

UDC 336.14:352:614.2

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City Medical Center for Hearing and Speech problems «SUVAG», Ukraine;**e-mail: suvagkiev@i.ua***HEALTHCARE FINANCING AND BUDGETING:****THE REGIONAL POLICY PRIORITIES IN RESPONSE TO COVID-19**

**Abstract.** This paper summarizes the arguments and counter-arguments in the scholarly debates on transformations in healthcare budgeting that should consider the differentiated regional vulnerability in responding to the pandemic. The primary purpose of the study is to identify priorities for local health development programs. The urgency of solving this problem is that the pandemic has revealed the unprecedented unpreparedness of the health care system to respond effectively to challenges; also, hidden problems accumulated during the last decades, which increase the emerging risks. The study is carried out in the following logical sequence: 1) collection, processing, and analysis of statistical data; 2) conducting a cluster analysis for group regions by vulnerability to different classes of diseases; 3) conducting correlation and regression analysis to compare the effects of the COVID-19 pandemic (cases and deaths) and the state of the region; 4) selection of the most significant features of the vulnerability of the region; 5) designing the matrix of the choice of priorities for financing targeted programs in the field of health care. Methodological tools of the study were methods of correlation and regression analysis, cluster analysis, testing for autocorrelation by Darbin — Watson method, sigma limited parameterization to identify the most significant coefficients. The method is tested for 25 regions of Ukraine (including Kyiv), as they can serve as pilots for other regions with similar demographic and economic characteristics. The article presents the results of an empirical analysis of the readiness of regions for critical conditions, such as COVID-19. Identifying such readiness and appropriate distribution of regions by disease classes allows to make decisions in financing and budgeting and improve the quality of health care.

**Keywords:** COVID-19, regional vulnerability to COVID-19, step-by-step nonlinear regression, morbidity, mortality, regional profile, pandemic, multicollinearity, targeting budgeting.

**JEL Classification** C21, C51, C31, C12, I15, I18, R58, R11

Formulas: 9; fig.: 5; tabl.: 7; bibl.: 36.

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## **ФІНАНСУВАННЯ І БЮДЖЕТУВАННЯ ОХОРОНИ ЗДОРОВ'Я: ПРІОРИТЕТИ РЕГІОНАЛЬНОЇ ПОЛІТИКИ У ВІДПОВІДЬ НА COVID-19**

**Анотація.** Узагальнено аргументи і контраргументи в межах наукової дискусії з питання зміни бюджетної оптимізації в галузі охорони здоров'я з урахуванням диференційованої регіональної вразливості від наслідків пандемії. Основною метою проведеного дослідження є визначення пріоритетних напрямів розвитку місцевих програм розвитку в галузі охорони здоров'я. Актуальність розв'язання наукової проблеми полягає в тому, що пандемія виявила неготовність системи охорони здоров'я реагувати ефективно на виклики, окрім того, виявила приховані проблеми, закумуляовані протягом останнього часу, яку підвищують ризики, що з'являться в майбутньому. Дослідження питання виявлення пріоритетних напрямів розвитку програм у галузі охорони здоров'я здійснено в такій логічній послідовності: 1) збір, обробка та аналіз масиву статистичних даних; 2) проведення кластерного аналізу для групування регіонів за вразливістю до різних класів хвороб; 3) проведення кореляційно-регресійного аналізу для зіставлення наслідків впливу пандемії COVID-19 і стану досліджуваної галузі в регіонах; 4) виділення найбільш впливових ознак на вразливість регіону; 5) запропонована матриця вибору пріоритетів фінансування цільових програм у сфері охорони здоров'я. Методичним інструментарієм проведеного дослідження стали методи кореляційно-регресійного аналізу, кластерного аналізу, перевірка на наявність автокореляції методом Дарбіна — Уотсона, проведена сигма обмежена параметризація для виявлення найбільш значущих коефіцієнтів. Об'єктом дослідження обрано 25 регіонів України (включно із м. Києвом), оскільки вони можуть служити пілотними для інших регіонів, схожих за демографічними та економічними характеристиками. Представлено результати емпіричного аналізу готовності регіонів до критичних станів, таких як COVID. Вииявлення такої готовності та відповідний розподіл регіонів за класами хвороб дозволить

знайти оптимальний шлях для перерозподілу фінансових ресурсів і поліпшення якості надання медичної допомоги.

**Ключові слова:** COVID-19, регіональна вразливість до COVID-19, покрокова нелінійна регресія, захворюваність, смертність, регіональний профіль, пандемія, мультиколінеарність, цільове бюджетування.

Формул: 9; рис.: 5; табл.: 7; бібл.: 36.

**Introduction.** The study is encouraged by the fact that the pandemic situation in Ukraine has revealed the unreadiness of the health care system to respond quickly to the crises, the low financial security of most of the primary and secondary health care facilities, low safety, and other unsolved problems. The crisis has revealed the complexity of interconnected problems that have existed for a long time at the state, regional and local levels in health care. There is a need for a detailed analysis of the state of population health (screening), the evaluation of the resource and technological support of health care facilities, accessibility, and quality of medical care at all levels. Another big problem is the lack of methodological approaches and a comprehensive toolbox to identify the key areas for further strategic actions. To this end, it is essential to conduct in-depth and detailed statistical studies to identify patterns that become the basis for further forecasting the state of regional health care systems and subsequent resource decisions.

The damage caused by the pandemic situation in the world as a whole and in the country due to the impact of COVID-19 is underestimated for a number of reasons. First, the waves of the disease are still ongoing, and secondly, the diagnosis of the consequences of the disease in people who have suffered the disease — also only at an early stage.

