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The concept of a health security system model during a pandemic

Koncepcja modelu systemu bezpieczeństwa zdrowotnego w czasie pandemii

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Abstract. The necessity of proper health security management is determined by its decisive role in ensuring survival conditions. Estimating the risk in the area of health security and striving to implement appropriate models of the health security system seems to be crucial in the process of managing it. The aim of this study is to propose a model of the health security system, taking into account the dynamics of changes in its determinants caused by the COVID-19 pandemic. The intention of the presented solutions is to optimize the use of available resources during the health crisis. The main research problem is the question: how would the new model of the health security system take into account the needs of health care in the conditions of the COVID-19 pandemic? Using the observational method, available research as well as exploratory and intervention data related to COVID-19, an attempt was made to propose a model aimed at efficient management of medical care provided to patients. Focusing on technology-oriented models together with a well-matched infrastructure may result in better results in the prevention and care of COVID-19 patients. The aforementioned technological development will also serve the implementation of new models enabling the application of genomics, proteomics, nanotechnology, materials science and digital devices for early diagnosis and infection control. The presented model has been developed taking into account various factors and conditions that may affect its efficiency, as well as the proper functioning of the health security system.
Keywords: model, system, health security, pandemic, COVID – 19

Abstrakt. Konieczność właściwego zarządzania bezpieczeństwem zdrowotnym determinowana jest jego decydującą rolą w zapewnieniu warunków do przetrwania. Szacowanie ryzyka w obszarze bezpieczeństwa zdrowotnego oraz dążenie do implementacji właściwych modeli systemu bezpieczeństwa zdrowotnego wydaje się kluczowe w procesie zarządzania nim. Skuteczne zarządzanie opieką zdrowotną jest jednym z głównych elementów zdrow-szego społeczeństwa, w którym pozytywne działania w zidentyfikowanym segmencie badań, technologii oraz zarządzania, mają ogromny potencjał, aby poprawić globalną reakcję na potencjalne przyszłe kryzysy zdro-wotne. Celem opracowania jest zaproponowanie modelu systemu

bezpieczeństwa zdrowotnego, uwzględniają-cego dynamikę zmian jego determinantów, spowodowaną trwaniem pandemii COVID–19, a intencją zaprezen-towanych rozwiązań jest optymalizacja wykorzystania dostępnych zasobów w okresie kryzysu zdrowotnego. Głównym problem badawczym artykułu jest: W jaki sposób nowy model systemu bezpieczeństwa zdrowotne-go uwzględniałby potrzeby opieki zdrowotnej w warunkach trwania pandemii COVID-19? Stosując metodę obserwacyjną oraz wykorzystując dostępne badania oraz dane eksploracyjne i interwencyjne związane z CO-VID-19, podjęto próbę zaproponowania modelu, którego celem jest sprawne zarządzanie opieką medyczną świadczoną dla pacjentów, w tym właśnie z COVID-19 i innymi chorobami oraz osób zdrowych, w ramach zintegrowanych ram szeroko rozumianej profilaktyki. Ukierunkowanie się w stronę modeli zorientowanych na technologię, z dobrze dopasowaną infrastrukturą, może skutkować lepszymi wynikami w profilaktyce i opiece nad chorymi na COVID-19. Rozwój technologii służyć będzie również implementacji nowych modeli, umożli-wiających zastosowanie: genomiki, proteomiki, nanotechnologii, materiałoznawstwa oraz urządzeń cyfrowych dla wcześniejszej diagnozy i kontroli zakażeń. Przedstawiony model opracowano przy uwzględnieniu różno-rod-nych czynników oraz uwarunkowań, które mogą mieć wpływ na jego wydajność, a także prawidłowe funkcjo-nowanie systemu bezpieczeństwa zdrowotnego.
Słowa kluczowe: model, system, bezpieczeństwo zdrowotne, pandemia, COVID-19

Introduction

Institutions and people responsible for responding to situations such as the COVID-19 pandemic must assess the current situation and prepare appropriate schemes for implementing appropriate procedures. This planning phase not only requires considering space-time dynamics and analyzing the impact of the pandemic using simulation models but must also consider anticipating and ensuring resource availability in various spread scenarios. State authorities responsible for creating regulations and rules applicable in the state of epidemic threat almost immediately began to use scientific data provided by epidemic models (Afzal, 2020, pp. 86-90). These models had a direct and significant impact on policy and decisions making, such as introducing the need to maintain social distance or closing schools, which were aimed at reducing the risk posed by COVID - 19 to public health (Habli *et al*., 2020, p. 78).

