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eHEALTH DIGITAL SETUP BENEFITS DURING COVID-19: MCDM PERSPECTIVE

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ABSTRACT
Digitalization of health organizations implies implementing and enforcing the eHealth concept as an integral part of health information systems. During the SARS-CoV-2 pandemic health organizations of the European Union, member states faced certain restrictions and limitations in the provision of health services through the usual physical healthcare system infrastructure. The accelerated need to provide real-time health services while monitoring the performance of a large number of patients' health parameters has led to the widespread use of digital health solutions. Virtual health services enabled more efficient allocation of health organization resources in emergencies during COVID-19, which includes gathering, processing, and analyzing health big data and on that basis virtual monitoring of infected patients, virtual health assessment, and video-teleconferencing between health organization stakeholders. Accelerated online reporting on patient status, sharing results via smart health applications, and using electronic health record instruments have enabled more efficient responses by healthcare professionals. Also, eHealth's "digital toolbox" have been reduced operating costs, data redundancy, and significantly increased interoperability in compliance with Internet security protocols. Digital data transmission in virtual health communities has provided strong support for making the right real-time decisions when providing health services during a pandemic. Accordingly, this study aims to determine the ranking among EU member states in the digital health services utilization during the COVID-19 pandemic, conducting a multi-criteria decision-making analysis. Utilizing the multi-criteria decision-making method- PROMETHEE I, EU countries will be ranked based on values of the following analyzed indicators from the Eurostat Database for 2020: Making an appointment with a practitioner via the website, Seeking health information using the Internet, Accessing personal health records online and Internet use for other health services via a website or app instead of having to go to the hospital or visit a doctor. In this way, PROMETHEE benchmarks development disparities in healthcare digitalization among EU countries to find EU leaders in the eHealth digital setup.
Keywords: Health digitalization, Covid-19, EU countries, PROMETHEE I
JEL classification: I15, C52, C63

1. INTRODUCTION

Interactive, interoperable, and multimedia-oriented electronic healthcare represents one of the main challenges in the further development of health information systems. Given that traditional ways of healthcare delivery are being phased out in favor of delivery via digital technology in health systems (Das and Sengar, 2022). Health information is increasingly made available on the Internet, people frequently resort to online platforms including blogs, social media, websites, and virtual communities in search of information about specific medical conditions, symptoms of diseases, and support services (Abdulai et al., 2020). To apply modern technological achievements to virtual health services, given health organizations must choose the appropriate digital solution. The interest in the use of eHealth services to support social challenges that emerged from the Covid-19 pandemic has increased globally (Vivian et al., 2021). One of the key parts of health information systems, which must be taken into account when choosing electronic health software solutions, is the electronic health record, which increasingly has a blockchain-based framework and architecture (Zou et al., 2021) that provides data provenance, auditing, and control in cloud repositories among healthcare providers. As a multimedia electronic health file, the electronic health record contributes to greater interaction of stakeholders who use its information about the health status and course of the disease, which has proven to be extremely useful during COVID-19.

In the last case, this increases the responsiveness to the health demands of patients after the electronic verification and evaluation of their health parameters, which are contained in the electronic health record itself. High personalization and customization of the content of the electronic health record, along with constant monitoring of IT trends in electronic health, contributes to the development of a scalable infrastructure of health information systems. This enables long-term treatment, drug monitoring, pre-operative assessment, post-operative follow-up, and patient education in pandemic conditions and it has great potential to ease the burden of the pandemic, thereby minimizing its human and economic impact, especially in primary care (Coves et al., 2022). Cross-border data flows between eHealth providers depend on consistency between epidemiological frameworks and technical functionalities.
COVID eHealth digital equipment will have to be used by a large portion of the population, not only a few tech-savvy. The eHealth apps should be secure out-of-the-box with settings that are secure-by-default. It is important to design an intuitive and user-friendly eHealth toolbox to avoid security issues due to misconfiguration or mistakes by the user. To enhance patient-centered healthcare with a rate of 75.9% of the total population using the Internet daily for getting health information (Munoz et al., 2022), digital solutions are intended to improve the quality of care and communication between doctors and patients. An adequate and flexible digital platform during the pandemic period should reduce F2F (face-to-face) clinic appointments, triage cases requiring urgent consultation, postpone non-urgent visits including elective surgeries, set up new infection control measures, and improve healthcare management skills (Fezzi et al., 2022).

