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Multi-Criteria Group Assessment of e-Commerce Websites Based on the New PROSA GDSS Method–The Case of Poland

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ABSTRACT Due to the COVID-19 pandemic and lockdowns, the popularity and number of users of e-commerce websites has increased significantly recently. In order to retain new users in the future, e-commerce websites need to develop their quality and constantly monitor it. The problem of assessing the quality of websites is a multi-criteria problem and multi-criteria decision making methods are used in it. Taking into account the need for a consensus of experts or users evaluating the website, the article developed a new multi-criteria group decision making method, called PROSA GDSS (PROmethee for Sustainability Assessment – Group Decision Support System), which allows to reward the consensus of decision makers' preferences and penalize conflicts of preferences. This method was used in the evaluation of e-commerce websites operating on the Polish market that offer the widest range of products. In the course of research works, a wide applicability of the developed method in the problems of group assessment and its broad analytical possibilities was demonstrated. As a result of the research, it has been found that local parties have an established position on the Polish e-commerce market, and parties operating from abroad, and those entering the Polish market, must catch up with the distance that separates them from local tycoons.

INDEX TERMS Decision making, decision support systems, e-commerce quality, multi-criteria group decision making, PROMETHEE GDSS, PROSA GDSS, website assessment.

I. INTRODUCTION

According to data from May 2021, the total number of Internet users is almost 4 billion [1], and the number of active websites has reached almost 200 million [2]. Along with the increase in the number of users and websites, related services, such as e-banking, e-government or e-tourism, are constantly developing. However, the largest Internet industry is e-commerce, the global value of which grows dynamically every year. The concept of e-commerce appeared in business in the 1970s, generally referring to any form of economic activity conducted with the use of electronic connections [3]. Currently, e-commerce is defined as commercial activity carried out with the use of digital technology via the Internet [4]. This activity goes beyond the boundaries of a single enterprise and can be applied to almost any type of business relationship, in particular business to customer and business to business [5]. E-commerce is considered to have drastically changed the production and delivery of goods and services, and affects operations and all other aspects of the business [6].

In the 2019-2020 period, the value of e-commerce increased by 27.6% reaching USD 4.28 trillion in 2020, compared to USD 3.354 trillion in 2019. In turn, the share of the e-commerce market in total retail sales in the 2019-2020 period increased by 32.3% from 13.6% to 18% [7]. In Poland, according to estimates, the value of the e-commerce market in 2020 amounted to approx. PLN 70 trillion, which is an increase of 40% compared to 2019. This result is almost 3% of the value of GDP (Gross Domestic Product) of Poland [8]. It is a very dynamic growth year to year, and its reasons include, among others: more and more people getting used to various online activities (e.g. e-banking, e-learning, social media), growing acceptance of online shopping and resignation from interaction in the store, as well as the convenience of home delivery [9]. Other

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advantages of e-commerce for consumers include: improved price competitiveness, market transparency [10], greater flexibility in terms of time, location and product variety [11]. On the other hand, the benefits for sellers are certainly: minimizing operating costs, increasing business efficiency and improving the market reach [10]. Nevertheless, in the 2019-2020 period, the main reason for the growth of the e-commerce market was the fact that in many countries during subsequent lockdowns, it was the only possible way for customers to purchase various goods [12]. On the other hand, from the sellers' perspective, it should be noted that the transition from stationary sales to e-commerce allowed many of them to survive the lockdowns [8]. Due to the SARS-Cov2 pandemic and lockdowns, almost all over the world at certain times in 2020, all stores, except for groceries, were closed. This fact, as well as the emphasis on the need to isolate oneself and avoid direct interaction with people, largely redirected consumers' attention to e-commerce. This has been confirmed by Guthrie *et al.* [13], according to whom the COVID-19 pandemic, lockdown and the need for social distancing disrupted existing purchasing practices and prompted consumers to experiment with new commercial channels and develop new buying habits. Due to the pandemic, the existing advantages of shopping in regular stores, such as immediate possession and social interactions [11], lost their importance or even became disadvantages. On the other hand, it is believed that online shopping can at least partially help reduce the effects of social isolation, such as anxiety, depression and stress [14]. In the pandemic, other advantages of online shopping were also highlighted, i.e. home delivery and the possibility of avoiding the stress and discomfort associated with new sanitary rules and regulations in regular stores [13]. Moreover, as noted by Tran [15], fear of a pandemic positively influences consumers' perception of the economic benefits of e-commerce. All these elements together contributed to the aforementioned significant increase in the value and share of the e-commerce market in the total retail sales in 2020. Significant acceleration of this growth is observed and repeatedly quoted in the literature [10], [11], [13], [14], [16], [17]. The above-mentioned above-average increase in online sales of individual retailers is primarily due to new and existing customers who previously shopped offline [17]. The indicated increase in the value of e-commerce is therefore associated with changes in behaviour and consumption habits [13], and, according to many researchers, these changes will be permanent and will persist also in the future [10], [11], [13], [18]. Therefore, the challenge for any e-commerce website will be to retain the acquired customers and increase their re-purchase intention [19]. As a result, user loyalty is important, mainly related to: trust in the website [20], satisfaction with its use [21] and broadly understood quality [19], [22]. It is recognized that the satisfaction with using the website is a strong predictor of the frequency of online purchases [23]. Customer satisfaction is positively influenced by such elements as the quality of information on an e-commerce website, the quality of the user interface [24], perceived security, order flow and product attractiveness [25]. However, research results indicate that customers who do not trust an e-commerce website will not be loyal to it, even if they are satisfied with the products/services provided [26]. Therefore, the basis for establishing and maintaining a customer-seller relationship is trust and reliability [15]. Trust is often a decisive factor as to whether the consumer will want to shop or return to a given e-commerce website [11]. The level of trust is influenced by, among others: ease of use, usability [27] and website functionality [28], including in particular the user interface [21] and navigation [28]. The quality of website is also an important element building consumer confidence [28]. The concept of quality also includes the aforementioned concepts of trust and satisfaction, detailed by even more precise indicators, such as, for example, reputation, a sense of security, or the attractiveness of appearance and positive experiences of using the website [29]. In practice, such a broadly understood quality of the website is a key factor determining online purchases on the customer side [30] and the sales level on the company's side [31]. Poor quality websites can lose customers to competition, escalate costs and diminish profits [30]. Therefore, assessing the quality of a website is an important manner of verifying that a company is providing information and interaction quality that is satisfactory for users [31]. Evaluation is also an aspect of website development and operation and can contribute to the maximum use of resources previously invested in the website [32]. It should be noted that the problem of evaluating websites, including e-commerce, is considered a multi-criteria problem that should be solved with the use of MCDM (multi-criteria decision making) methods [33]. Multi-criteria evaluation of e-commerce websites is often carried out on the basis of many experts, using the MCGDM (multi-criteria group decision making) methods. However, all the MCGDM methods used have a certain disadvantage related to the use of arithmetic mean to aggregate expert judgements. Such aggregation assumes that the agreement of experts' opinion or the lack of such agreement does not affect the aggregation result. As a result, these methods by no means take into account the experts' consensus.

