes over time. Typically, such studies focus on the local unit, and the process of model development and validation is based on historical data while assuming that future demand will behave in a similar manner. These models are used to make short-term predictions for hourly, daily, or monthly patients arrivals. The applied methods are usually time series analysis methods.

The most common methodological approach assumes that the future demand for healthcare services may be properly approximated by the past supply of the services delivered to the patients. However, when formulating forecasts related to the structure and the level of the capacity of resources needed to cover the demand for healthcare services, the knowledge about both the exposed and the unexposed demand is essential. When neglecting this information, the forecasts are constructed without the link to the specificity of the changes observed in demographic and epidemiological structure of the population. Moreover the influence of the different types of uncertainty (objective and subjective) and randomness should also be considered. The incorrectly estimated demand may lead to the erroneous assumptions when formulating the health policy both for the particular supplier and on the regional or national level.

When dealing with the performance of the healthcare systems the new class of demand models would enable to estimate the level and the structure of the exposed and the unexposed demand for healthcare services. The key element of the methodology is the inclusion of the factors of which the incidence, intensity and the consequences are uncertain and/or random in relation to: time, diagnosis, healthcare provider, administrative area, demography and people's behavior. The attempts to develop this kind of the research have already been made, however the published results are still unsatisfactory and still a methodological gap may be observed.

## **The basic research to be carried out**

The research studies aiming at the methodological aspects of the healthcare demand estimation may be supported, instrumentally and conceptually, by the systematic approach to formulate, analyze and solve the decision problems. The research methods, belonging to the domain of Operations Research and Management Science (OR/MS) help to find the solutions which are economically rational and medically valid. OR/MS has always been an applied scientific discipline, dealing with real life systems, processes and complex decision problems. Healthcare and the boundaries of clinical and managerial decision making, have for many years been one of the most important application domains for OR. However, the obstacles when introducing OR/MS tools into the managerial practice of healthcare management are the complexity, heterogeneity and uncertainty of the ongoing processes. The main determinants influencing the decision making strategy in the healthcare domain are the dynamic interactions between its elements, continuously changing environment and the strong influence of stochastic and unsteady factors. The difficulty when conducting the scientific research of healthcare systems is also the weak structuralism of the issues related to the delivery of healthcare services. This often excludes the possibility to apply analytic models and inspires the scientists to search for the tools to improve the decision analysis process and increase the effectiveness of the decisions taken. It seems, that the objectives of the proposed project are well correlated with timeliness, importance and development direction of the healthcare management.

The range of quantitative and qualitative methods is used in the field of management science, and the simulation and modelling approaches are seen as the most promising when studying the system with the high occurrence of uncertain and random type phenomena. Computer simulation possesses the unique properties to study the mutually adversative aspects related to the delivery of healthcare services, namely the patient satisfaction and the economic effectiveness of the unit. It can also be assumed that the new paradigms appearing during last few years, like agent simulation and the hybrid approaches (for example, the discrete rate modelling), may substantially contribute to the development of the scientific methods to analyze the delivery of the healthcare services. The accomplishment of the objectives defined in the proposed project will increase the utility of computer simulations, especially regarding the estimation of healthcare needs.

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## **The objective of the project**

The main research objective is to formulate the methodology of developing simulation models and performing computer experiments that would enable to estimate the level and the structure of the exposed and the unexposed demand for healthcare services. The key element of the methodology is the inclusion of the factors of which the incidence, intensity and the consequences are uncertain and/or random in relation to: time, diagnosis, healthcare provider, administrative area, demography and people's behavior.

The research will be focused on identifying the healthcare needs in relation to:

- the patients with the particular medical diagnosis;
- the selected healthcare unit: outpatient department, admission unit, hospital ward;
- administrative region: for example the set of communes or the whole voivodship;
- one type of the healthcare services, for example the services provided to patients in emergency wards or by the ambulance teams.

It is planned to conceptually elaborate a set of simulation models to estimate volume and structure of the healthcare demand:

The 1st class of simulation models will enable to forecast the time dependent structure and parameters of the healthcare demand. The changes of the demand according to time of the day, day of the week, the successive years, the calendar seasons will be considered.

The 2nd class of simulation models will enable to forecast the age pyramid dependent structure and parameters of the healthcare demand. The intensity and the structure of population needs depend on age-gender profiles, that change according to the increasing the average expected length of life, the decreasing birth and death rates. Additionally, the needs for services for the patients with the diagnosed disease are changing according to the time that has passed from the moment the diagnosis was formulated.

The 3rd class of simulation models will enable to forecast the structure and parameters of the healthcare demand taking into account the randomness and uncertainty, like for example the development of new medical technologies, the ongoing changes in the population epidemiological profile, the unpredictability of people's behavior (like the choice of the healthcare unit) and others.

The 4th class of simulation models will enable to forecast the structure and parameters of the healthcare demand taking into account: (1) the social factors like migration, family status, fertility rates; (2) environmental: urbanization, contamination of the environment; (3) economic: unemployment rates, wealth, income.

The models will be developed using different simulation approaches: discrete event simulation (DES), agent based simulation (ABS), Monte Carlo method (MC), system dynamics approach (SD) and the selected analytic methods (the forecasting cause and effect models). The discrete-event simulation has been the most used technique in the healthcare management field. It belongs to stochastic approaches and it is used to model the systems, for which the significant share of random factors is observable. In DES healthcare modelling, the probabilistic distributions are used to describe the arrival processes, service times, intervention risks and other random factors. Monte Carlo models are applied when supporting the clinical decisions directly linked to the treatment processes. For example, the MC model may consider the randomly changing demand for healthcare services and the goal of the simulation is to study the time needed to receive the service. The system dynamics focuses on the dynamic analysis of complex phenomena. The SD approach is particularly helpful when attempting to formalize the mental model of the given problem. It is also useful when analyzing the relations between the system's structure and its behavior after some changes were initialized. Agent based simulation (ABS) has gained the increasing interest over the past several years. The most popular area of applications of this approach is the spread of infectious disease.

It is planned to study the abilities of particular simulation methods and the purposefulness of using the above mentioned techniques to study the healthcare management related problems for which the key issue is the estimation of the future level and structure of the demand.