Being a threat, COVID-19 revealed many hidden problems in the health care system and security, and one of the findings of this study at the primary stage is that in Ukraine, unlike in the EU, there are few targeted programs in the sphere of health care. The implementation of such programs is a separate operational and strategic goal because it requires highly-skilled experts in several fields such as health care, financial, and management studies. However, there is no particular targeted program to ensure a response to COVID-19. Still, there is a cooperation between the Ministry of Health and territorial units, as well as its subordinate central executive bodies: the State Sanitary and Epidemiological Service of Ukraine, the State Service of Ukraine for medicines, the State Service of Ukraine for Combating HIV / AIDS and Other Socially Dangerous Diseases. And yet, it's not enough to react effectively and to prevent further threats.

The case of Ukraine, one of the biggest countries in Europe, may become a pilot for further replication of the statistical data research and policies identification. Ukrainian regions may be compared to the regions of the EU.

Therefore, this study is aimed to bring new understanding in the priorities and targeting in a sphere of regional health policy in response to the challenge of COVID-19 using the statistical data for Ukraine as a case.

**Literature review and the problem statement.** Aside from the health crisis, COVID-19 hit many industries across the country, including the news and communications industry, which is important in times of crisis for bringing authentic and true information [6]. There are some finding in a sphere of industrials performance that was damaged by COVID-19 impact [30], or labour market dynamics that was damaged too [12]. The outbreak became a test and a catalyst for a change in many spheres, such as the service sector [10], sales and hospitality [9], governments and SMEs [29], green technologies and sustainability [16; 31], energy sector [36]. The research in public sector development has to be enriched by new data [2] to make institutions capable of responding rapidly to environmental shocks.

The performance indicators, monitoring technologies, resilience, and vulnerability of health care are highly discussed topics. The scholars and policy-makers debate about the focus of attention in further reforming of health care; for instance, it could be staff training in health care [24] or health care infrastructure innovations [26], or it should be communications through social media platforms [5] as an effective tool of informing and protecting communities.

Processing statistics data to predict country transformations through the pandemic COVID-19 is another stream of research for scholars [32], but the pandemic is not over yet, and more attention should be paid to the readiness for a new challenge.

Many papers have health care in their focus, for instance, the dynamics of health care tourism can be considered as one of the drivers of sphere development [24]. Health security capacities are under tremendous pressure now, and countries vary in terms of their capabilities to respond effectively to such outbreaks, as it was performed in numerous studies [2; 8; 13; 15; 17; 21] with particular attention to unprecedented opportunities for a transformational change [23] and innovations in health care [7; 22].

COVID-19 opened the sources of upcoming crises, such as failure of health care delivery, coordination, and low-quality treatment, and at the same time showed the directions for the positive transformations [4], innovations [20; 33], and paths of impact-investing in the healthcare [35], new possible legislation rules [1] and a new round of possible cross-country cooperation [3].

The number of papers in the field increased recently, and one of the studies performed the resilience analysis for 11 countries in the COVID-19 crises [11], offering recommendations for the improvements based on detailed, indicator-based resilience analysis and emerging risks. Some antecedents of the research performed by other scholars emphasized the vulnerability of certain regions [14]. Another study identified the financial, environmental, social, and economic determinants of regions' vulnerability to COVID-19 [17]. This is the same study that put the lights on antecedents of low readiness of the health care system to such challenges [17]. However, the strategizing of the decisions in response to COVID-19 remains an unexplored area for scholars and practitioners. Therefore, the current study is aimed to design the method for decision-making and choice of the policies in health care based on detailed, in-depth statistical analysis.

The main hypothesis is that some preconditions for higher mortality or morbidity caused by COVID-19 are formed as a complex of region-related specific types of diseases (profile). If this hypothesis is proved, then the profiles of the regions should be evaluated to make health care support targeted according to the morbidity profile to reduce possible threats in the future.

**Methodology.** The methodology part is a step-by-step algorithm which the authors tested for 25 regions.

Step 1. Initial data. To reveal the readiness of the regional health care system to fight against the COVID the hypotheses should be checked. The leading hypothesis is that morbidity by different types of diseases is an indicator of the development state of the regional health care system, and therefore identifies the readiness of each region to respond to challenges, such as the COVID pandemic.

The dependent variables are chosen to be the number of reported cases and deaths caused by COVID-19 in Ukraine from the beginning of the pandemic till 22<sup>nd</sup> of January, 2021 [19]. Nineteen factors are independent variables: data on the cases detected for the first time classified by classes (infectious diseases, neoplasms, blood, mental disorder, endocrine system, nervous system, eyes diseases, ears diseases, respiratory system diseases, digestion system diseases, skin diseases, musculoskeletal system diseases, genitourinary system diseases, pregnancy, perinatal period diseases, congenital diseases, and traumas. The data are retrieved from official open data sources [27].

Step 2. Determining the measures of central trends. Measures of central trends are applied to determine the average level of morbidity for each indicator, and to rank the regional data at three levels: high, medium and low. Using this breakdown enables to compile a retrospective profile of each region in terms of the readiness of health care facilities to meet the challenges. To reflect the results more accurately, the incidence rate is determined per 1 person by dividing the data by the number of available population as of January 1, 2020. The data are retrieved from official open data sources [28]. This allows to find the quartiles  $Q_1, Q_2, Q_3$  as follows (please see formulas (1) — (3):

$$\bar{y} = \frac{\sum x_i}{n} = Q_2; \quad (1)$$

$$Q_1 = \frac{\bar{y} + \min\{x_i\}}{2}; \quad (2)$$



$$Q_3 = \frac{\max\{x_i\} + \bar{y}}{2}, \quad (3)$$

where  $\bar{y}$  — the arithmetic mean of the level of the spatial series;  $x_i$  — the value of each indicator for  $i$  region;  $\max\{x_i\}$ ,  $\min\{x_i\}$  — the maximum and minimum value of the factor, respectively. If the morbidity rate per person in the region exceeds  $Q_3$ , then the region is assumed as a «high» level; if less than  $Q_1$  — then the region has a «medium» level, and in other cases — «average».