2. LITERATURE BACKGROUND

The pandemic crisis caused by the emergence of COVID-19 required very precise and rapid analyzes in all sectors, including in the electronic health sector. In general, the pandemic has confirmed the importance of multi-criteria decision-making for decision-making in crisis situations. Multi-criteria decision making software toolbox have formulated methods that recommend the top few alternatives, where only one among these similar alternatives is optimal (Pamučar et al., 2020). Different MCDM models such as AHP, ANP, ELECTRE, TOPSIS, PROMETHEE and VIKOR have different effectiveness and applicability depending upon the problem of investigation (Vivian et al., 2021) because of the intuitionistic nature of fuzzy decision-making (Munoz et al., 2020). In addition to the application of statistical tools for assessing the significance of factors for the evaluation of healthcare institutions, there are a number of publications in which the evaluation of healthcare institutions is performed using multi-criteria tools (Mishra et al., 2021). Yıldırım et al. used a hybrid methodology based on the application of two well-known multi-criteria tools: (1) Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) and (2) Vlsekriterijuska Optimizacija I Kompromisno Resenje (VIKOR) method. Jamshidiantehrani et al. have designed an interpretive structural model (ISM) to examine the effect of each variable on other variables, which contributes to the further development of MCDM, especially in the field of electronic health.

3. METHODOLOGY

The applied methodology in this paper refers to the ranking of the member states of the European Union regarding the use of electronic health tools during the pandemic. The ranking of alternatives based on the selected eHealth indicators will be carried out in the multi-criteria decision aid (MCDA) software Visal PROMETHEE 1.4 in order to evaluate several possible decisions or items according to multiple often conflicting criteria. Using the PROMETHEE I method for multi-criteria decision-making, EU member states were ranked based on four Eurostat eHealth indicators and available data for 2021 (Eurostat, 2022):
• Internet use: making an appointment with a practitioner via a website- C1 (unit of measurement - percentage of individuals)[1]
• Internet use: seeking health information- C2 (unit of measurement - percentage of individuals)

[1]C1- C4: four indicators are marked with C as Criteria, respectively.

• Internet use: accessing personal health records online – C3 (unit of measurement - percentage of individuals)
• Internet use: for other health services via a website or app instead of having to go to the hospital or visit a doctor. – C4 (unit of measurement - percentage of individuals).
Scaled indicator values from the smallest (sequential light-blue) to the largest (sequential dark-blue) are shown in the form of a map chart of the countries of the European Union. The percentage values of the indicators are shown in decimal notation for the purpose of simplified presentation (Figure 1).