Therefore, the aim of the article is to assess the quality of the largest e-commerce websites in Poland based on a multi-criteria model. The contribution of the article is the use of the new PROSA GDSS (PROmethee for Sustainability Assessment – Group Decision Support System) multi-criteria method on the assessment. This method is based on two MCDM methods: PROMETHEE GDSS (Preference Ranking Organization METHod for Enrichment Evaluation) [34] and PROSA [35]–[37]. The new PROSA GDSS method, similarly to the PROMETHEE GDSS method, enables the group assessment of alternatives, and similarly to the PROSA method, is based on the idea of the balance factor between decision factors. In the case of PROSA GDSS, this factor makes it possible to define a balance between many decision-makers, thus rewarding the consensus of decision-makers

and penalizing the lack of consistency between the assessments of decision-makers. The article is structured as follows. Section 2 discusses the state of the art on the use of MCDM methods in the evaluation of websites, especially e-commerce websites. Section 3 presents the calculation procedure used in the new PROSA GDSS method. Section 4 contains the results of the quality assessment of e-commerce websites in Poland and a discussion. The article ends with the conclusions set out in section 5.

II. LITERATURE REVIEW

Classic methods for assessing the quality of services and websites, such as SERVQUAL [38], E-S-Qual [39], Website Quality Index [40], or eQual [29] are used less frequently. This is due to their basic disadvantage, which is the use of trivial calculation procedures. In these methods, preferences are not defined at all or are expressed as trade-offs, not importance coefficients/voting power [41]. The reason for this is the use of simple or weighted arithmetic mean in the aggregation of indicators [42]. On the other hand, these methods have a well-defined and validated set of quality indicators that allow for the detailed examination of websites in terms of quality perceived by users [43]. For this reason, many of the current approaches to assessing website quality take the criteria model from the classical quality assessment methods. Modern approaches use MCDM methods and thus extend the classic methodology with more advanced computational procedures for aggregating indicators. Table 1 summarizes the research on website quality and e-commerce related analyses using MCDM methods.

The literature review presented in Table 1 showed that the problem of assessing the quality of websites is indeed a multi-criteria problem, in which usually certain groups of criteria are distinguished, with detailed criteria inside them. Usually at least a few decision alternatives are considered, although there are also works ([54], [57]), where criteria are ranked, not alternatives. In the assessment of various types of websites (e-commerce, e-tourism, e-banking, e-health), the following MCDM methods are used: TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), DEMATEL (DEcision MAking Trial and Evaluation Laboratory), AHP (Analytic Hierarchy Process), PROMETHEE, MUSA (MUlticriteria Satisfaction Analysis) and ELECTRE (ELimination Et Choice Translating REality). In addition, in other decision-making problems related to e-commerce, the following methods are also used: AHP, ANP (Analytical Network Process), VIKOR (VIšekriterijumsko KOmpromisno Rangiranje), GRA (Gray Relational Analysis). There are also studies where variants of AHP or ANP methods are used to weight criteria, sometimes together with the DEMATEL method, and methods such as TOPSIS, PROMETHEE, GRA or VIKOR are used to evaluate alternatives. As mentioned earlier, many of the works presented in the aspect of the criteria model are based on simple web quality assessment methods, such as E-S-QUAL, eQual, Technology Acceptance Model, etc. Many studies use methods that allow websites to be assessed by multiple decision makers/experts/users. It is of great importance because group assessment helps to reduce uncertainty and to some extent objectify the results. A single decision-maker may be guided by an individual model of preferences, significantly different from the preferences of the entire user population. On the other hand, aggregating the assessments of a group of decision-makers gives a greater chance of obtaining results similar to the preferences of the entire population, because individual outliers can be largely corrected by the assessments of other decision-makers. On the other hand, outliers may indicate that a certain group of users may have a different opinion about the website than the general public. The MCDM method used should be able to capture such outliers and account for them appropriately in the final evaluation. However, it should be noted that the MCDM methods used so far cannot cope with this kind of outlier because these methods tend to aggregate the ratings of multiple decision makers based on some type of arithmetic mean. For this reason, a new MCGDM method was developed, called PROSA GDSS, which, apart from multi-criteria assessment of decision alternatives, is also able to aggregate the assessments of many decision-makers, taking into account the consensus and discrepancies in the assessments of individual experts. Based on this method, the quality of e-commerce websites available in Poland has been assessed. The eQual model was used as the methodological basis, containing all the important dimensions of quality such as trust, empathy, information quality, usability and user interface design [29].

III. MATERIALS AND METHODS

A. PROSA GDSS METHOD

The methodology used in PROSA GDSS is derived from the PROMETHEE GDSS [34] and PROSA-C [35] methods. Like the first method, the PROSA GDSS enables the aggregation of multiple individual rankings of alternatives into one group assessment. This is done by treating the individual ranking of each decision maker as a criterion. On the other hand, similarly to the second method, the PROSA GDSS allows to capture discrepancies, in this case between decision makers. This is possible because the PROSA-C method considers the balance/consistency between criteria, while in the PROSA GDSS (similar to the PROMETHEE GDSS), when aggregating individual rankings into a group score, these rankings are treated as criteria. The calculation procedure used in PROSA GDSS consists of 3 stages:

1) generation of alternatives and criteria,
2) individual evaluation by each decision-maker,
3) global evaluation by the group [34].