Step 3. Cluster analysis of the input array. Based on the previous step and the distribution of the number of levels, all regions of Ukraine are divided into 4 classes, depending on the state of vulnerability and readiness of the level of public health: «1», «2», «3» and «4». Group «1» includes such regions (oblasts) as: Dnipropetrovsk, Ivano-Frankivsk, Lviv, Odesa, Kharkiv regions, and Kyiv city. Group «2» means Rivne, Zakarpattia, Kyiv region, Zhytomyr, Khmelnytskyi, and Mykolayiv regions. Group «3»: Volyn, Chernivtsi, Cherkasy, Zaporizhia, Kirovohrad, Chernihiv and Kherson regions. And finally, group «4» contains Vinnytsia, Poltava, Sumy, Ternopil, Donetsk and Luhansk regions.

Step 4. Conducting correlation and regression analysis. The multiple linear regression is developed to identify the impact of each independent factor on regional indicators of pandemic vulnerability. A symmetric correlation matrix is designed to check the presence of the multicollinearity effect in the input data set. The analysis of pairwise correlation coefficients showed that there is indeed a close linear relationship both between the performance indicator and within the data set, independent variables. To build an adequate model, it is necessary to eliminate the linear dependence among independent indicators by removing variables.

Thus, the indicators that have the highest number of high, in absolute terms, correlation coefficients with other factors, and vice versa, the lowest values of correlation with dependent variables were removed from the study. The best multiple linear regression equation was constructed by the MNC method with the step-by-step exclusion of the least significant factors with 19 independent indicators. For the number of confirmed factors of those who were infected with COVID-19, the indicators of diseases of the eye, ear, respiratory system, skin, nervous system, musculoskeletal system, and symptoms detected during laboratory tests were the least significant. A multiple linear regression used for the remaining factors is:

$$y = -5,2x_1 + 2,35x_2 + 2,68x_3 - 0,46x_4 + 0,92x_5 - 0,25x_6 + 0,52x_7 - 0,93x_8 + 9,89x_9 - 13,61x_{10} + 0,24x_{11} + 4444,21, \quad (4)$$

where  $y$  — cases, or number of people infected with COVID-19;  $x_1$  — blood diseases;  $x_2$  — endocrine system diseases;  $x_3$  — mental disorders;  $x_4$  — cardiovascular diseases;  $x_5$  — ingestion diseases;  $x_6$  — bone and muscular diseases;  $x_7$  — diseases of genitourinary system;  $x_8$  — number of pregnancies and deliveries;  $x_9$  — number of disorders that appeared in the perinatal period;  $x_{10}$  — number of congenital anomalies;  $x_{11}$  — traumas (accidents) and poisoning.

The closeness of the relationship between the dependent variable and the indicators of the level of morbidity (by disease classes) in the region (4) were checked by sigma-limited parameterization. According to the analysis, the most significant variables are:  $x_1$  — blood diseases (that include diseases of blood-forming organs and certain disorders involving the immune mechanism);  $x_2$  — endocrine system diseases (including eating disorders, metabolic disorders);  $x_4$  — cardiovascular diseases;  $x_5$  — ingestion diseases;  $x_9$  — quantities of disorders that appeared in the perinatal period;  $x_{10}$  — number of congenital anomalies.

Elimination of the insignificant factors out of the model (4) allows putting the nonlinear multiple regression as follows:

$$y = c_0 + \sum_{i=1} (a_i x_i^2 + b_i x_i). \quad (5)$$

The critical values of each indicator are:

$$\frac{\partial y}{\partial x_i} = 2a_i x_i + b_i = 0$$

$$x_i = \frac{-b_i}{2a_i}. \quad (6)$$

If in the polynomial model (5) the coefficient  $a_i$  is for a positive variable, then the critical value is the minimum point, meaning that the independent variable decreases, and only after reaching this point, it increases, and vice versa, for the points of maximum (Tabl. 1–3).

Table 1

**Indicators, values, and extremum points**

Parameters	a	b	Critical value	
Endocrine system diseases, including eating disorders, metabolic disorders	-4,7E-05	2,696269	28836,25	Max
Blood diseases including diseases of blood-forming organs and certain disorders involving the immune mechanism	-7,6E-05	-1,17333	-7668,94	Max
Cardiovascular diseases	1,06E-06	0,010651	-5020,56	Min
Ingestion diseases	-7,8E-07	0,321404	206569,5	Max
Disorders that appeared in the perinatal period	-0,00046	12,88002	14120,39	Max
Congenital anomalies	0,003025	-22,2817	3682,752	Min

Table 2

**Multiple regression results for the number of infected COVID-19**

Parameter	Beta	Std.Err. - of Beta	B	Std.Err. - of B	t(13)	p-level
Intercept			4444,20	7110,33	0,62504	0,54276
Blood diseases including diseases of blood-forming organs and certain disorders involving the immune mechanism	-0,7584	0,21600	-5,204	1,482	-3,5111	0,00383
Endocrine system diseases, including eating disorders, metabolic disorders	0,66792	0,28429	2,345	0,998	2,34940	0,03526
Mental disorders	0,24850	0,18198	2,683	1,965	1,36554	0,19524
Cardiovascular diseases	-0,79027	0,34466	-0,460	0,200	-2,2928	0,03917
Ingestion diseases	0,91524	0,35998	0,915	0,360	2,54242	0,02454
Bone and muscular diseases	-0,3961	0,42394	-0,251	0,269	-0,9345	0,3670
Diseases of genitourinary system	1,17472	0,5789	0,518	0,255	2,02889	0,06346
Number of pregnancies and deliveries	-0,3113	0,2685	-0,934	0,806	-1,1594	0,26711
Disorders that appeared in the perinatal period	0,46383	0,18182	9,889	3,876	2,55095	0,02414
Number of congenital anomalies	-0,8510	0,28481	-13,606	4,553	-2,9880	0,01047
Traumas (accidents) and poisoning	0,42912	0,26662	0,243	0,151	1,60948	0,13151