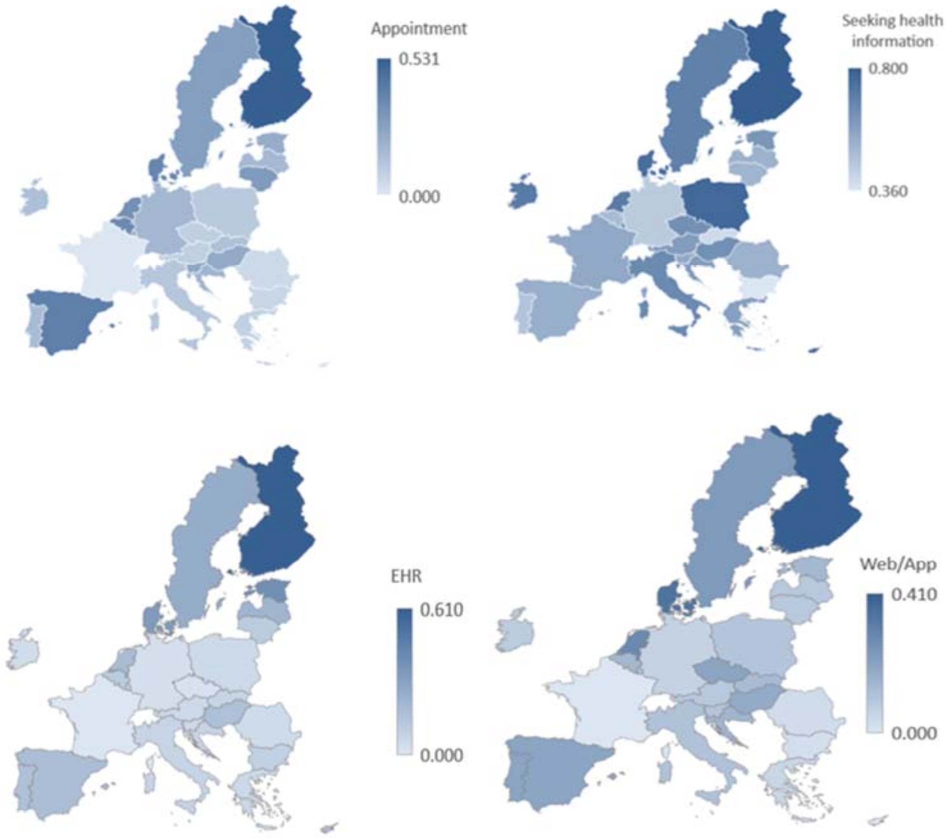


Figure 1: EU members map chart for analyzed e-Health indicators
Source: Based on available data from Eurostat

PROMETHEE (Preference Ranking Organization Method for Enrichment) also belongs to the methods for multi-criteria decision-making and was developed in 1982 by Jean-Pierre Berns. First, it was used especially for decision-making in healthcare. The application of this method in Visual PROMETHEE 1.4 is characterized by three steps:
Construction of fuzzy relation for each criterion
The construction of global preference in a set
Order construction.
The decision maker in this analysis chooses a preference function for each criterion R_i, whereby a fuzzy relation of preference is formed where S_i (a,b) implies the intensity of preference a in relation to preference b (Pierre and Bertrant, 1986):

$$S_i: AxA \rightarrow [0,1];\ S_i(a,b) = P_i\big(f_i(a) - f_i(b)\big) = P_i(d)$$

For each alternative (preference) a ∈ A, an input and output flow is formed based on the Phi ± coefficient in the interval from -1 to 1. Namely, the value of this coefficient can be from -1 to 1, and it shows the degree of conjucture between two or more variables or alternatives based on the dichotomy of their criteria. It is basically very similar to Pearson's correlation coefficient (Brans et al., 1986). The higher the value of the Phi+ coefficient, the higher the dominance of the given alternative in the total set:

$$\Phi^{+}(a) = \frac{1}{n-1}\sum_{x \in A} S(a,x)$$

$$\Phi^{-}(a) = \frac{1}{n-1}\sum_{x \in A} S(x,a)$$

The values of the weight coefficients of each of the analyzed indicators or criteria were obtained using the Entropy method, which contains four calculation steps (Hussein and Mandal, 2017):

Step 1: Calculation of feature weight Pij for the i[th] alternative and j[th] criterion

$$P_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}^{2}} \quad (1 \le i \le m, 1 \le j \le n)$$

Step 2: The output entropy ej of the j[th] factor

$$e_j = -k\sum_{i=1}^{m}(P_{ij} \ldots . lnP_{ij}) \ \ (1 \le j \le n)$$

$$k = {}^{1}/_{(lnm)}$$

Step 3: Calculation of variation coefficient of j[th] factor gj

$$g_j = |1 - e_j| \ \ (1 \le j \le n)$$

Step 4: Calculation of weight of the entropy wj

$$w_j = \frac{g_j}{\sum_{i=1}^{m} g_j} \ \ (1 \le j \le n)$$

4. RESULTS AND DISCUSSION

Using the Entropy method, the values of the weighting coefficients for all four mentioned indicators were first obtained.

