Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 192 (2021) 4037–4046

Procedia Computer Science

www.elsevier.com/locate/procedia

25th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems

Impact of the healthcare potential in the European countries on infections and mortality caused by Covid-19

Mariusz Borawski[a], Jarosław Duda[b], Konrad Biercewicz[c]*

[a]Prof., University of Szczecin, al. Papieża Jana Pawła II 22a, 70-453 Szczecin, Polnad
[b]PhD, University of Szczecin, al. Papieża Jana Pawła II 22a, 70-453 Szczecin, Polnad
[c]MSc, University of Szczecin, al. Papieża Jana Pawła II 22a, 70-453 Szczecin, Polnad

---

Abstract

The COVID-19 outbreak posed several challenges to healthcare professionals in treating patients: limiting the spread of infection; develop appropriate short-term strategies; and formulating long-term plans. Each of the affected countries had specific capacities before the outbreak began. This potential may have helped reduce the spread of the disease and should help reduce its impact. This paper uses the VMCM method to determine the capacity of health services in European countries. It allowed for a ranking of countries in terms of this potential. This allows the capacity of the health service to be related to the number of infected and deceased people. The purpose of this article is to examine the relationship of infections and mortality on COVID-19 to health care capacity.

Keywords: COVID-19; VMCM; healthcare

---

* Corresponding author.
E-mail address: konrad.biercewicz@usz.edu.pl

10.1016/j.procs.2021.09.178

1. Introduction

The COVID-19 pandemic poses a challenge to healthcare across the entire globe. It is important to what extent its potential, i.e. the forces and resources it has, can help cope with the pandemic. If the impact of the potential to counteract the pandemic was significant, it would serve as the basis to look at the countries with the highest potential in order to determine what factors have facilitated the healthcare service to act.

Before COVID-19, Europe had a strong drive for access to high-quality services and financial protection, and most countries in the region is legally entitled to health insurance [1]. However, the evidence shows that some Europeans feel as if they cannot access care [2]. In some European countries, such as Bulgaria, Croatia, Latvia, Poland, Romania and Sweden, people without access to care represent more than 10% of the population [3]. Determining why people do not have access to healthcare services can be difficult, especially if they are legally entitled to use healthcare [3]. Gaps in the access to healthcare in countries with universal coverage can result from a number of reasons, such as financial barriers, i.e. user charges or informal payments, or non-financial barriers such as waiting times, exclusions from services, or poor quality of care.

The appearance of the virus in the world has made the pandemic something new [4], therefore, the fact how the health service is doing may not necessarily depend on its potential but on other factors, such as, for example, the preparation of staff to deal with difficult situations. Mental stress [5] and general well-being of health care workers have gained increased awareness, and the research continues to show high rates of burnout [6], mental stress, and suicide [7].

The COVID-19 pandemic has been a challenge [8] while in many cases it has exceeded the capacity of hospitals and intensive care units worldwide [9,10]. Healthcare employees care for patients despite exhaustion [11], personal risk of infection [12], fear of transmission to family members [13,14], illness or death of friends and colleagues, and the loss of many patients. Unfortunately, healthcare employees have also faced many additional - often avoidable - sources of stress [15]and anxiety [16], and long working hours [17,18] and shifts [19,20], combined with unprecedent population constraints, including personal isolation, have affected people's coping ability [21].

Insufficient resources and the lack of specific treatments for COVID-19 have increased the challenges of treating severely ill patients [22,23]. Healthcare employees had to take care for sick colleagues, provide comfort to dying patients who were isolated from their loved ones, and remotely inform and console family members of the patients. Some healthcare employees were burdened with emotional and ethical decisions about rationing resources and withholding CPR or admission to the ICU. They shared the pain of non-COVID-19 patients whose surgery or other necessary treatments have been cancelled or postponed [24].

The purpose of this article is to investigate the relationship between infections and COVID-19 mortality on the healthcare potential.

2. Materials and Methods

The research used the VMCM method (Vector Measure Construction Method), which enables to rank objects on the basis of selected diagnostic variables [25]. As part of the ranking procedure, a pattern and anti-pattern are determined, against which the positions of the compared objects are determined. It consists of 8 stages:

Stage 1. Selection of diagnostic variables.
Stage 2. Elimination of variables.
Stage 3. Defining the diagnostic variables character.
Stage 4. Assigning weights to diagnostic variables.
Stage 5. Normalisation of variables.
Stage 6. Determination of pattern and anti-pattern.
Stage 7. Building the synthetic measure.
Stage 8. Classification of objects.