Table 3

**Sigma-restricted parameterization, effective hypothesis decomposition**

Parameter	Degr. of - Freedom	Confirmed - SS	Confirmed - MS	Confirmed - F	Confirmed - p
Intercept	1	3,628205E+07	3,628205E+07	0,39067	0,542764
Blood diseases including diseases of blood-forming organs and certain disorders involving the immune mechanism	1	1,144923E+09	1,144923E+09	12,32804	0,003831
Endocrine system diseases, including eating disorders, metabolic disorders	1	5,126213E+08	5,126213E+08	5,51969	0,035265
Mental disorders	1	1,731765E+08	1,731765E+08	1,86469	0,195247
Cardiovascular diseases	1	4,882443E+08	4,882443E+08	5,25721	0,039174
Ingestion diseases	1	6,003113E+08	6,003113E+08	6,46389	0,024542
Bone and muscular diseases	1	8,110644E+07	8,110644E+07	0,87332	0,367073
Diseases of genitourinary system	1	3,822969E+08	3,822969E+08	4,11641	0,063463
Number of pregnancies and deliveries	1	1,248531E+08	1,248531E+08	1,34436	0,267119
Disorders that appeared in the perinatal period	1	6,043470E+08	6,043470E+08	6,50735	0,024149
Number of congenital anomalies	1	8,292212E+08	8,292212E+08	8,92870	0,010476
Traumas (accidents) and poisoning	1	2,405772E+08	2,405772E+08	2,59043	0,131515
Error	13	1,207329E+09	9,287146E+07		
Total	24	1,428375E+10			

For the variable that reflects the number of confirmed deaths caused by COVID-19, the relevant indicators are:

$$z = -0,016y_1 - 0,039y_2 + 0,03y_3 - 0,004y_4 + 0,003y_5 + 0,017y_6 - 0,004y_7 + 0,008y_8 - 0,013y_9 + 0,077y_{10} - 0,153y_{11} + 207,243, \tag{7}$$

where  $z$  — number of deaths caused by COVID;  $y_1$  — number of parasitic and infectious diseases;  $y_2$  — endocrine system diseases;  $y_3$  — mental disorders;  $y_4$  — eye diseases;  $y_5$  — diseases of the respiratory system;  $y_6$  — ingestion diseases;  $y_7$  — bone and muscular diseases and connective tissues;  $y_8$  — diseases of the genitourinary system;  $y_9$  — number of pregnancies;  $y_{10}$  — number of disorders that appeared in the perinatal period;  $y_{11}$  — number of congenital anomalies.

To test the significance of the multiple linear regression coefficients, sigma-limited parameterization was performed, which revealed the relationship between the number of confirmed deaths and responses from the model parameters. According to the results of the analysis, the significant variables are:  $y_1$  (number of parasitic and infectious diseases);  $y_2$  (endocrine system diseases);  $y_5$  (diseases of the respiratory system);  $y_6$  (ingestion diseases);  $y_{11}$  (number of congenital anomalies). Thus, these indicators will be taken into account as significant (*Tabl. 4–6*).

Table 4

**Sigma-restricted parameterization, effective hypothesis decomposition**

Indicator	a	b	Critical value	
Number of parasitic and infectious diseases	-1,1E-07	0,008781	40633,53	Max
Endocrine system diseases, including disorders of digesting, methabolisms disorder	-1E-06	0,011754	5765,836	Max
Diseases of the respiratory system	1,6E-09	-5,2E-05	16336,45	Min
Ingestion diseases	-4,5E-10	0,009936	11135072	Max
Number of congenital anomalies, including deformations and chromosomal abnormalities	1,04E-05	-0,15266	7320,421	Min

Table 5

**Multiple regression results for the number of confirmed deaths caused by COVID-19**

Indicator	Beta	Std.Err. - of Beta	B	Std.Err. - of B	t(13)	p-level
Intercept			207,24	117,843	1,75862	0,10214
Number of parasitic and infectious diseases	-0,7524	0,33718	-0,0163	0,0073	-2,2315	0,04387
Endocrine system diseases, including disorders of digesting, methabolisms disorder	-0,5434	0,22841	-0,0391	0,0164	-2,3790	0,03336
Mental disorders	0,1333	0,15813	0,0295	0,0350	0,84342	0,41424
Eye diseases	-0,276	0,3401	-0,0041	0,0050	-0,8113	0,4317
Diseases of the respiratory system	1,39727	0,29369	0,0025	0,0005	4,75752	0,00037
Ingestion diseases	0,82970	0,27725	0,0170	0,0057	2,99257	0,01038
Bone and muscular diseases and connective tissues	-0,2786	0,37214	-0,0036	0,0048	-0,7487	0,4673
Diseases of the genitourinary system	0,83226	0,46974	0,0075	0,0042	1,77175	0,09985
Pregnancies & deliveries	-0,2038	0,17418	-0,0125	0,0107	-1,1704	0,26284
Number of disorders that appeared in the perinatal period	0,17594	0,15723	0,0769	0,0687	1,11900	0,28339
Number of congenital anomalies, including deformations and chromosomal abnormalities	-0,4653	0,21296	-0,1525	0,0698	-2,1852	0,04777