Table 1: Entropy weights for analyzed criteria

Weights	Criteria				Sum of weights
	C1	C2	C3	C4	
Wj	0.244	0.278	0.239	0.238	1.000

Source: Author's elaboration based on available data

After entering the data into the software model, the values of the Phi coefficient were obtained, which represented the ranking of the member countries. As can be seen in the Table, the best alternative regarding the use of electronic health tools for the mentioned indicators during the pandemic is Finland, and the last alternative is Bulgaria.

Table 2: Phi coefficient values for ranking EU members

No.	Country	Phi	Phi+	Phi-	Country Rank	No.
A1[2]	Austria	0,5170	0,5170	0,0000	**Finland**	**A9**
A2	Belgium	0,4558	0,4864	0,0306	Denmark	A7
A3	Bulgaria	0,3839	0,4451	0,0612	Netherlands	A20
A4	Croatia	0,3334	0,4252	0,0918	Sweden	A27
A5	Cyprus	0,2480	0,3779	0,1300	Poland	A21
A6	Czechia	0,2034	0,3549	0,1515	Hungary	A13
A7	Denmark	0,1561	0,3320	0,1759	Italy	A15
A8	Estonia	0,1347	0,3213	0,1866	Luxembourg	A18
A9	Finland	0,1254	0,3166	0,1912	Estonia	A8

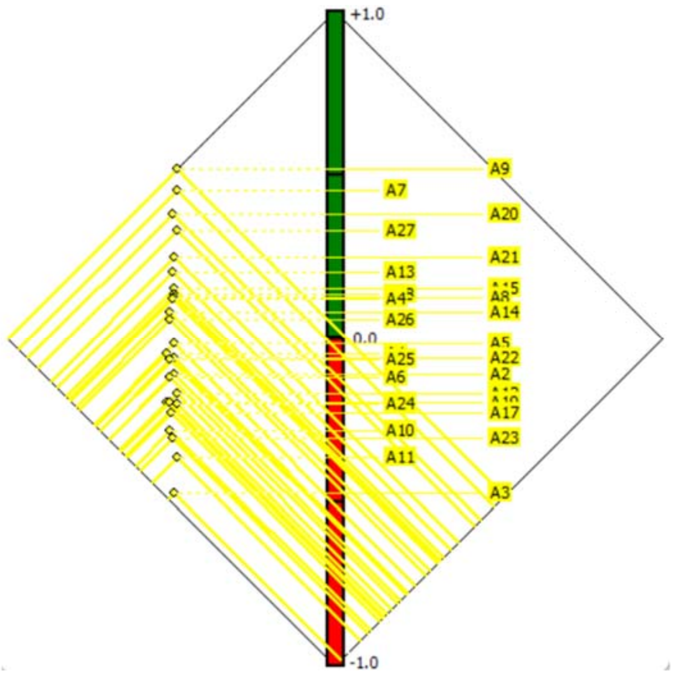
[2] Alternative 1: Austria and etc.

A10	France	0,1208	0,3136	0,1928	Croatia	A4
A11	Germany	0,0812	0,2892	0,2080	Ireland	A14
A12	Greece	0,0595	0,2783	0,2188	Spain	A26
A13	Hungary	-0,0150	0,2464	0,2614	Cyprus	A5
A14	Ireland	-0,0443	0,2218	0,2661	Austria	A1
A15	Italy	-0,0583	0,2248	0,2831	Portugal	A22
A16	Latvia	-0,0627	0,2172	0,2799	Slovenia	A25
A17	Lithuania	-0,1103	0,1988	0,3091	Belgium	A2
A18	Luxembourg	-0,1176	0,1898	0,3074	Czechia	A6
A19	Malta	-0,1682	0,1744	0,3426	Greece	A12
A20	Netherlands	-0,1943	0,1468	0,3411	Latvia	A16
A21	Poland	-0,1973	0,1499	0,3472	Malta	A19
A22	Portugal	-0,2021	0,1575	0,3596	Slovakia	A24
A23	Romania	-0,2265	0,1361	0,3626	Lithuania	A17
A24	Slovakia	-0,2829	0,1071	0,3900	France	A10
A25	Slovenia	-0,3044	0,1010	0,4053	Romania	A23
A26	Spain	-0,3641	0,0765	0,4406	Germany	A11
A27	Sweden	-0,4712	0,0183	0,4895	**Bulgaria**	**A3**