Stage 1. Selection of diagnostic variables

At this stage, variables are selected on the basis of which the ranking of objects is made. The variables should properly characterise the objects so that the ranking took place in the manner specified by the researcher. The principles of selecting diagnostic variables are widely presented in the literature [26]. The determining factors in selecting variables often include data availability. After the set of diagnostic variables is determined, an observation matrix is created $O[n \times m]$, where n refers to the number of objects and m refers to the number of diafgnostic variables.

When performing calculations in the vector space, objects are represented by vectors, and variables can be treated as their coordinates ($\underset{j}{x_i}$). j is the designation of the vector number and i is the designation of the variable.

Stage 2. Elimination of variables

Not all variables can be used in the ranking process. There are a number of methods to eliminate these kinds of variables. For the variables, the significance factor of features can be determined [27]:

$$V_i = \frac{\sigma_i}{\bar{x}_i}, \tag{1}$$

where $\bar{x}_i$ is the mean value, and σ_i is a standard deviation i-th diagnostic variable.

This coefficient shows the variability of the value of a given variable. Too low value of this coefficient may mean that the variable values for a given object are very low, which means that they do not differentiate objects sufficiently. Low differences may be due to a random factor, for example, due to a different measurement time of the variable. As a result, the differences between the values of the variables become insignificant. During normalisation, the variability of all variables is equalised to a more or less similar level. As a result, the random factor for low-variable variables may significantly affect the ranking results. To eliminate this problem, a certain threshold is assumed. If V_i for a given variable is below this threshold, this variable is eliminated. In the literature [27,28] the value of this threshold is determined at the level of 0.1.

Stage 3. Defining the diagnostic variables character

Variables can influence the ranking of an object in various ways. For some variables it is desirable to have the highest values possible, for others the lowest. For example, when ranking of electric cars is created, it is desirable that their range is the largest and the price is as low as possible. Variables the values of which are as high as possible are called stimulants, and those for which the lowest values are desired are called destimulants. Sometimes it happens that specific variable values or a certain range of them are desired. Such variables are called nominants. An example would be the number of seats in a car. As a rule, the client expects 4 or 5 seats in a passenger car. Both greater and smaller values are less desirable. The VMCM method does not allow the use of nominants. However, there are methods that enable to change nominants into stimulants.

Stage 4. Assigning weights to diagnostic variables

Some of the variables may be much more important than others, in the opinion of those performing the ranking. An example would be the price when buying a car. This variable is often the most important determining factor in the selection of a car. This can be accounted for by the weights given to the diagnostic variables. Each variable can be assigned a number determining its importance; the greater this number, the greater the importance of the variable. This can be done, for example, using a point system, assigning values from 1 to 10, where one is a low-importance variable and ten is a very important variable. The values assigned to the variables are normalised to obtain the weights:

$$w_i = \frac{v_i}{\sum_{i=1}^{m} v_i}, \tag{2}$$

where v_i are point values assigned to individual variables.

After the normalisation, the sum of the weights is equal to one:

$$\sum_{i=1}^{m} w_i = 1, \tag{3}$$

Stage 5. Normalisation of variables

Diagnostic variables can have different units of measure and different ranges of values. Using them in this form would mean that variables with higher absolute values would have a greater impact on the result of the ranking than those with lower values. If the variables have different measure units, and in some cases also different ranges of values, the variables should be normalised. An example of a normalisation method is standardization:

$$\underset{j}{x'_i} = \frac{\underset{j}{x_i} - \bar{x}_i}{\sigma_i}. \tag{4}$$

Stage 6. Determination of pattern and anti-pattern

VMCM-based ranking requires specification of the pattern object and the anti-pattern object. The pattern object should have relatively high values of the variables, and the anti-pattern object - relatively low. The pattern object and the anti-pattern object can be real objects, but most often they are synthetic objects, in which the values of the variables are determined on the basis of the variable values of all objects participating in the ranking procedure. In the VMCM method, they are determined on the basis of the first and third quartil:

$$\underset{w}{x'_i} = \begin{cases} \underset{\mathrm{q_{III}}}{x'_i} & \text{dla stymulant} \\ \underset{\mathrm{q_I}}{x'_i} & \text{dla destymulant} \end{cases}, \tag{5}$$

where $\underset{w}{x'_i}$ is the value of *i*-th normalised variable for the pattern, $\underset{\mathrm{q_I}}{x'_i}$ - the value of *i*-th normalised variable for the first quartil, and $\underset{\mathrm{q_{III}}}{x'_i}$ - the value of *i*-th normalised variable for the third quartil.