Table 6

**Sigma-restricted parameterization, effective hypothesis decomposition**

Indicator	Deaths registered - SS	Deaths registered - MS	Deaths registered - F	Deaths registered - p
Intercept	58762	58761,6	3,09275	0,102143
Number of parasitic and infectious diseases	94613	94613,4	4,97971	0,043877
Endocrine system diseases, including disorders of digesting, methabolisms disorder	107539	107538,9	5,66000	0,033365
Mental disorders	13516	13515,6	0,71136	0,414244
Eye diseases	12506	12505,9	0,65821	0,431796
Diseases of the respiratory system	430042	430041,7	22,63401	0,000374
Ingestion diseases	170152	170151,8	8,95545	0,010386
Bone and muscular diseases and connective tissues	10650	10650,4	0,56056	0,467367
Diseases of the genitourinary system	59642	59642,5	3,13911	0,099859
Pregnancies & deliveries	26027	26026,8	1,36985	0,262847
Number of disorders that appeared in the perinatal period	23791	23790,8	1,25216	0,283390
Number of congenital anomalies, including deformations and chromosomal abnormalities	90733	90733,3	4,77549	0,047770
Error	246997	18999,8		
Total	5999487			

Step 5. Adequacy check of the model. That is accomplished with the help of Darbin-Watson's criterion (8):

$$DW = \frac{\sum(e_i - e_{i-1})^2}{\sum e_i^2}, \quad (8)$$

where  $DW$  — the value of the Darbin — Watson test;  $e_i$  — the difference between the empirical and the theoretical value accordingly. The calculated values for the obtained models (4) and (7) are 1.6 and 2.9, respectively. The value of the Dabrin — Watson test for the model hit the critical zone, and that allows to reject the hypothesis of the presence of autocorrelation in the model. For the second model, this value hit the blind spot.

The coefficients of determination of models (4) and (7) have values of 0.915 and 0.959, respectively, which confirms the presence of a close linear relationship. The Fisher test values for these models are 12.8 and 27.5, respectively, which is significantly higher than the critical value of 2.9 under the freedom degrees of 11 and 13, and under the significance level of 0.05.

It is important to define and interpret the results from Cook's distance (9), which indicates whether the input data are anomalous.

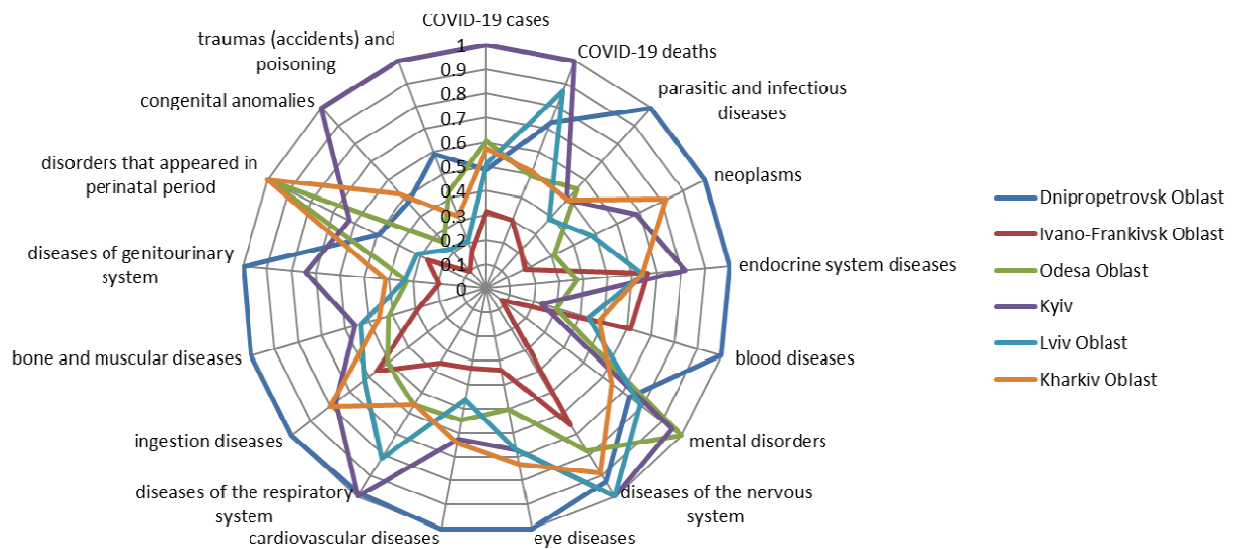
$$D_i = \frac{\sum_1^{25} (\hat{Y}_i - \hat{Y}_{i/j})^2}{7MSE}. \quad (9)$$

As a result of Cook's distance identification, the Kyiv and Dnipropetrovsk region data are proved to be anomalous and were eliminated from both models (4) and (7).

**Research results.** According to the results of cluster analysis, group «1» includes the following regions: Dnipropetrovsk, Ivano-Frankivsk, Lviv, Odessa, Kharkiv regions, and the Kyiv city. These regions (or oblasts by their name) have a high number of diseases at a high level, compared to other regions. Dnipropetrovsk region has the highest incidence rates of infectious and parasitic diseases, the cases of tumors, eye and ear diseases, circulatory and respiratory systems diseases, skin, musculoskeletal system, and genitourinary system morbidity per capita. The Dnipropetrovsk region is well-known as an industrial center, and as a result, it's ranked as TOP-2 biggest environmental pollutant while Kyiv is in the first place. Kyiv region has a huge number of operating industrial enterprises, and the relevant amount of incinerated waste, that even with a sufficiently high level of environmental costs, negatively affects public health. As a result, a big number of registered diseases of the respiratory system, genitourinary system, injuries, poisonings, and congenital anomalies are observed in the region. Kyiv city also ranks first in the number of diseases and deaths caused by COVID-19 in Ukraine. Ivano-Frankivsk region has high morbidity of such systems as blood, nervous system, eye, and ear systems, circulatory system, respiratory and