Source: Author's calculation based on Visal PROMETHEE 1.4 MCDA software

In the Visual PROMETHEE diamond (Figure 2) output, the ranked alternatives are marked with blue contours at an angle of 45°, so the values of the Phi coefficients for those alternatives can be easily determined to which part of the -1 to 1 interval they belong. Given that in the case of ranking, there is no overlap of the contours that mark the ranking area of each alternative individually, meaning that the ranked alternatives are comparable. As the alternatives are comparable, they are ranked above each other with yellow contours, according to importance, so it can be concluded that the best-ranked alternative is Finland.

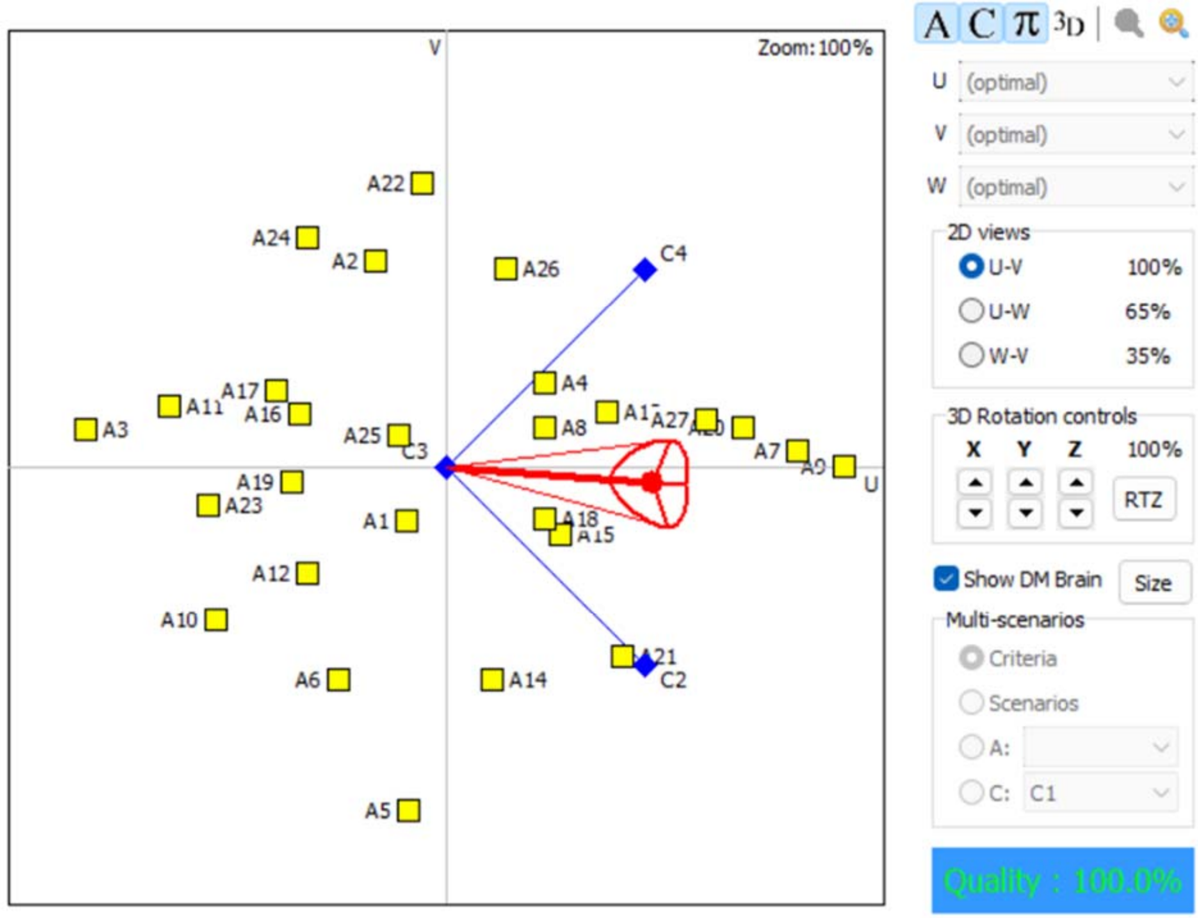
Figure 2: Visual PROMETHEE Diamond
Source: Author's calculation based on Visal PROMETHEE 1.4 MCDA software