$$\underset{aw}{x'_i} = \begin{cases} \underset{\mathrm{q_I}}{x'_i} & \text{dla stymulant} \\ \underset{\mathrm{q_{III}}}{x'_i} & \text{dla destymulant} \end{cases}, \tag{6}$$

where $\underset{aw}{x'_i}$ is the value of *i*-th normalized variable for anti-pattern.

Stage 7. Building the synthetic measure

The measure values are calculated based on the one-dimensional coordinate system. Fig. 1 shows a graphical interpretation of the determination of the measure value. The pattern and anti-pattern vectors define two points in space through which the line passes on which the axis of the coordinate system lies. This axis is the vector being the difference between the pattern-vector and anti-pattern-vector. The length of this vector is the unit of measure in this coordinate system. If the measured length is equal to the length of this vector, then in this coordinate system it is equal to one. The coordinates in the one-dimensional coordinate system can be determined based on the formula [28,29]:

$$c = \frac{(A,B)}{(B,B)}. \tag{7}$$

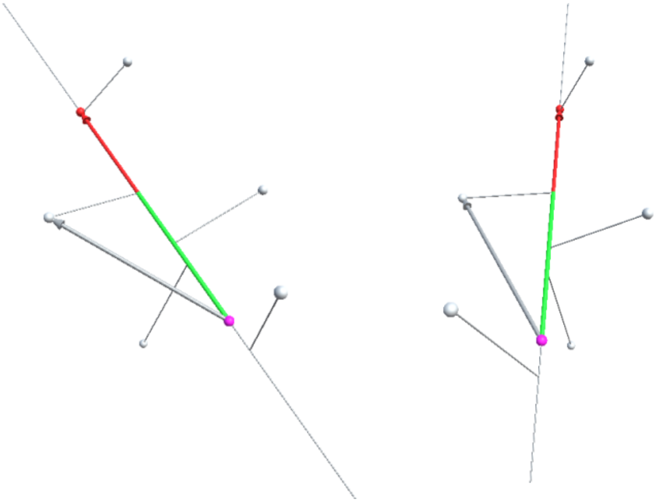

Fig. 1. Graphical interpretation of the determination of the measure value presented in different ways.

c is the component of vector A along vector B, where vector B can be identified with one-dimensional coordinate system, c with the coordinate of vector A in this system. (A,B) is a scalar product:

$$(A,B) = \sum_{k=1}^{n} a_k b_k \,. \tag{8}$$

where a_k and b_k are coordinated of A and B vectors.

The point set by the anti-pattern is assumed as the origin of the coordinate system. Therefore, before the component is determined, the anti-pattern vector is subtracted from each vector for which the value of the measure is determined. The formula for determining the value of the measure is obtained in this way [28,29]:

$$m_{a_j} = \frac{\sum_{i=1}^{m}\left(x'_{i_j} - x'_{i_{aw}}\right)\left(x'_{i_w} - x'_{i_{aw}}\right)}{\sum_{i=1}^{m}\left(x'_{i_w} - x'_{i_{aw}}\right)^2}. \tag{9}$$

m_{a_j} is coordinate of the object in one-dimensional coordinate system, the origin of which is determined by the anti-pattern vector, the direction is determined by the vector being the difference between the pattern vector and the anti-pattern vector. The unit of measure is the length of this vector. Due to the fact that m_{a_j} is the coordinate, it can also have negative values.

Stage 8. Classification of objects

For easier analysis of the results and for some visualisation of the results, objects can be classified based on the measure value. The division into four classes is used quite often [25]:

$$\begin{cases} 1 \quad \text{for} \quad m_{s_j} \in \left\langle \overline{m}_{m_{s0}} + \sigma_{m_{s0}};\ \infty \right), \\ 2 \quad \text{for} \quad m_{s_j} \in \left\langle \overline{m}_{m_{s0}};\ \overline{m}_{m_{s0}} + \sigma_{m_{s0}} \right), \\ 3 \quad \text{for} \quad m_{s_j} \in \left\langle \overline{m}_{m_{s0}} - \sigma_{m_{s0}};\ \overline{m}_{m_{s0}} \right), \\ 4 \quad \text{for} \quad m_{s_j} \in \left(-\infty;\ \overline{m}_{m_{s0}} - \sigma_{m_{s0}} \right). \end{cases} \tag{10}$$