The problem of making management decisions in the context of uncertainty, controversy and turbulence does not apply only to healthcare. The mainstream of previous theoretical work in operations research and management science has focused in many aspects on the paradigm of "substantive rationality": rational choice is the option that logic and the laws of probability suggest as the one that will lead to the best or most preferred set of outcomes (Simon, 1976, p. 34). These works were devoted primarily to methods of analysis and optimization, methods of describing the system under consideration, estimation of the likely impact of choosing a specific option or a set of so-called "best" solutions. It should be noted, however, that in the earlier period much less emphasis was placed on sophisticated mathematical methods. The focus was primarily on a good understanding of the problem and conducting analyzes in which the people responsible for the analysis worked closely with decision makers, examining the implications of various choices in many considered scenarios.

Nowadays, the fields of theory and practice have come closer together, and procedural rationality has become a much more widespread and recognized concept. As a result, various approaches were developed for the "decision support", which is defined as "a way of identifying the necessary information about options and impact on the results and organizing and processing this information in a way that leads to appropriate decisions, thus increasing the capability of decision makers to process this information"(Sanderson, Gruen, 2006, p. 12). The basis of the decision support is a properly prepared model of the considered system.

The purpose of this study is to propose a model of the health security system, taking into account the dynamics of changes in its determinants caused by the COVID - 19 pandemic. The main research problem should be seen as the question: how the new model of the health security system would take into account the needs of healthcare in the conditions of the COVID-19 pandemic? Theoretical methods used for verification of the research problem are as follows:

- literature analysis,
- synthesis,
- comparison,
- generalizations.

During works on the model formulation, the following variables were taken into account:

- independent variables, including: total population, total area, percentage of fully vaccinated population, ratio of positive test results to the total number of COVID-19 tests, number of patients in ICU wards/million inhabitants, availability of emergency care, total health care expenditure by all financing entities (in total, public and private sector), number of hospital beds (per 1,000 inhabitants), number of doctors (per 10,000 inhabitants); length of life; number of healthy years; BMI;
- dependent variables, which, after measuring and analysis, will allow to understand their relationship with independent variables that refer to cumulative, excessive mortality.

The subject scope of the publication is the model of the health security system, along with its elementary indicators, implying its proper functioning, allowing for illustrating issues related to the described area. The intention of the presented model, resulting from the analysis of available research and statistical data, is to optimize the use of available resources during the health crisis. The presented model has been developed taking into account various factors and conditions that may affect its performance and proper functioning.

The use of the developed model allows for the identification of factors responsible for the deterioration of health in the society and the development of appropriate, long-term preventive measures in this area. The literature on the subject provides various examples of the positive impact of social campaigns and regulations on the

health of the society. Certain limitations of the proposed model may result from the fact that it was formulated on the basis of analyzes carried out in developed countries, where health care systems provide services of relatively high quality, and social awareness, resulting from the level of education, allows for proper prevention.

The proposed model can be the starting point for detailed research, which aims at understanding the relationship between various factors determining the level of health in the society and the response of the population and the system to the occurrence of situations leading to health crises. The data obtained in this way can be used by institutions that are responsible for shaping the health security system to take appropriate actions and implement appropriate strategies.

Types of models used in the decision making process

Modeling is a process aimed at simplyfying the understanding, defining, quantifying, visualizing or simulating of a specific part or feature of the real world around us. The scientific model is a physical and / or mathematical and / or conceptual representation of a system of ideas, events, or processes. The model can be treated as a simplified description or the essence of a particular system, which can be used for better understanding of the scheme or the decision - making process itself. Scientists strive to identify and understand patterns in the world around us, making use of their knowledge to develop solutions (models) that will enable the prediction of these patterns (Gilbert and Boutler, 1998, pp. 53-56).