GAIA (Graphical Analysis for Interactive Aid) represents a very specific analysis within the Visual PROMETHEE program for multi-criteria decision-making. Namely, this analysis makes it possible to see the spatial distribution of alternatives and criteria, in the coordinate system, by quadrants and the mutual interaction of these alternatives and criteria. This analysis, mathematically speaking, is based on the concept of statistical analysis of the main components (Principal Component Analysis). For this analysis, the validity (quality of information) of the model is very important, i.e. validly chosen criteria and alternatives for ranking, and if it exceeds 75%, it can be said that the model is satisfactory when it comes to multi-criteria decision-making (in the analyzed model it is 100.0%). GAIA analysis groups the alternatives into mini-clusters by quadrants, based on the criteria that are dominant for the given alternatives.

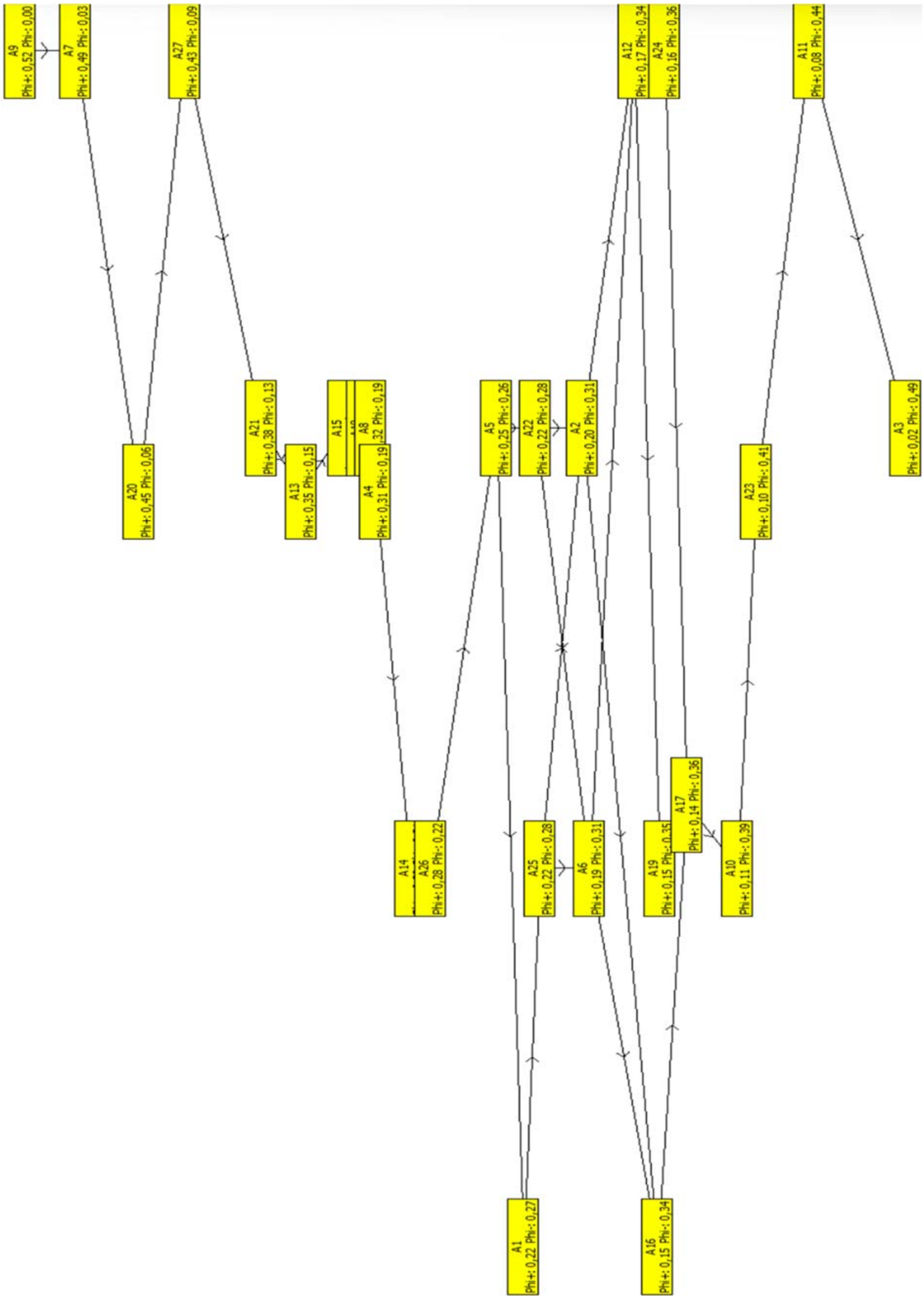
Accordingly, in the example of multi-criteria decision-making, the first group of alternatives is the one that stands out the most in the coordinate system and is located in the first quadrant. Quadrants are marked and counted in a counter-clockwise direction. In the first quadrant, Finland stands out, which corresponds to criterion C4-Internet use: for other health services via a website or app instead of having to go to the hospital or visit a doctor (Figure 3). The "red decision stick" indicates that the alternatives from the second quadrant are optimal solutions and that the decision-making on the best alternative should be oriented towards them - A9 (Finland), A7 (Denmark), A20 (Netherlands).