3. Results

To determine the potential of the health service, the research used the data from Eurostat for 2018 concerning Health care expenditure by provider, Hospital beds by type of care (Germany, data for 2017), Medical technology MRI (Germany – 2017, Great Britain – 2014), Medical technology Tomography (Germany – 2017, Great Britain – 2014), Physicians by sex and age (Luxembourg, Poland – 2017), Technical resources in hospital (Hungary – 2012, Great Britain 2016), Population on 1 January. The data for 24 European countries were collected (the countries for which the data were not available were omitted. Based on the data, six indicators were created: X_1 - Health care expenditure per 10 000 people, X_2 - Hospital beds per 10 000 people, X_3 – The number of MRI per 10 000 people X_4 – the number of Tomography per 10 000 people X_5 – the number of Physicians per 10 000 people X_6 - Operation theatres in hospital per 10 000 people. The results obtained are presented in table 1. The table also presents calculations of the values of measure. When calculating, it was assumed that the weights for all variables are identical.

Table 1. The measure values and comparative data (source: own calculations, Eurostat and [30])

Country	Measure	Classes	Visits to doctors [%]	2020			2021		
				Case	Deaths	Deaths/Case	Case	Deaths	Deaths/Case
Germany	1.52	1	87.1	212.64	4.08	172.44	169.90	5.62	157.63
Austria	1.35	1	86.2	408.98	7.05	302.06	266.06	4.19	139.42
Greece	1.03	1	76.7	129.27	4.50	374.56	165.74	4.38	420.05
Bulgaria	0.77	2	73.5	286.90	10.75	54.04	264.61	11.11	49.91
Italy	0.70	2	80.9	348.38	12.26	161.13	292.94	7.12	191.75
Belgium	0.66	2	84.2	567.17	17.13	191.94	267.69	3.73	331.02
France	0.60	2	89.7	399.50	9.66	81.81	399.78	5.46	97.00
Lithuania	0.57	2	76.4	505.38	6.39	348.43	328.52	7.03	264.11
Luxembourg	0.55	2	86.9	771.01	8.22	263.64	311.11	4.83	175.09

Latvia	0.52	2	77	211.46	3.28	241.85	365.14	7.35	136.51
Cyprus	0.52	2	65.1	254.78	1.38	185.93	405.70	2.02	275.36
Ireland	0.48	3	75.2	190.00	4.63	295.71	314.95	5.38	367.89
Czechia	0.42	3	85.5	677.34	10.91	243.74	833.22	15.98	170.84
Netherlands	0.40	3	75.5	470.51	6.71	351.94	365.06	3.27	243.16
Malta	0.35	3	79.9	268.53	4.60	126.52	362.66	3.99	213.92
Spain	0.29	3	84.5	413.27	10.90	106.65	321.50	5.63	155.37
Slovakia	0.24	3	74.9	329.85	3.93	155.24	361.05	16.60	201.18
Croatia	0.24	3	75.8	513.55	9.55	171.44	237.15	6.53	110.13
Estonia	0.21	3	75.7	212.18	1.74	142.57	680.69	6.60	89.68
Romania	0.18	3	46.1	323.68	8.07	220.51	204.17	5.43	239.77
Slovenia	0.15	3	71.7	591.00	13.05	249.37	532.97	7.11	266.14
Hungary	0.13	3	84.5	329.82	9.75	220.79	440.44	16.20	133.44
Poland	0.13	4	81.2	340.97	7.52	119.08	368.77	8.84	459.69
United Kingdom	-0.02	4	75.5	376.66	11.11	294.93	288.18	8.13	282.23

For the value of measure obtained and visits to doctors, correlation with the number of infected and deceased persons was calculated. The results are presented in table 2.