In the first stage, alternatives should be identified that will be considered in the decision-making process. We also need to define criteria that describe each alternative and assign the alternatives a value for each of the criteria. These criteria define the perspective from which alternatives will be viewed. The set of alternatives and criteria should be

TABLE 1. Applications of MCDM methods in the assessment of websites and in the e-commerce problems.

Application	Methodological basis for evaluation	MCDA method	No of decision-makers	No of groups/ criteria	Main groups of criteria	No of alternatives	Ref.
Evaluation of B2C e-commerce websites in Korea	E-S-QUAL	Fuzzy hierarchical TOPSIS	3	4/22	Efficiency, Fulfilment, System availability, Privacy	6	[33]
Evaluation of B2C e-commerce websites	E-S-QUAL	SVTN-DEMATEL	4	4/22	Efficiency, Fulfilment, System availability, Privacy	6	[44]
Evaluation of e-commerce websites in Taiwan	Technology Acceptance Model	Fuzzy TOPSIS	12	3/12	Specific holdup cost, Website service quality, Technology acceptance factor	4	[45]
Rank of B2C e-commerce websites in e-alliance	-	AHP + Fuzzy TOPSIS	1	9/-	Price, Abundance, Appearance, Ease use, Security, Intelligence, Confidence, Trust, Speed	5	[46]
Evaluation of the most popular e-commerce websites	eQual	PROMETHEE II	41 (survey)/ 20 (eye tracking)	4/28	Usability, Information quality, Service interaction, Perceptual	10	[47]
Evaluation of websites quality in Turkish e-business market	Information Systems success model	Fuzzy AHP + Fuzzy TOPSIS	3	4/9	Information, Service, System, Vendor	3	[48]
Evaluation the quality, effectiveness and usability of e-banking websites	-	TOPSIS	334	20	Economic, Technical, Visual, Security, Anti-crisis measures	21	[49]
Evaluation of e-tourism/e-commerce websites)	Information Systems success model	AHP	156/156/ 34*	4/14	Information, Service, Systems, Vendor-Specific	4/4/4*	[50]
Identify and analysing factors affecting Greek e-tourism websites usability	-	MUSA	80	6/37	Accessibility, Interactivity, Personalization, Content, Navigation, Design-Structure	8	[51]
Evaluation websites of touristic destinations in Spain and Europe	Web Quality Index	ELECTRE III-H	1	12/47	Home page, Usability and accessibility, Brand image, Interactivity	10	[41]
Quality evaluation of e-health websites	SERVQUAL and Kano quality model	AHP + Fuzzy PROMETHEE	9 (weights) /7 (alternatives)	7/17	Tangibles, Reliability, Responsiveness, Assurance, Empathy, Quality of information, Integration of communication	9	[52]
Ranking of websites of enterprises in Prefecture of Thessaloniki promoting renewable energy	-	PROMETHEE II	1	18	Content, Web design, Navigation, E-commerce and internet adoption	30	[53]
Evaluation of e-commerce success factors	-	Fuzzy AHP	1	5/17	Trust, System quality, Content quality, Online service, Use	-	[54]
Ranking, selection, improving and creating e-store marketing strategies	-	DEMATEL + DANP + VIKOR	8 (weights) /1018 (alternatives)	5/14	Need recognition, Information search, Evaluation of alternatives, Choice/Purchase, Post-purchase behaviour	3	[55]

TABLE 1. *(Continued.)* **Applications of MCDM methods in the assessment of websites and in the e-commerce problems.**

Developing, evaluation and improving e-store marketing strategies	-	DANP + GRA	10 (weights) /1027 (alternatives)	5/14	Need recognition, Information search, Evaluation of alternatives, Choice/Purchase, Post-purchase behaviour	3	[56]
Rank of barriers of e-commerce in Iran	-	Fuzzy ANP	17	4/13	Technical, Organizational, Individual, Environmental	-	[57]
Assessment of e-commerce security	-	AHP	1	3/8/27	Technical, Environmental, Managerial	1	[58]

TOPSIS - Technique for Order of Preference by Similarity to Ideal Solution; SVTN-DEMATEL – Single-Valued Trapezoidal Neutrosophic DEcision MAking Trial and Evaluation Laboratory; AHP - Analytic Hierarchy Process; PROMETHEE - Preference Ranking Organization METHod for Enrichment Evaluation; MUSA - MUlticriteria Satisfaction Analysis; ELECTRE-H - ELimination Et Choice Translating REality – Hierarchical; DANP – DEMATEL-based Analytical Network Process; VIKOR - VIšekriterijumsko KOmpromisno Rangiranje; GRA – Gray Relational Analysis
* Three studies were conducted, 1- 156 participants, evaluation of 4 e-tourism websites; 2 – 156 participants, evaluation of 4 e-commerce websites; 3 – 34 participants, evaluation of 4 e-tourism websites

consistent, and therefore the same for each of the decision makers. Of course, decision-makers may use different weights of criteria, depending on their opinions, views and interests. Therefore, individual decision makers may give the selected criteria a weighting of 0, so in practice they may not use these criteria [59]. In the first step, a set of m alternatives $A = \{a_1, a_2, \ldots, a_m\}$, a set of n criteria $C = \{c_1, c_2, \ldots, c_n\}$ and a set of K decision makers $DM = \{dm_1, dm_2, \ldots, dm_K\}$ $\mathrm{DM} = \{\mathrm{dm}_1, \mathrm{dm}_2, \ldots, \mathrm{dm}_\mathrm{K}\}$ are obtained.