There are various methods of classifying types of model in the literature. One approach divides the models into three basic types (Sanderson and Gruen, 2006, p. 12):

- iconical,
- graphical,
- symbolical or mathematical.

Iconical models show physical or spatial relationships between objects. They reproduce the real object in a very accurate way, differing primarily in scale - an example can be a model of an airplane, ship or house. Most of these models are used to convey ideas or gather information on a proposed project (Skyttner, 2005, p. 17).

Graphical or conceptual models are basically diagrams that show non - spatial relationships between a set of elements. It is useful to distinguish between the following representations of objects:

1. Logical sequences of activities - represent the connections between the various activities that may be involved in achieving the goal. The purpose of such a model is most often to design and communicate a certain plan or schedule.
2. Influences or effects (mutual relations between variables) - the main task is to capture and convey understanding of how (and why?) the modeled

system works. The diagrams show cause - effect chains to make decisions about how to change or affect the variable - "result".

3. Flows of objects between system elements. In flow models, the object of interest is usually to understand how the various components of the system contribute to the overall performance and the management of the system performance.

An example of a conceptual model would be a UML (Unified Modeling Language) diagram (https://en.wikipedia.org/wiki/Unified_Modeling_Language, 2021) used in systems engineering to describe the functional requirements of a system (Bozyiğit, Aktaş and Kılınç, 2021, pp. 71 – 82).

The main purpose of graphic models is to develop and communicate a qualitative understanding of a system or situation. Where a quantitative assessment is required, it is essential to build **a symbolical** or **mathematical model**. In the process of mathematical modeling, the idea of how a certain system functions is translated into mathematical language, which is extremely precise. Math modeling provides an environment that, based on the data, helps you understand how changes in that environment can affect the outcome. Modeling in combination with data can explain past behavior, predict and forecast future actions, and evaluate how changes can revise those predictions. The main purpose of mathematical modeling is to generate answers to questions that cannot be answered through observation (Panovska-Griffiths at al., 2021, pp. 291-326).

As an example of mathematical modeling, there is a fairly common use of the gravity model to calculate the hospitals' occupancy (Kiok Liang Teowa *at al.*, 2018, p.65-70; Lowe and Sen, 1996, pp. 437-467):

$$P_{a,h} = \frac{\frac{G_h}{d^e_{a,h}}}{\sum_{i=n}^{n} \frac{G_i}{d^e_{a,i}}},$$

where: G_h- gravitational constant for a particular hospital h,
n – number of hospitals,
$P_{a,h}$ - hospital' occupancy h in the area a,
$d_{a,h}$ - distance to the hospital h in the area a,

$\frac{G_h}{d^e_{a,h}}$ it represents therefore the gravitational pull of the hospital h,

$\sum_{i=n}^{n} \frac{G_i}{d^e_{a,i}}$ is the sum of the gravitational pull values for all hospitals in the area a.

This publication presents a conceptual graphical model of the health security system.

Model of the health security system

Citizens' health security depends, i. a., on the full availability and efficiency of the functioning of medical services, especially on the existence of efficient public health services, therefore the introduction of restrictions on the availability of medical services and implementations of limits of these services is a threat to the public health security.

A similar definition of (patient) health security, focusing mainly on the availability of services, is used by the WHO: *preventing healthcare-related adverse events in order to achieve zero avoidable harm to the patient* (World Health Organization, 2020). However, it should be emphasized here, that if health services are not of good quality and safe, then making them available in the same way is irrelevant and may even turn out to be harmful. The COVID-19 pandemic has also shown that national health systems that are well prepared, flexible and agile are better able to respond and save lives, thereby increasing the health security of the public (Legido-Quigley *et. al.*, 2020, pp. 849-850).

However, the availability of services is not a sufficient factor for ensuring security. Various activities of the state are also needed, the aim of which is to create opportunities to ensure health for all citizens, including creating organizational and legal conditions for the efficient functioning of public health services (Paplicki, 2020). In the event of an epidemic threat, interaction between public health services and state authorities responsible for introducing regulations aimed at inhibiting the spread of the virus in society is essential. The presented conceptual graphical model of the health security system (Fig. 1) is based on the above mentioned definitions.