Table 2. Correlation between the value of measure and visits to doctors, and the number of infected and deceased persons

Correlation	Visits to doctors	2020			2021		
		Case	Deaths	Deaths/Case	Case	Deaths	Deaths/Case
Measure	0.349146	-0.19439	-0.15766	0.13236	-0.40408	-0.31536	-0.10958
Visits to doctors	1	0.259539	0.211936	-0.11562	0.142843	0.129805	-0.19517

4. Discussion

Fig. 2 shows a comparison of the health care potential for the analysed European countries. The countries have been divided into four classes, where the first class denotes countries with the greatest potential, and the fourth class denotes the countries with the lowest potential. High potential means that countries have a lot of doctors, hospital beds, specialist equipment, etc. The countries with the lowest potential turned out to be Great Britain and Poland. The figure shows that the countries of Central Europe, such as Germany or Austria, have higher potential, and the countries of Eastern Europe have lower potential. Poland is the weakest country in Eastern Europe.

The value of the measure determining the potential showed the highest correlation in terms of the absolute value with the number of infected people in 2021. Most likely, however, there is no strong cause-and-effect relationship. The vaccinated people may play a role in the indicators in 2021, reducing the number of infected and deceased people. The proportion of vaccinated people in the death rate per 10,000 of the infected should be lower as they are less likely to become infected. The correlation of the value of the measure with this indicator is minor. Therefore, it can be concluded that the influence of the potential on the number of infected and deceased people is insignificant. The correlation with the number of infected and deceased people may result most probably from the better financial condition of the countries with higher potential, which translated into the effectiveness of fighting the epidemic, including faster purchase of more vaccines.

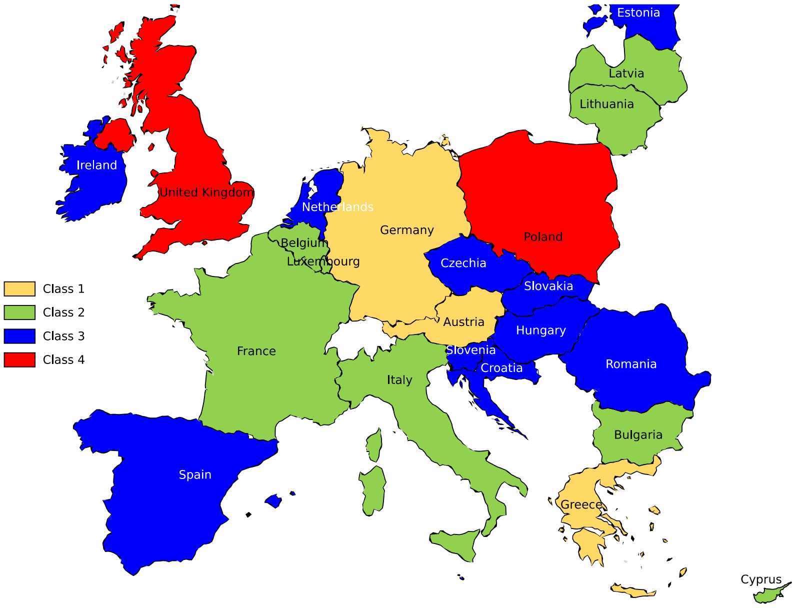

Fig. 2. Comparison of the health service potential in the European countries

It should be remembered that the correlation is calculated with the total number of infected and deceased people in the entire year 2020 and early 2021. The values of the correlation could be completely different if only data from the peak incidence period were considered. Health service potential could then play a greater role as it would not be able to treat all patients properly in countries with lower potential. A different result could probably also be obtained by analysing countries around the world. The research would then involve countries where the potential of the health service is so low that it does not provide basic services to all citizens.

The highest values of correlation with the number of visits to a doctor were obtained for infections in 2020 and it is a positive correlation, which means that the more patients used to see a doctor, the greater the number of the infected. The value of the correlation in this case was not high enough to make an unambiguous conclusion in this case. The value of this correlation dropped significantly in 2021.

4. Conclusions

The study conducted did not show a direct relationship between the health service potential and the number of infected and deceased people. Although the correlation of the value of measure with the number of infected and deceased persons could indicate such a relationship, the correlation with the number of deaths per 10,000 of the infected indicates that this is a result of the dependence of the examined variables on some other factor that is not described by the data used in the article. It may be suspected that such correlation would occur in critical cases, when the number of infected people was very large. Such situations in most countries were too short-lived for this to affect the correlation with the aggregate data.