Individual assessment of alternatives by each of the decision-makers consists in the use of the decision model defined in the first stage, including criteria and their weights, as well as alternatives together with their assessment on individual criteria. In the PROMETHEE GDSS method, individual assessment should be carried out using the PROMETHEE II method [60] that allows to obtain a net flow score [34]. In the PROSA GDSS method, I postulate a more universal approach and propose that the individual assessment be carried out using one of the MCDA methods from the PROMETHEE family. Depending on the input data available to decision makers, it may be: the classic PROMETHEE II method [61], fuzzy versions of PROMETHEE (e.g. NEAT F-PROMETHEE II [62], [63]), or also the PROSA-C or PROSA-G methods [35]. In particular, if the evaluation of alternatives on the criteria are fuzzy, then the NEAT F-PROMETHEE method will apply, and when the decision-maker considers it important to balance between criteria or groups of criteria, then PROSA-C or PROSA-G should be used, respectively. As a result of the actions taken, each of the decision makers should receive a score ς representing the net flow score ϕ_{net} value, PROSA net sustainable value PSV_{net} or PROSA group net sustainable value $PSVg_{net}$ for each decision alternative. The obtained individual results show the personal perception of the solution to the decision problem by each of the decision makers. As a result of the second stage, the set of K sequences $R = \{r_1, r_2, \ldots, r_K\}$ is obtained, where each k-th sequence corresponds to the results of the individual assessment of the k-th decision maker and describes each of the m alternatives using the value ϕ_{net}, PSV_{net} or $PSVg_{net}$: $\forall_{k=1..K} r_k = \left\{\varsigma^k(a_1), \varsigma^k(a_2), \ldots, \varsigma^k(a_m)\right\} : \varsigma^k(\cdot) = \phi^k_{net}(\cdot) \vee PSV^k_{net}(\cdot) \vee PSVg^k_{net}(\cdot)\,\mathrm{PSV}_{\mathrm{gnet}} : \forall_{\mathrm{k=1..K}}\mathrm{r_k} = \left\{\varsigma^{\mathrm{k}}(\mathrm{a}_1), \varsigma^{\mathrm{k}}(\mathrm{a}_2), \ldots, \varsigma^{\mathrm{k}}(\mathrm{a}_\mathrm{m})\right\} : \varsigma^{\mathrm{k}}(\cdot) = \phi^{\mathrm{k}}_{\mathrm{net}}(\cdot) \vee \mathrm{PSV}^{\mathrm{k}}_{\mathrm{net}}(\cdot) \vee \mathrm{PSV}^{\mathrm{k}}_{\mathrm{gnet}}(\cdot)$ (see [34], [35], [62]).

In the third step of the original PROMETHEE GDSS method, the results of individual decision-makers' assessment are aggregated into a group assessment using the PROMETHEE II method. In the case of the proposed PROSA GDSS method, the PROSA-C computational procedure, whose initial steps are also stages of the PROMETHEE II method, applies at this stage. A set of alternatives A and a set of sequences R representing individual solutions to the decision problem of individual decision makers are considered. At the beginning, for each sequence r_k, the preference relations between the alternatives are calculated (1):

$$P_k(a_i, a_j) = F\left[\varsigma^k(a_i) - \varsigma^k(a_j)\right] \tag{1}$$

In the GDSS procedure, a V-shaped preference function is used, formally described by the formula (2) [34], while the expression $\varsigma^k(a_i) - \varsigma^k(a_j) > 2$ can be true only when used in the second stage of the PROSA-C and PROSA-G methods:

$$P_k(a_i, a_j) = \begin{cases} 0 & for\ \varsigma^k(a_i) - \varsigma^k(a_j) \le 0 \\ \dfrac{(a_i) - \varsigma^k(a_j)}{p_k} & for\ 0 < \varsigma^k(a_i) - \varsigma^k(a_j) \le 2 \\ 1 & for\ \varsigma^k(a_i) - \varsigma^k(a_j) > 2 \end{cases} \tag{2}$$

Then, for each i-th alternative, individual net flows from individual sequences are calculated (3):

$$\phi_k(a_i) = \frac{1}{m-1} \sum_{j=1}^{m} \left[P_k(a_i, a_j) - P_k(a_j, a_i)\right] \tag{3}$$

In the next step, global net flows are calculated for each i-th alternative. Their calculation is based on the individual

net flows of each k-th decision maker and its weight ω_k (4):

$$\phi_{net}(a_i) = \sum_{k=1}^{K} \phi_k(a_i)\,\omega_k \tag{4}$$

Weights ω_k should be normalized to 1, and so $\sum_{k=1}^{K} \omega_k = 1$ [64].

Determining the values $\phi_k(a_i)$ and $\phi_{net}(a_i)$ allows to specify the relations of sustainability, compensation and being compensated, for alternatives assessed by individual decision makers:

1) The relation of being sustainable ($\approx$) – holds when $\phi_k(a_i) \approx \phi_{net}(a_i)$ and means that the evaluation of the alternative a_i made by the k-th decision maker is sustainable.
2) The relation of being compensated (Cd) – occurs when $\phi_k(a_i) \ll \phi_{net}(a_i)$ and means that the low assessment of the alternative a_i made by the k-th decision-maker is compensated by the higher scores of other decision-makers ($\exists \phi_{k'}(a_i) : \phi_k(a_i)\, Cd\, \phi_{k'}(a_i)$).
3) Compensation relation (Cs) – occurs when $\phi_j(a_i) \gg \phi_{net}(a_i)$ and means that the high assessment of the alternative a_i made by the k-th decision-maker compensates for the lower scores of other decision-makers ($\exists \phi_{k'}(a_i) : \phi_k(a_i)\, Cs\, \phi_{k'}(a_i)$).

The Cd and Cs relations mean that the evaluation of the alternative a_i made by the k-th decision maker is not sustainable. Operators $\ll$ and $\gg$ denote the contractual relations 'much less than' and 'much greater than', expressing a subjective view about the difference between the compared values.

The analysis of the sustainability relations can provide an indication of the expected values of the balance coefficient $s_k \in [0, 1]$, used in the next step of the procedure. Increasing the value of the s_k coefficient allows to increase the impact of sustainability on the solution obtained, as presented in formula (5) defining the calculation of individual absolute deviations and in formula (6) allowing to determine individual PROSA net sustainable values:

$$AD_k(a_i) = |\phi_{net}(a_i) - \phi_k(a_i)|\, s_k \tag{5}$$

$$PSV_k(a_i) = \phi_k(a_i) - AD_k(a_i) \tag{6}$$

The PROSA GDSS computational procedure ends with the calculation of the global PROSA net sustainable value according to the formula (7):