The purpose of the presented model is to describe the relationship between:

- the condition of the health care system, which is characterized by the following indicators:
  - availability of healthcare,
  - total healthcare expenses,
  - number of beds in hospitals (per 100 inhabitants),
  - number of doctors (per 1,000 inhabitants),
  - the effectiveness of the government's response to an epidemic threat;
- health state and public awareness, defined by the following factors:
  - average life length,
  - average health - adjusted life expectancy,
  - body mass index,
  - civilization diseases,
  - quality of health education and awareness in society;
- state decision - making authorities that are responsible for introducing appropriate regulations aimed at stopping the development of an epidemic in a particular area;
- the existing epidemic threat, which will cause serious burden on the health care system - an excessive number of patients requiring care.

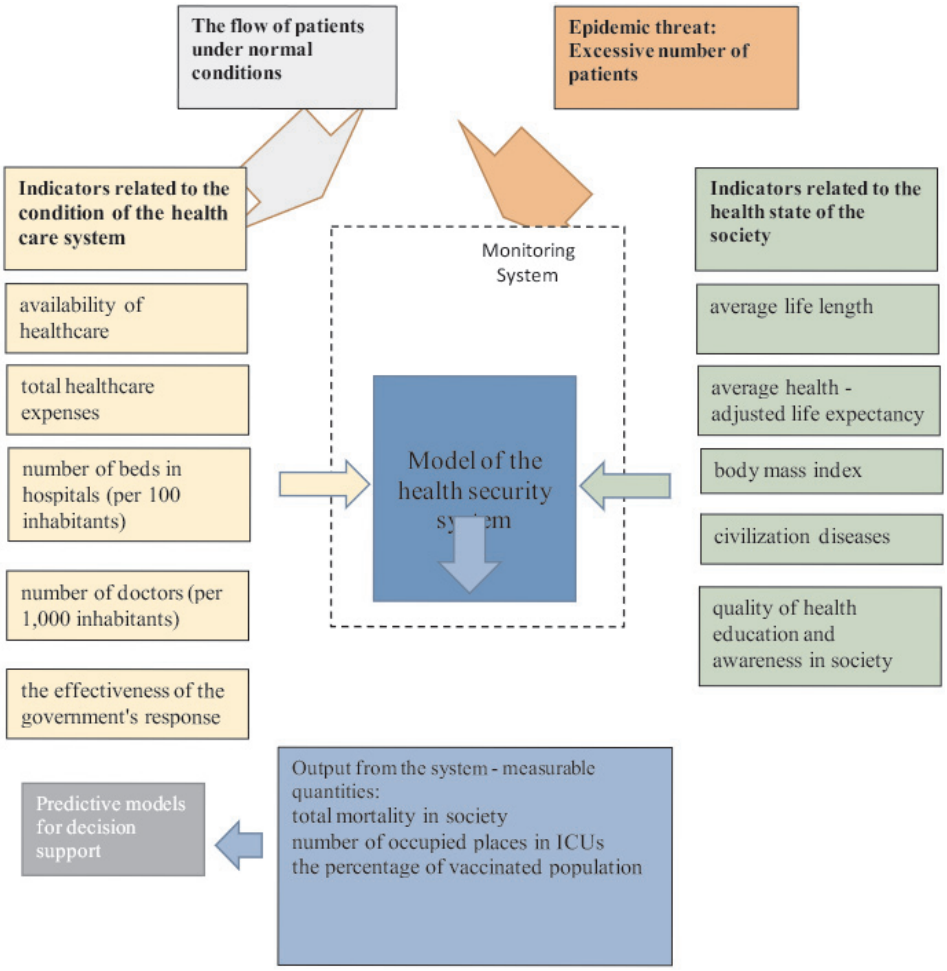

Fig. 1. Model of the health security system
Source: Own elaboration

The tool, necessary to link the above - mentioned values, will be the monitoring system, which will return the values illustrating the course of the pandemic at the output of the health security system model:

- total mortality in society;
- number of occupied places in ICUs;
- the percentage of vaccinated population.