References

[1] Stuckler, David, Feigl, Andrea B, Basu, Sanjay and Martin Mckee (2010). "The political economy of universal health coverage". *Background paper for the global symposium on health systems research*. Technical Report. WHO, Geneva. https://researchonline.lshtm.ac.uk/id/eprint/2157

[2] Allin, Sara, Grignon, Michel and Julian Le Grand (2010). "Subjective unmet need and utilization of health care services in Canada: What are

the equity implications?" *Social Science & Medicine* **70(3)**: 465–472. https://doi.org/10.1016/j.socscimed.2009.10.027

[3] Cylus, Jonathan and Irene Papanicolas (2015). "An analysis of perceived access to health care in Europe: How universal is universal coverage?" *Health Policy* **119(9)**: 1133–1144. https://doi.org/10.1016/j.healthpol.2015.07.004

[4] Cucinotta, Domenico and Maurizio Vanelli (2020). "WHO Declares COVID-19 a Pandemic" *Acta Bio-Medica : Atenei Parmensis* **91(1):** 157–160. https://doi.org/10.23750/abm.v91i1.9397

[5] Demerouti, Evangelia, Bakker, Arnold B., de Jonge, Jan, Janssen, Peter P. and Wilmar B. Schaufeli (2001). "Burnout and engagement at work as a function of demands and control." *Scandinavian Journal of Work, Environment & Health* **4**: 279–286. https://doi.org/10.5271/sjweh.615

[6] Chemali, Z., Ezzeddine, F. L., Gelaye, B., Dossett, M. L., Salameh, J., Bizri, M., Dubale, B., & Fricchione, G. (2019). "Burnout among healthcare providers in the complex environment of the Middle East: A systematic review." *BMC Public Health* **19(1):** 1337. https://doi.org/10.1186/s12889-019-7713-1

[7] Santarone, Kristen, McKenney, Mark and Adel Elkbuli (2020). "Preserving mental health and resilience in frontline healthcare workers during COVID-19." *The American Journal of Emergency Medicine* ***38*(7)**: 1530–1531. PubMed. https://doi.org/10.1016/j.ajem.2020.04.030

[8] Jiang, Li, Broome, Marion E. and Chuanyi Ning (2020). "The performance and professionalism of nurses in the fight against the new outbreak of COVID-19 epidemic is laudable." *International Journal of Nursing Studies* **107**, 103578. https://doi.org/10.1016/j.ijnurstu.2020.103578

[9] Arabi, Yaseen M., Murthy, Srinivas and Steve Webb (2020). "COVID-19: A novel coronavirus and a novel challenge for critical care." *Intensive Care Medicine* **46(5)**: 833–836. https://doi.org/10.1007/s00134-020-05955-1

[10] Xie, Jianfeng, Tong, Zhaohui, Guan, Xiangdong, Du, Bin, Qiu, Haibo and Arthur S. Slutsky(2020). "Critical care crisis and some recommendations during the COVID-19 epidemic in China." *Intensive Care Medicine* **46(5)**: 837–840. https://doi.org/10.1007/s00134-020-05979-7

[11] Lam, Stanley Kam Ki, Kwong, Enid Wai Yung, Hung, Maria Shuk Yu and Wai Tong Chien (2020). "Emergency nurses' perceptions regarding the risks appraisal of the threat of the emerging infectious disease situation in emergency departments." *International Journal of Qualitative Studies on Health and Well-Being* **15(1):** e1718468. https://doi.org/10.1080/17482631.2020.1718468

[12] Lansbury, Louise, Lim, Benjamin, Baskaran, Vadsala and Wei Shen Lim (2020). "Co-infections in people with COVID-19: A systematic review and meta-analysis." *Journal of Infection* **81(2):** 266–275. https://doi.org/10.1016/j.jinf.2020.05.046

[13] Lancet, The (2020). "COVID-19: Protecting health-care workers." *Lancet (London, England)* **395(10228)**: 922. https://doi.org/10.1016/S0140-6736(20)30644-9

[14] *Coronavirus: Remembering 100 NHS and healthcare workers who have died—BBC News*. (n.d.). Retrieved May 20, 2021, from https://www.bbc.com/news/health-52242856

[15] Li, Yulan, Tokura, H., Guo, Y. P., Wong, A. S. W., Wong, T., Chung, J., & Newton, E. (2005). "Effects of wearing N95 and surgical facemasks on heart rate, thermal stress and subjective sensations." *International Archives of Occupational and Environmental Health* **78(6)**: 501–509. https://doi.org/10.1007/s00420-004-0584-4

[16] Liao, Changju, Guo, Linghong, Zhang, Cuicui, Zhang, Meiqi, Jiang, Wenjing, Zhong, Ying, Lin, Qingfang and Yin Liu (2021). "Emergency stress management among nurses: A lesson from the COVID-19 outbreak in China–a cross-sectional study." *Journal of Clinical Nursing* **30(3–4)**: 433–442. https://doi.org/10.1111/jocn.15553