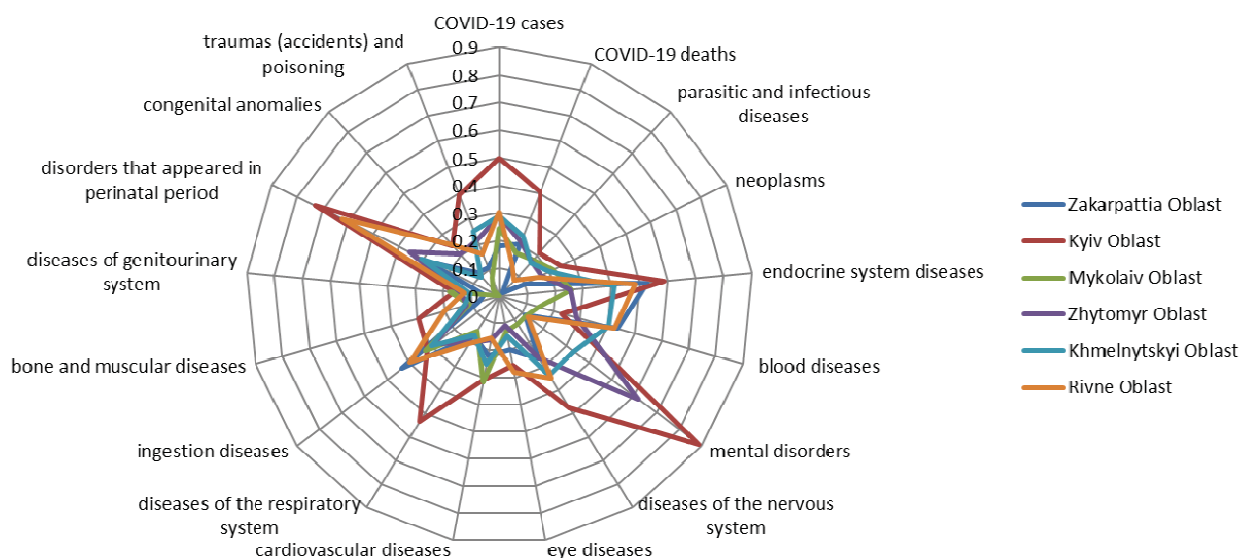
digestive organs, skin as well. Other classes of diseases, except for mental disorders, have an average level. This region is also one of the most polluted regions in the country (third in terms of carbon disulfide emissions). Lviv region has high morbidity rates of such classes as diseases of the nervous system, eyes, and ears, as well as respiratory organs. However, this region, in contrast to the above, has low levels of morbidity of poisoning cases and conditions that occur in the prenatal period. Odessa region has a high rate only for infectious and parasitic diseases, but other diseases are reaching a high level. Kharkiv region has a high level of eye and ear morbidity, the number of tumors. A common feature of all regions of group «1» is a relatively high level of morbidity, negative environmental situation, and, consequently, high or comparatively high level of morbidity and mortality caused by COVID-19 (Fig. 1).



**Fig. 1. Petal diagram of morbidity for group «1»**

Source: Constructed by authors.

Group 2 is presented in Fig. 2: Rivne, Zakarpattia, Kyiv region, Zhytomyr, Khmelnytskyi, and Mykolaiv regions.



**Fig. 2. Petal diagram of morbidity for group «2»**

Source: Constructed by authors.

Zhytomyr region has a high level of mental illness and disorders. Rivne region in this group is the leader in the number of types of diseases at a high level: diseases of the blood, eyes, digestive organs, the number of congenital anomalies. Zakarpattia has high levels of morbidity of blood and hematopoietic system and digestive system; these indicators are quite significant for the number of infected with coronavirus infection in 2019. Kyiv region is a leader among mental disorders, respiratory systems, and certain conditions diagnosed during laboratory tests. The Mykolayiv area has a high level of infectious diseases, neoplasms, and circulatory system diseases. Khmelnytskyi region is a leader among diseases of the blood and blood-forming organs.

Group 3 is presented in Fig. 3 and consists of Volyn, Chernivtsi, Cherkasy, Zaporizhia, Kirovohrad, Chernihiv and Kherson regions. This group’s main feature is the low number of morbidity at a high level, but the medium level of the diseases is presented, and some of the statistics data are very close to being high. Volyn region has a large number of respiratory diseases and certain conditions that occur during the perinatal period. Zaporizhia region is characterized by the absence of «high» level morbidity, but some diseases are close to being high, such as infectious diseases, tumors, respiratory diseases, and certain conditions that occur in the perinatal period. Kirovohrad region is a leader among the number of registered neoplasms and the number of congenital anomalies. Kherson and Cherkasy regions are leaders in the number of neoplasms, but Cherkasy region also has a high level of eye diseases. Chernivtsi region is a unique region according to the data analysis because it has a high level of vulnerability to COVID-19, with the overall previous incidence is average, on the contrary, the number of congenital anomalies and the number of injuries is almost exemplary in Ukraine. Chernihiv region has high rates of respiratory and eye diseases.