The monitoring of the above values is primarily aimed at collecting relevant statistical data on the epidemic status in a particular area. The collected statistical data can be used as input data for the so - called predictive models supporting

decision making. Prediction can be broadly defined as the estimation of results for input data that are currently invisible (unavailable). For this purpose, it is necessary to develop and train, using the available data *x*, a model that will result in an estimator *f(x)* that allows the prediction of results based on new input data *x* (Lobo Marques *et al*., 2021). The results obtained from the predictive models, on the basis of the input data recorded at the output of the health security system, can be used in making decisions about introducing restrictions (or reducing them), creating new temporary hospitals for patients in selected regions, etc.

Since the beginning of the epidemic, the literature offers many proposals of predictive models supporting decisions, e.g.:

- models based on the commonly used Kalman filtering with the use of epidemiological compartmental models (in epidemiology) SIR, SEIR (Han *et al*., 2021, pp. 1-16);
- models based on artificial neural networks (Kuvvetli *et al*., 2021);
- regression models (Kalippan, *et al*., 2021).

The purpose of the decisions made on the basis of the prediction models is to reduce the burden on the health care system resulting from the excessive number of patients in the crisis created by an epidemic threat. The problem of making decisions in a state of an emergency is a complicated process and requires appropriate analysis of large numbers of variables.

An example of this type of process may be making a decision of preparing additional hospitals for patients with severe disease caused by the SARS-CoV-2 virus based on the analysis of a data on the occupancy of beds. This action may seem sufficient from the point of view of COVID-19 patients, but it should be remembered that the consequence of such a decision will be the deprivation of equipment and staff in other hospital departments. The shortage of staff will result in the cancellation of planned treatments and, consequently, creating the so - called health debt (Pulsmedycyny, 2021). In order for the health care system to function efficiently despite the state of emergency, it is necessary to take decisions introducing restrictions limiting the spread of the virus in the society. Due to the enormous amount of data needed to analyze, available tools, such as the aforementioned data monitoring systems and predictive models, should be used in the decision - making process in an epidemic emergency.

Making current decisions in order to reduce the negative effects of a pandemic, based on the output data from predictive models, is one of the functions of the developed model of the health security system. This model may also have a long - term function through appropriate action, governmental organizations may influence indicators characterizing the state of health of the society. Improving the general health of a population can have a huge impact on the functioning of the health care system in the event of future threats. Since the beginning of the pandemic, the main

factors increasing the risk of severe COVID-19 have been identified (Mayoclinic, 2021; WHO, 2021):

- age over 65,
- lung diseases (including asthma),
- cardiovascular disease,
- diabetes,
- obesity,
- hypertension.

The reason for the presence of many of the above-mentioned risk factors in society is the lack of health awareness and, as voiced earlier, inadequate lifestyle: lack of physical activity, dietary mistakes, smoking, alcohol abuse (Surma, Szyndler and Narkiewicz, 2017). The created model allows to identify the causes of poor health in the society (indicators of the health state of the population) and to develop appropriate long - term policies. In the literature, you can find many examples of the positive impact of social campaigns and regulations on the health of the society:

- the impact of regulations on the sale of alcohol in Sweden on the improvement of the state of health (Sockwell *et al*., 2018);
- UK public awareness campaigns about the effects of overuse of antibiotics (McNulty *et al*., 2019), (Thomson, Berry and Robinson, 2020);
- social campaigns increasing public awareness of the positive impact of physical activity on health (Kahn *et al.,* 2002).

The analysis of indicators directly related to the condition of the health care system may also lead to activities increasing the security of the health care system in the event of a future threat. One example of long - term corrective actions may be an increase in health care spending. An excellent example of such policy can be find in Germany, which was the country best prepared for the coronavirus pandemic, mainly due to the enormous funding of the health sector from the state budget.

Discussion

It should be noted that the use of the proposed model will create opportunities for the process of optimizing the health security system, taking into account the existing systems and institutions, provided that:

- gaining the necessary abilities for proper functioning;
- achieving by them the goals defined in the documents and strategies;
- improving their activities in accordance with the assumptions of the developed model.