[17] Li, Jian, Fu, Hua, Hu, Yan, Shang, Li, Wu, Yinghui, Kristensen, Tage Søndergård, Mueller, Bernd Hans and Hans Martin Hasselhorn (2009). "Psychosocial work environment and intention to leave the nursing profession: Results from the longitudinal Chinese NEXT study." *Scandinavian Journal of Public Health* **38(3_suppl)**: 69–80. https://doi.org/10.1177/1403494809354361

[18] Peñaloza, Blanca, Rada, Gabriel, Pantoja, Tomás, Bastias, Gabriel and Cristian Herrera (2009). "Interventions for controlling emigration of health professionals from low and middle-income countries." *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD007673

[19] Lockley, Steven W., Barger, Laura K., Ayas, Najib T., Rothschild, Jeffrey M., Czeisler, Charles A. amd Christopher Landrigan (2007). "Effects of health care provider work hours and sleep deprivation on safety and performance." *Joint Commission Journal on Quality and Patient Safety* **33(11 Suppl)**: 7–18. https://doi.org/10.1016/s1553-7250(07)33109-7

[20] Mokoka, Kgaogelo E., Ehlers, Valerie J. and Martha J. Oosthuizen (2011). "Factors influencing the retention of registered nurses in the Gauteng Province of South Africa." *Curationis* **34(1)**: E1-9. https://doi.org/10.4102/curationis.v34i1.16

[21] Mofijur, M., Fattah, I. M. R., Alam, M. A., Islam, A. B. M. S., Ong, H. C., Rahman, S. M. A., Najafi, G., Ahmed, S. F., Uddin, M. A., & Mahlia, T. M. I. (2021). Impact of COVID-19 on the social, economic, environmental and energy domains: Lessons learnt from a global pandemic. *Sustainable Production and Consumption*, *26*, 343–359. https://doi.org/10.1016/j.spc.2020.10.016

[22] Choi, Kristen R., Skrine Jeffers, Kia and M. Cynthia Logsdon (2020). "Nursing and the novel coronavirus: Risks and responsibilities in a global outbreak." *Journal of Advanced Nursing* **76(7)**: 1486–1487. https://doi.org/10.1111/jan.14369

[23] Mehta, Sangeeta, Machado, Flavia, Kwizera, Arthur, Papazian, Laurent, Moss, Marc, Azoulay, Élie and Margaret Herridge (2021). C"OVID-19: A heavy toll on health-care workers." *The Lancet Respiratory Medicine* ***9*(3)**: 226–228. https://doi.org/10.1016/S2213-2600(21)00068-0

[24] Moynihan, Ray, Sanders, Sharon, Michaleff, Zoe A, Scott, Anna Mae, Clark, Justin, To, Emma J, Jones, Mark, Kitchener, Eliza, Fox, Melissa, Johansson, Minna, Lang, Eddy, Duggan, Anne, Scott, Ian and Loai Albarqouni (2021). "Impact of COVID-19 pandemic on utilisation of healthcare services: A systematic review." *BMJ Open* ***11*(3)**: 343-359. https://doi.org/10.1136/bmjopen-2020-045343

[25] Nermend, Kesra (2009). *Vector calculus in regional development analysis: Comparative regional analysis using the example of Poland*.

Physica-Verlag, Physica-Verlag HD, https://doi.org/10.1007/978-3-7908-2179-6

[26] Nermend, Kesra (2017). *Metody analizy wielokryterialnej i wielowymiarowej we wspomaganiu decyzji (in Polish)*. Wydawnictwo Naukowe PWN.

[27] Kukuła, Karol (2000). *Metoda unitaryzacji zerowanej (in Polish)*. Wydawnictwo Naukowe PWN.

[28] Nermend, Kesra (2007). "Taxonomic Vector Measure of Region Development (TWMRR)." *Polish Journal of Environmental Studies* **16(4A)**: 195–198.

[29] Nermend, Kesra (2006). "A synthetic measure of sea environment pollution." *Polish Journal of Environmental Studies* **15(4b)**: 127–130.

[30] Max Roser, E. O.-O., Hannah Ritchie and J. Hasell (2020). "Coronavirus Pandemic (COVID-19)." *Our World in Data*.