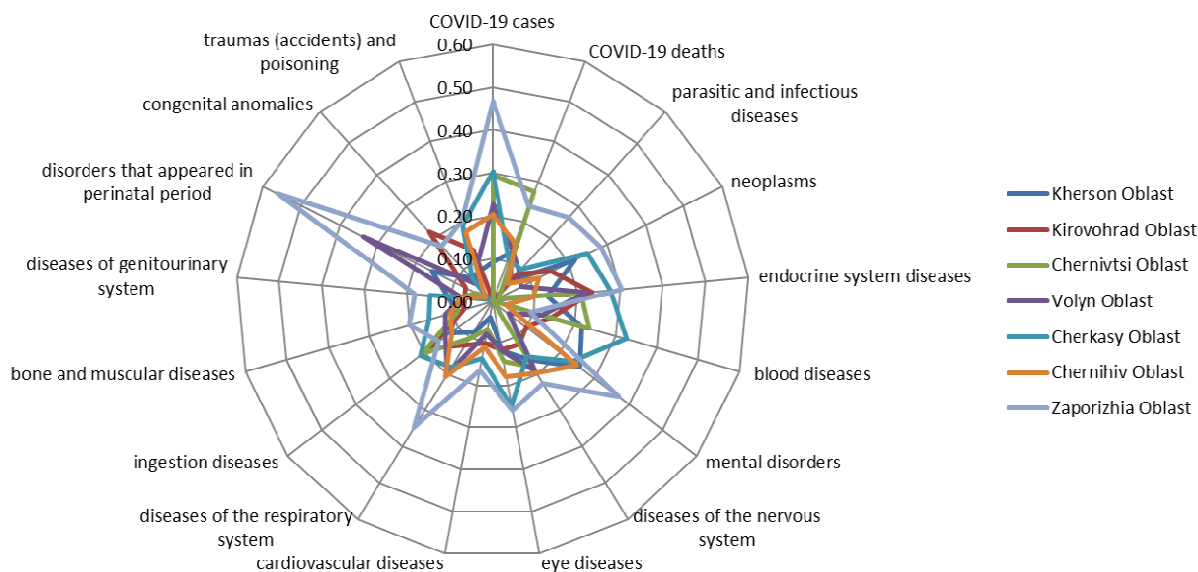
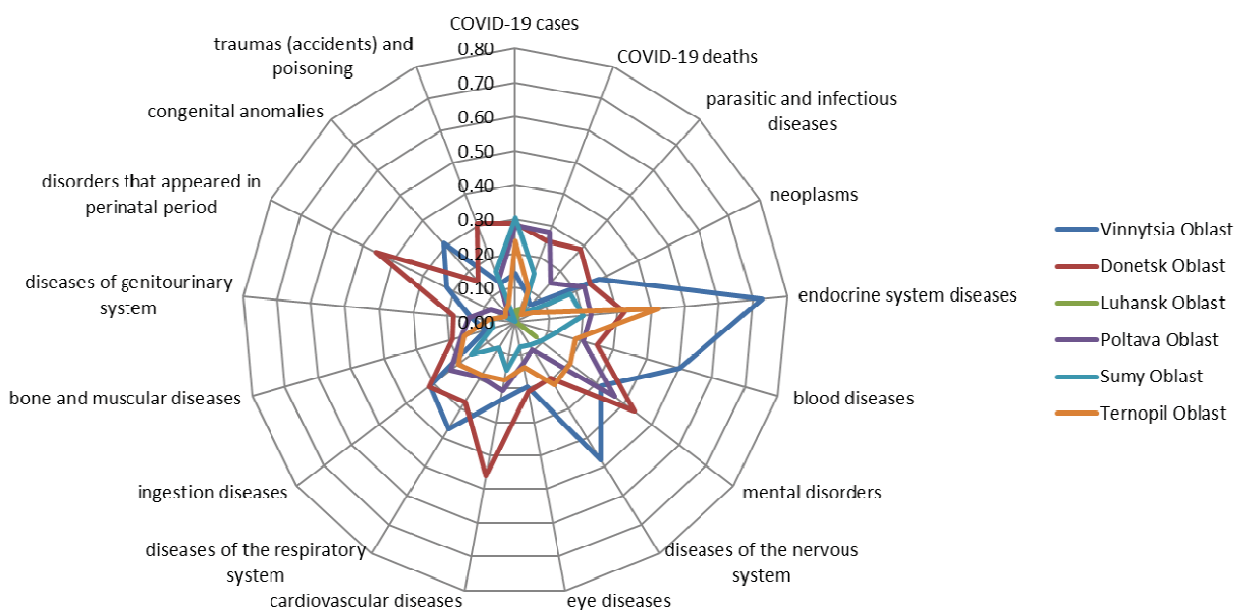


Fig. 3. Petal diagram of morbidity for group «3»

Source: Constructed by authors.

Group 4 analysis is performed in Fig. 4, with the details for Vinnytsia, Poltava, Sumy, Ternopil, Donetsk, and Luhansk regions. This group’s common characteristic is the absence of high levels in the number of registered cases by disease classes. The group includes Luhansk and Donetsk regions, which the Ukrainian government does not control, so the statistical information may not fully reflect reality.



**Fig. 4. Petal diagram of morbidity for group «4»**

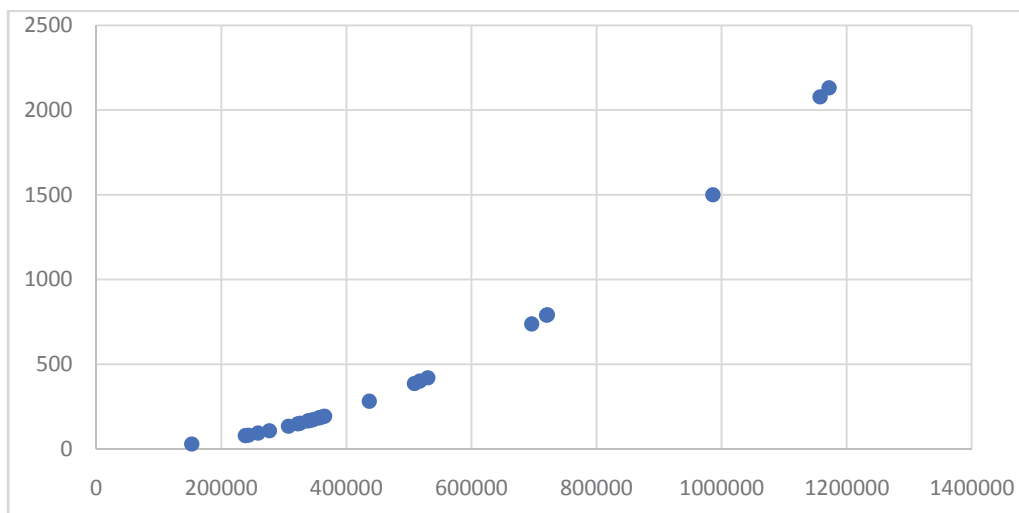
Source: Constructed by authors.