Guaranteeing an appropriate level of health security, in the long term, in accordance with the assumptions of the developed model, will largely depend on strengthen the potential to overcome difficulties that will go beyond its classically perceived threats.

The fundamental challenge for the health security system is the improvement of the indicators presented in the proposed model, such as:

- availability of healthcare;
- total healthcare expenses;
- number of beds in hospitals;
- number of doctors;
- the effectiveness of the government administration's response to a state of emergency;
- improving population health.

The implementation of the health security system model, which would effectively increase the level of security, should be preceded by a legislative process, as a result of which legal acts would be adopted ensuring appropriate formal and legal conditions for its functioning. It is also crucial to ensure appropriate tools for the executive authorities at various levels.

The implementation of the model, which enables the use of the concept of solutions improving health security in Poland, should be carried out with consideration of:

- adapting the way it is managed at the central level;
- environmental conditions;
- the changing spectrum of existing threats.

Productive use of opportunities, resisting the emerging challenges, effective risk management, as well as facing the threats linked to the model implementation process will require taking into account the conditions related to its functioning, which consist of internal and external factors. To the first of the above mentioned (the so - called positive features of the organization) can be included primarily:

- solidarity and active participation, based on partnership relations, of public administration, as well as private and state operators of infrastructure belonging to the healthcare system in the process of improving its efficiency;
- growing health awareness, which is a key determinant of the health of the society.

A complex, interdisciplinary and multi - stage process, which is the implementation of the health security system model, as well as its optimization in the conditions of existing threats, will be extremely complicated. It will be a consequence of:

- the need of coordination of many different, usually complex projects, which often have to be implemented within precisely defined time frames, stages, cycles and iterations, which are determined by major and detailed organizational transformations;

– other, necessary organizational activities, the fulfillment of which will be crucial for the proper functioning of the model.

The impact of a number of external and internal conditions will also be decisive when determining the necessary parameters and defining a multifaceted methodology for implementing the designed model, as well as the subsequent improvement of system solutions. Fundamental to the optimal functioning of the developed model will be the predisposition of personal resources involved in the creation of individual elements, such as: competences, skills, experience and specialist knowledge. The implementation of the proposed solutions in this area should be based on the improvement of executive and medical personnel and enhancement of their cooperation at particular levels (Kitler, 2014).

External factors that have a significant impact on the effective implementation of the health security system model are (Prawo.pl, 2021):

– demography - the age structure of the society and the life expectancy of citizens are changing; medical facilities should prepare solutions and an offer of services for elderly patients, which is related to, inter alia, staff training and infrastructure adaptation; in 2035, almost every fourth Pole will be over 65 years old;
– economics - the health care system requires financing; the state of the country's economy and its budget have a significant impact on the quality of health care;
– technological progress - it requires constant changes in the health care system; new drugs and technologies enable the diagnosis and treatment of diseases that were previously undetectable or considered incurable;
– globalization.

To sum up, apart from the development and application of effective legal instruments and organizational solutions, as well as ensuring the proper preparation of personnel, activities aimed at operationalizing the developed model will require constant improvement of communication between all its elements.

Conclusions

Effective implementation of the proposed model of the health security system will depend on four areas:

First. Preventing possible health security threats related to the health status of the population. The COVID - 19 pandemic emphasized the need to improve health, because the basic indicators influencing the course of the epidemic in a particular area were precisely those related to its level: life expectancy, average number of healthy years, body mass index, incidence of civilization diseases , health education and awareness in society.

Second. Preparation of the system in the event of emergencies in the area of health security. The current pandemic has highlighted the need to improve the health system's preparedness to respond to crises. The key indicators in this matter were: availability of health care, total expenditure on health care, maintaining a sufficient number of hospital beds, having an adequate number of medical personnel.

Third. Responding to emerging threats caused by emergencies in the area of health security. The effectiveness of the government administration's response to a pandemic turns out to be a fundamental factor that has an impact on the positive final effects of the entire process.

Fourth. Removal of consequences in the area of health security. The more efficiently the elimination of the consequences caused by a pandemic, the faster and more efficient the process of returning to the state before its occurrence will be.

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