$$PSV_{net}(a_i) = \sum_{k=1}^{K} PSV_k(a_i)\,\omega_k \tag{7}$$

An additional element of the PROSA GDSS method is the analysis of conflicts between decision-makers using the GAIA (Geometrical Analysis for Interactive Assistance) plane. GAIA for PROSA GDSS was based on the PROSA-C GAIA procedure [35]. PROSA GDSS GAIA uses a PSV performance table containing the values of $PSV_k(a_i)\,\forall_{k=1..K}\forall_{i=1..m}$. The performance table is described by the formula (8):

$$PSV = \begin{pmatrix} PSV_1(a_1) & PSV_2(a_1) & \cdots & PSV_K(a_1) \\ PSV_1(a_2) & PSV_2(a_2) & \cdots & PSV_K(a_2) \\ \vdots & \vdots & \ddots & \vdots \\ PSV_1(a_m) & PSV_2(a_m) & \cdots & PSV_K(a_m) \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_m \end{pmatrix} \tag{8}$$

where row α_i describes the i-th alternative, represented by the point A_i in the K-dimensional space $\mathbb{R}^K$. Then the variance-covariance matrix is computed to reduce the K-dimensional space to 2-dimensional plane (9):

$$tC = PSV^T * PSV \tag{9}$$

where T is transposition, C is a variance-covariance matrix, and t is a positive integer. For matrix C, the eigenvalues $\lambda = \{\lambda_1, \ldots, \lambda_K\}$ are determined, and the eigenvectors $u \perp v$ correspond to the two largest eigenvalues. These are column vectors that make up the 2-dimensional $\mathbb{R}^2$ plane. These vectors determine the coordinates of each point A_i on the plane, according to the formula (10):

$$\begin{cases} u_i = \alpha_i * u \\ v_i = \alpha_i * v \end{cases} \tag{10}$$

Along with the alternatives, vectors representing the views of decision makers are also included at the GAIA plane. These vectors are generated using the formula (11):

$$\begin{cases} u_k^{DM} = e_k * u \\ v_k^{DM} = e_k * v \end{cases} \tag{11}$$

where e_k is the k-th row of the identity matrix of the size K × K. The vector π is also presented on the GAIA plane, representing the direction of searching for the best solution. Its coordinates are determined based on the formula (12):

$$\begin{cases} u^{\pi} = \omega * u \\ v^{\pi} = \omega * v \end{cases} \tag{12}$$

where ω is the vector of the normalized weights of the decision-makers. Note that due to the reduction of the K-dimensional space to a plane, some information is lost. The amount of information transferred to the 2-dimensional space is represented by the δ value calculated using the formula (13):

$$\delta = \frac{\lambda_u + \lambda_v}{\sum_{k=1}^{K} \lambda_k} \tag{13}$$

By analysing the GAIA plane, one can obtain information on the preferences of decision-makers and their impact. The more the vector u_k^{DM} is directed towards the point A_i and the closer the tip of the vector is to this point, the more k-th decision maker prefers the alternative a_i. If the vector u_k^{DM} is directed opposite to the point A_i, it means that the

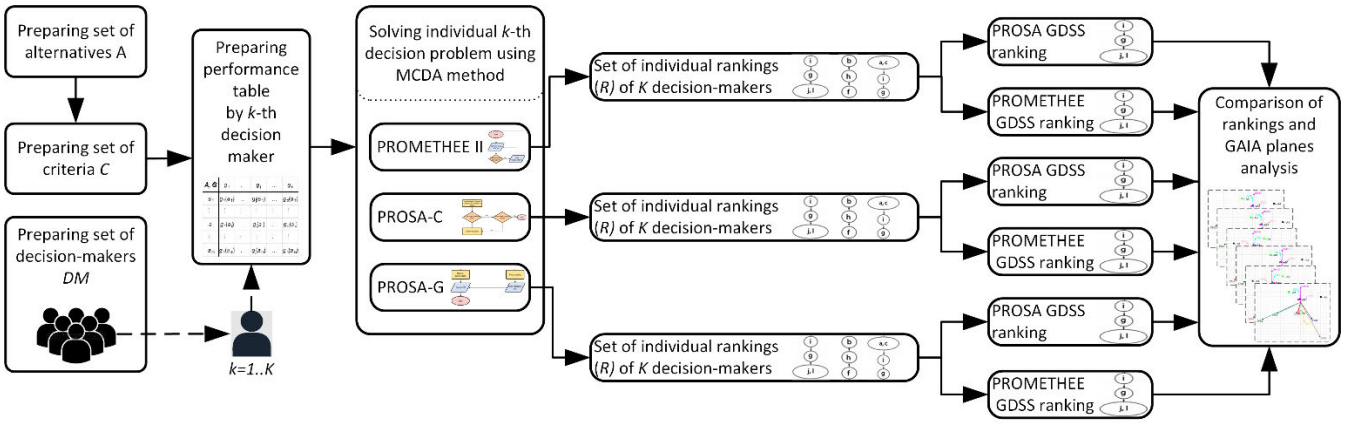

FIGURE 1. Research procedure.

decision maker negates the alternative a_i. When the points A_i, A_j are close to each other, it means that the alternatives a_i, a_j are similar to each other. The length of the vector u_k^{DM} symbolizes the influence of the k-th decision maker on the final solution: the longer the vector, the greater the impact. If the vectors u_k^{DM}, u_l^{DM} have a similar direction, it means that the preferences of these decision makers are similar, when the indicated vectors are orthogonal, then the preferences are unrelated, while the opposite directions of the vectors indicate a conflict between the views of the decision makers. In a situation where the GAIA analysis shows that the preferences of decision makers are in great conflict with each other, it is recommended to change the weights of decision-makers, change individual assessments, change criteria, change alternatives, add another decision-maker. The subsequent steps are necessary if the earlier steps do not bring the expected results in the form of conflict elimination [34].

B. PROCEDURE FOR ASSESSING THE QUALITY OF e-COMMERCE WEBSITES BASED ON THE PROSA GDSS

The quality assessment of the largest e-commerce websites available in Poland has been carried out on the basis of a three-stage calculation procedure used in the PROMETHEE GDSS and PROSA GDSS methods. The evaluation procedure has been extended to include the aspect of comparing the results obtained with the various combinations of MCDA methods used in the various stages of the calculations. The diagram of the research procedure is shown in Figure 1.