The profile analysis of the regions was done by revealing the critical value of certain types of diseases that impacts the COVID-19 cases and COVID-19 deaths. The main thought is that regions are different in terms of their vulnerability to a pandemic situation. Some regions have more chances to have morbidity and at the same time more chances to have a high recovery rate, while regions with another specificity may have fewer numbers in cases and higher mortality rate due to COVID-19 because of certain diseases profile. The disease profiles (Please see appendix A) were created for 25 regions as a testing of the method offered in the study. That may become a pilot for profiling the regions of similar type in terms of density, mortality, and morbidity rates to check the readiness to respond to COVID (or similar infections) in the future.

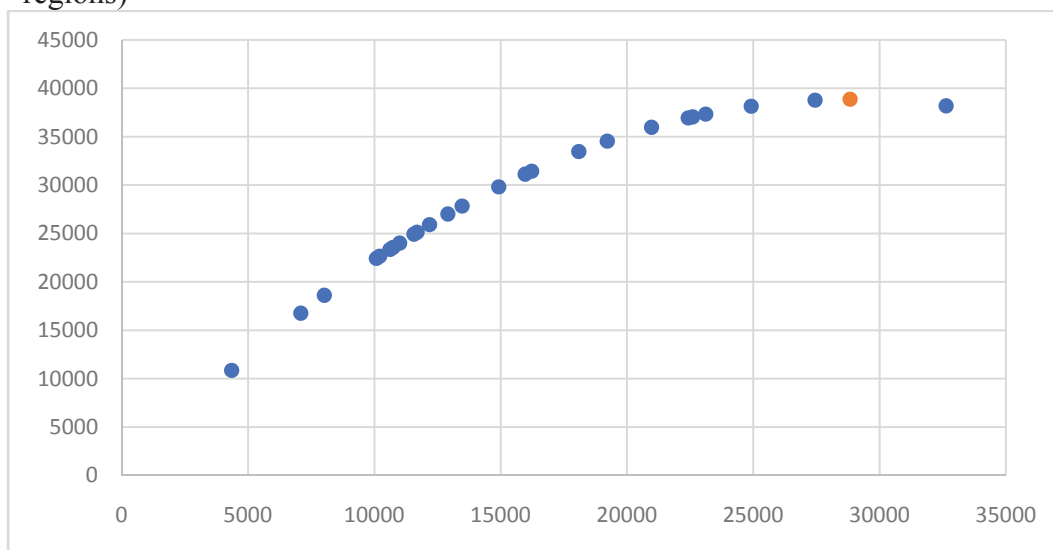
In *Fig. 5 (a and b)*, the fragments of the data processing are presented that show a clear dependence between types of diseases that were dominant in the region due to its specificity (a type of industries, environmental pollution, and so on) and mortality/morbidity due to COVID-19.

The results of matching the data of mortality, morbidity caused by COVID-19, types of diseases, and revealed dependences allowed to improve the methodology of prioritization in health care policy for further financing and budgeting.

Strategic decisions can be made using the offered Policy Identification Matrix that is presented in *Table 7* in a simplified way, and outcomes of it are shown in Appendix A for 25 regions (see Appendix). This method allows identifying the budgeting directions under limited resources, or in other words, to identify the most vulnerable spheres for further budgeting via target programs to increase the system's readiness to respond the challenges such as COVID-19. The logic is simple: the higher value and evaluation is, then that region has more priority to be financed targeting the certain type of disease related to the COVID-related mortality/morbidity.



a) the dependence between the deaths due to COVID-19 and respiratory diseases (25 regions)



b) the dependence between registered cases of COVID-19 and endocrine diseases (25 regions)

Fig. 5. The fragment of the regions' profiling (the dependence identification between disease profile and mortality / morbidity due to COVID-19)

Table 7

**Policy Identification Matrix (PIM) adjusted for health care, with a fragment of demonstration of the research outcomes**

Diseases	Type of diseases		
	Registered cases	Value*	Evaluation*
Regions / countries			
Country 1 / region 1			
Country 2 / region 2			
Country 3 / region 3			
...			
...			
Country N / region n			

Diseases	Endocrine diseases		
	Registered cases	V	E
Oblasts			
Winnytsya	24918	1	H
Volyn	10619	1	

\* where V — value that shows if it is critical, close to critical, or else in terms of dependence between mortality/morbidity caused by COVID-19 (1, 2, 3) and E — an evaluation using statistical data (high, middle, low).

Source: constructed by authors.



As we see from Appendix A, matching data in offered matrix gave some insights on further directions of the targeted budgeting: for instance, number 1 priorities are programs in a sphere of screening, prevention, and mitigation of endocrine diseases for Vinnytsya; disorders that appeared in the perinatal period — for Rivne oblasts, congenital anomalies — for Kyiv city and respiratory system diseases — for Dnipropetrovsk, Luhansk, and Kyiv.

**Conclusions.** The paper analyzed the correlation between mortality/morbidity caused by COVID-19 and the antecedents of regions' vulnerability to respond to the pandemic. This study revealed a strong correlation between certain diseases dominant in a particular region and COVID-19 outcomes. That makes one region more vulnerable than others in terms of mortality and recovery rates. It was revealed that there is an urgent need to identify the regional system's readiness to respond effectively to the current crisis and emerging risks. The step-by-step method is offered in this study that can be replicated for other regions and countries to reveal the most vulnerable spheres (disease types / region profile) that need special attention. The method may be implemented as a monitoring tool and argument for the targeted budgeting programs in health care. However, there should not be a reallocation of the resources between oblasts unless the mortality rates increase significantly; the decision is offered for resources reallocation between targeted programs by switching the budgets to the disease types that increase vulnerability to COVID-19.

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Статтю рекомендовано до друку 05.04.2021

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The article is recommended for printing 05.04.2021

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