Figure 3: Graphical Analysis for Interactive Aid in Visual PROMETHEE
Source: Author's calculation based on Visal PROMETHEE 1.4 MCDA software



Visual PROMETHEE Network is another output in the set model. The network was formed based on the value of the Phi coefficient, where the network nodes in the form of arrows show the relationship between the alternatives, where the best alternative - Finland - is at the top of the network.

Figure 4: Visual PROMETHEE Network
Source: Author's calculation based on Visal PROMETHEE 1.4 MCDA software



5. CONCLUSION

The management of health information systems represents, above all, the management of information and data generated in healthy ecosystems, between stakeholders of health entities. Therefore, for the management of health information systems, it is crucial to understand the type of health data and the digital content that is transmitted in such an information-intensive sector as the health sector, especially in case of a pandemic crisis with fast- adaptable web health environment. Clear and precise data enable decision-makers to rationally allocate health resources in COVID- 19 conditions, in the case of managing health information systems, so that the provision of health services becomes as efficient as possible. The management of health information systems must therefore ensure the processing and analysis of all relevant information to properly reach the destination over the Internet, which results in a successfully implemented medical intervention and provided health service.

The results obtained by applying the Visual PROMETHEE software for the ranking of EU member states only confirm the leadership position of Finland, which is ranked among the three strongest health technology economies in the world in 2021. Finland is the first country in the world that has digitized national health registries originating in the 1960s and also digitized biobank data from the 1920s. Finland has strong eHealth background. Despite being the second most advanced digital economy in the EU and "flagship" in health digitalization, according to DESI (Digital Economy and Society) index, Finland has significant advance in digital health and genomics in the world, not only in EU. Finland has the only EHR in the world where clinical and social data are layered on top of each other. Furthermore Finland healthcare ecosystem enables access to patients' EHR for all patients in real time. This adds a very unique third layer of data to the EHR, which is real-time patient-reported and patient- monitored health outcomes. The fourth layer of the EHRs is e-prescription history and soon patient-drug interaction which leads to integration of all four layer into one persistent and most effective virtual health orbit.

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