In the first stage, a set of alternatives and a set of criteria have been defined. Five e-commerce websites popular in Poland, offering the widest range of goods, were considered to be a set of decision-making alternatives: A1 – pl.aliexpress.com, A2 – allegro.pl, A3 - amazon.pl, A4 - pl.banggood.com, A5 – ebay.pl. The set of criteria was taken directly from the eQual quality model, consisting of 22 characteristics grouped in 3 dimensions and 5 quality subdimensions. The characteristics are assessed using a 7-point Likert scale and this criteria evaluation scale was also used in the research procedure. The set of criteria, along with the groups and subgroups of criteria, are presented in Table 2.

In addition to criteria and alternatives, decision makers should also be mentioned here. At this stage, decision makers have been recruited to evaluate the examined websites. They were Polish citizens and each of them had experience in using at least three e-commerce websites surveyed. Additionally, prior to the assessment, they got acquainted with websites that they had not used before. The selection of decision-makers reflected the dominant demographic profile of e-commerce website users in Poland [65]. There were five men and five women, aged 22-50. Four people (two men and two women) were residents of respectively: a city with up to 200,000 inhabitants and a city of over 200,000 inhabitants, and the other two people were residents of the village.

In the second step, ten decision makers assessed each of the alternatives against the indicated criteria. At this stage, a unified model of preferences was used for all decision-makers and an assumption was made about equal weights of all criteria in order to avoid the impact of individual preferences of decision-makers on the final ranking. In this way, only the evaluations of individual criteria assigned to alternatives by decision makers has an impact on the obtained ranking. It allowed to directly compare the results of criteria aggregation obtained with the use of different MCDA methods, acceptable in the PROSA GDSS computational procedure. It should be noted, however, that in the PROSA GDSS procedure, there are no obstacles for each of the decision-makers to use their own model of preferences at this stage. To aggregate the evaluation of the criteria, the PROMETHEE II, PROSA-C and PROSA-G methods were used individually for each of the decision makers, obtaining three groups of rankings, ten individual rankings in each group.

The third step was to aggregate individual rankings into a group ranking using the PROSA method. This aggregation was performed separately for each of the three groups of individual rankings. Therefore, three separate PROSA GDSS group rankings have been obtained for individual rankings using the PROMETHEE II, PROSA-C and

TABLE 2. Assessment criteria used in assessing the quality of e-commerce websites.

No	Group	Subgroup	Criterion
C1	Usability	Usability	I find the site easy to learn to operate
C2			My interaction with the site is clear and understandable
C3			I find the site easy to navigate
C4			I find the site easy to use
C5		Design	The site has an attractive appearance
C6			The design is appropriate to the type of site
C7			The site conveys a sense of competency
C8			The site creates a positive experience for me
C9	Information quality	Information quality	Provides accurate information
C10			Provides believable information
C11			Provides timely information
C12			Provides relevant information
C13			Provides easy to understand information
C14			Provides information at the right level of detail
C15			Presents the information in an appropriate format
C16	Service interaction	Trust	Has a good reputation
C17			It feels safe to complete transactions
C18			My personal information feels secure
C19			I feel confident that goods/services will be delivered as promised
C20		Empathy	Creates a sense of personalization
C21			Conveys a sense of community
C22			Makes it easy to communicate with the organization

TABLE 3. Preference model used in individual assessment of alternatives by decision makers.

Criterion	Preference direction	Value scale	Preference function	Preference threshold (p)	Sustainability coefficient (s)
C1 - C22	Max	[1-7]	V-shape	6	0.3

PROSA-G methods. In addition, for comparative purposes, the same individual rankings were aggregated using the PROMETHEE II method, obtaining three group rankings of PROMETHEE GDSS. This allowed the rankings of e-commerce websites obtained using different sets of MCDA methods to be compared. Furthermore, for each of the obtained group solutions, the GAIA plane was also generated and the analysis of conflicts between decision-makers was performed.

IV. RESULTS

As noted in section 3, the evaluation of e-commerce websites has been carried out by ten decision makers based on one common preference model. Table 3 shows the preference model and Appendix A provides individual assessments of alternatives for each of the ten decision makers.

As a result of aggregation of evaluation using the PROMETHEE II, PROSA-C and PROSA-G methods, individual rankings of alternatives were obtained, presented in Table 4. When analysing individual rankings, it should be noted that the orders of alternatives may vary to some extent depending on the applied MCDM method. This is despite the fact that in reality the PROMETHEE II, PROSA-C and PROSA-G methods are very similar to each other, because the PROSA methods are derived directly from PROMETHEE II. This can be seen in the rankings of decision maker 8 and 9. In the case of decision-maker 8, the PROSA-C ranking differs from the rankings PROMETHEE II and PROSA-G in the order of positions 4 and 5. However, in the case of decision maker 9, there is a difference between the ranking PROMETHEE II and the PROSA-C, PROSA-G rankings. Again, this is the difference in the last two positions of the rankings. Based on Table 4, it is difficult to indicate the similarities of the preferences of decision makers. It can be indicated that the views of the decision makers DM1:DM4:DM7 and DM2:DM6 are to some extent similar, but this analysis is difficult to carry out without studying the correlation. Therefore, the correlations between the rankings of decision makers were additionally examined. For this purpose, Kendall's tau was used, as suggested in the literature [66]. The correlation values presented in Table 5 confirm the observations on the similarities between the rankings of decision makers, indicating also opposing views and several less statistically significant similarities and conflicts.

TABLE 4. Individual results and rankings of alternatives.

Method		PROMETHEE II (ϕ^k_{net})					PROSA-C (PSV^k_{net})					PROSA-G ($PSVg^k_{net}$)				
Alternative		A1	A2	A3	A4	A5	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5
DM1	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	-.144	.206	-.078	.017	-.002	-.187	.162	-.140	-.016	-.064	-.156	.178	-.129	-.001	-.056
(k=1)	Rank	5	1	4	2	3	5	1	4	2	3	5	1	4	2	3
DM2	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	.008	.197	.292	-.494	-.002	-.023	.173	.278	-.528	-.026	.005	.192	.289	-.508	-.011
(k=2)	Rank	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4
DM3	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	-.066	.028	-.133	-.085	.256	-.104	-.019	-.171	-.123	.236	-.086	.001	-.141	-.096	.252
(k=3)	Rank	3	2	5	4	1	3	2	5	4	1	3	2	5	4	1
DM4	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	-.013	.214	-.373	.205	-.032	-.041	.190	-.395	.172	-.101	-.028	.213	-.377	.186	-.070
(k=4)	Rank	3	1	5	2	4	3	1	5	2	4	3	1	5	2	4
DM5	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	-.140	-.036	.172	.030	-.027	-.186	-.114	.140	-.024	-.055	-.180	-.108	.153	.010	-.038
(k=5)	Rank	5	4	1	2	3	5	4	1	2	3	5	4	1	2	3
DM6	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	-.047	.114	.152	-.313	.095	-.087	.082	.116	-.360	.051	-.069	.098	.149	-.323	.073
(k=6)	Rank	4	2	1	5	3	4	2	1	5	3	4	2	1	5	3
DM7	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	-.150	.163	-.093	.210	-.131	-.188	.132	-.137	.180	-.182	-.181	.136	-.119	.197	-.167
(k=7)	Rank	5	2	3	1	4	5	2	3	1	4	5	2	3	1	4
DM8	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	.112	.055	-.059	-.030	-.078	.091	.026	-.100	-.073	-.094	.108	.046	-.071	-.046	-.082
(k=8)	Rank	1	2	4	3	5	1	2	5	3	4	1	2	4	3	5
DM9	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	.013	-.129	-.119	.051	.184	-.040	-.166	-.168	.027	.148	-.007	-.141	-.143	.040	.157
(k=9)	Rank	3	5	4	2	1	3	4	5	2	1	3	4	5	2	1
DM10	$\phi^k_{net}/PSV^k_{net}/PSVg^k_{net}$	.087	-.140	.049	.011	-.008	.029	-.190	.025	-.026	-.042	.038	-.162	.035	-.005	-.033
(k=10)	Rank	1	5	2	3	4	1	5	2	3	4	1	5	2	3	4

TABLE 5. Kendall's tau correlations between individual expert rankings.

	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
DM1	-0.20	0.20	0.60	0.00	0.00	0.60	0.07	-0.07	-0.80
DM2		-0.20	-0.20	0.00	0.80	-0.20	-0.07	-0.73	0.00
DM3			0.20	-0.40	0.00	-0.20	0.07	0.33	-0.40
DM4				-0.40	-0.40	0.20	0.47	-0.07	-0.40
DM5					0.20	0.40	-0.67	-0.13	0.20
DM6						0.00	-0.27	-0.53	-0.20
DM7							-0.07	-0.07	-0.40
DM8								-0.19	0.13
DM9									-0.13

TABLE 6. The preference model used in the group assessment.

Decision-maker	Preference direction	Net value scale	Preference function	Preference threshold (p)	Sustainability coefficient (s)
DM1–DM10	Max	[≈-1, ≈1]	V-shape	2	0.3

The next step was the aggregation of individual rankings into a group ranking. It was carried out using the preference model described in Table 6. Individual rankings obtained using the PROMETHEE II, PROSA-C and PROSA-G methods were aggregated separately. Additionally, the aggregation was performed using two methods: PROMETHEE II (in the PROMETHEE GDSS procedure) and PROSA-C (in the authorial PROSA GDSS procedure). As a result, six different group rankings, presented in Table 7, were obtained. The results presented in Table 7 vary depending on the applied MCDM methods. This is true for the MCDM method used primarily in the third step of the GDSS procedure. Regarding the difference between the results depending on the methods used in the second step, these differences only appeared when the aggregation method PROMETHEE was used in the third step. However, such differences did not appear when PROSA aggregation was used in the third step. This allows to conclude that the PROSA method may give more stable results

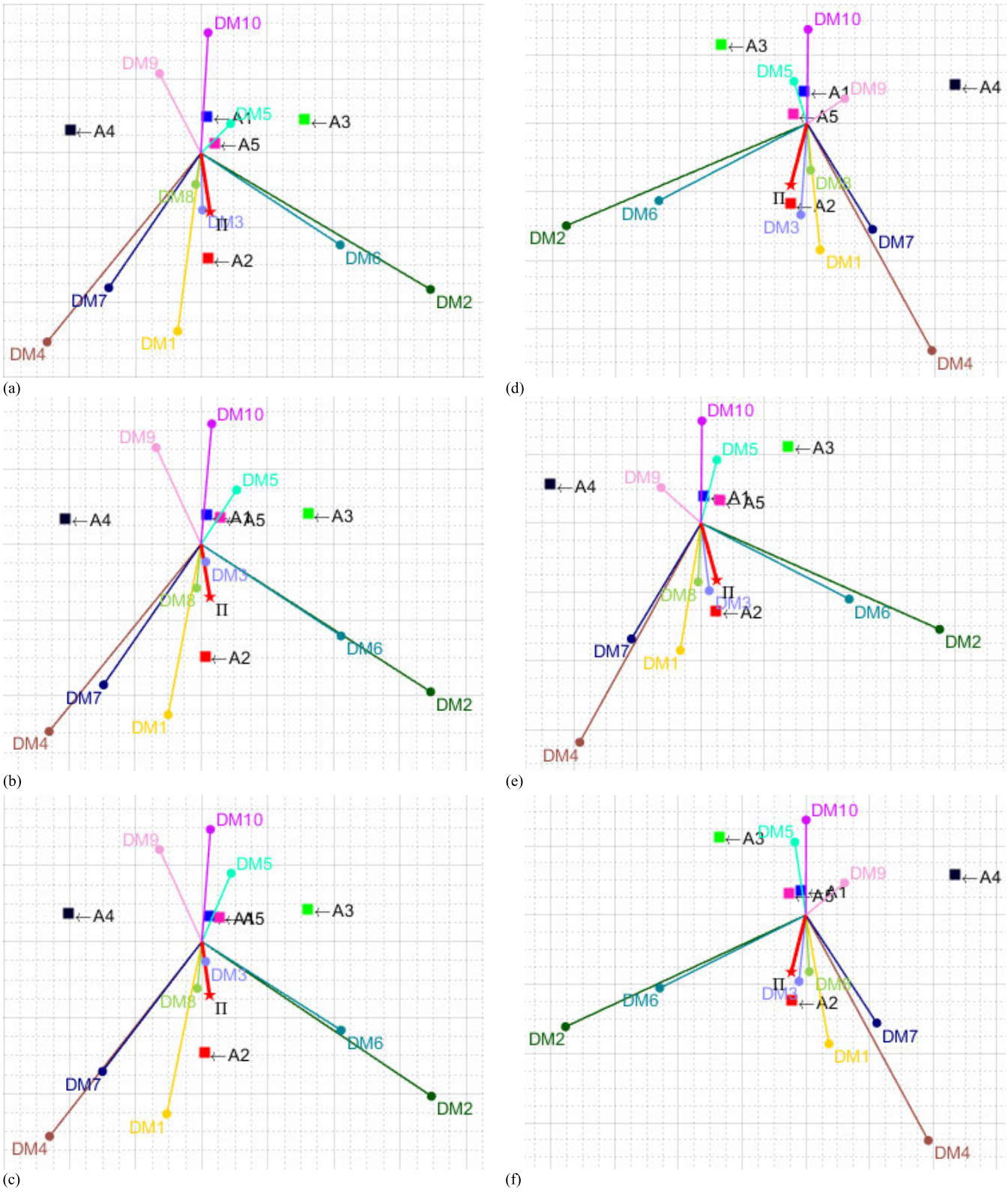

FIGURE 2. GAIA planes obtained using the following aggregation methods: (a) PROMETHEE II + PROMETHEE GDSS; (b) PROSA-C + PROMETHEE GDSS; (c) PROSA-G + PROMETHEE GDSS; (d) PROMETHEE II + PROSA GDSS; (e) PROSA-C + PROSA GDSS; (f) PROSA-G + PROSA GDSS.

than PROMETHEE. In particular, the PROSA GDSS is less sensitive to the method used in the individual assessment compared to the PROMETHEE GDSS. As for the differences in the results between PROSA and PROMETHEE at the stage

TABLE 7. Group rankings of alternatives.

Stage III	PROMETHEE GDSS						PROSA GDSS					
Stage II	PROMETHEE II		PROSA-C		PROSA-G		PROMETHEE II		PROSA-C		PROSA-G	
	Net	Rank	Net	Rank	Net	Rank	Net	Rank	Net	Rank	Net	Rank
A1	-.021	4	-.022	4	-.023	5	-.035	3	-.036	3	-.036	3
A2	.042	1	.041	1	.041	1	.021	1	.019	1	.018	1
A3	-.012	3	-.011	3	-.010	3	-.040	4	-.040	4	-.039	4
A4	-.025	5	-.024	5	-.022	4	-.054	5	-.054	5	-.051	5
A5	.016	2	.016	2	.014	2	-.001	2	-.002	2	-.004	2

TABLE 8. Evaluations of alternative e-commerce websites by decision maker 1.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	5	4	5	5	5	3	4	4	3	5	6	4	5	6	4	3	4	5	5	5	4	4
A2	7	7	7	7	5	6	7	7	6	6	5	5	6	6	5	6	7	7	6	7	4	6
A3	4	4	4	3	3	5	5	3	4	6	5	5	5	5	4	6	7	7	7	3	3	7
A4	6	6	6	6	7	5	5	5	5	5	7	5	5	5	6	5	5	5	5	3	3	5
A5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	3	1	6	1	1	6

TABLE 9. Evaluations of alternative e-commerce websites by decision maker 2.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	6	5	6	7	5	5	5	6	7	6	4	5	6	6	4	6	6	5	6	6	6	5
A2	7	7	7	7	5	7	6	6	6	7	6	6	7	6	6	7	7	7	7	6	6	7
A3	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7
A4	3	4	3	3	2	2	2	4	3	3	5	3	3	3	4	4	3	3	3	4	3	3
A5	5	6	6	6	6	6	6	5	6	5	5	5	5	6	5	6	6	5	6	5	5	6

of aggregating group assessments, in the case under study these differences appear in positions 3-5 in the rankings, while two leading alternatives remain unchanged.

GAIA is an important element of the PROMETHEE/PROSA GDSS procedure. The GAIA planes for each of the six group solutions are shown in Figure 2. For each plane in Figure 2, the δ value ranged from 0.77 to 0.79, so almost 80% of information about the decision problem and its solution is presented on each of the GAIA planes. Each of the GAIA planes presents similar information, and the differences essentially come down to slightly different vector lengths representing the discriminatory power of individual decision makers. On each of the planes, a certain similarity of individual ratings of the A1 and A5 alternatives in the rankings and a strong differentiation of the other alternatives can be noticed. Referring to Table 5 describing the correlations between the rankings of decision makers, the GAIA planes clearly show the similarity of the preferences of DM4:DM7 decision makers and DM1:DM3 similar to them to some extent, as well as the similarity of the preferences of DM2:DM6. Moreover, there is a conflict between the preferences of DM1:DM10, DM2:DM9, DM6:DM9. Analysing the GAIA plane, it can be seen that the A2 alternative is supported by the majority of decision makers: DM1-DM4, DM6-DM8. In opposition to them are the preferences of decision makers DM5, DM9, DM10. Due to the partial loss of information when reducing the problem from K-dimensional space to two dimensions, not all information can be read, but the most important data has been presented graphically and therefore easy to capture and analyse. Of course, the GAIA analysis is only an aid in the decision problem analysis and the observed dependencies should always be verified on the basis of numerical data.

V. CONCLUSION

The article deals with the problem of evaluating websites operating on the Polish e-commerce market. As part of the review work, the current situation and trends in the e-commerce market were analysed and the importance of the quality of e-commerce websites for customer retention and development of this market was shown. At the same time it was indicated that the quality assessment is a multi-criteria problem and is currently performed with the use of MCDM methods, which was confirmed by a wide literature review on this subject. Due to the fact that the quality of websites is often assessed by a group of users rather than by a single expert, group MCDM (MCGDM) methods are used. Taking into account the importance of outliers and consensus,

TABLE 10. Evaluations of alternative e-commerce websites by decision maker 3.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	5	5	6	4	4	4	5	6	5	5	7	5	5	5	6	6	6	6	6	5	5	6
A2	7	5	7	6	6	7	7	6	6	4	6	6	6	6	6	6	7	7	4	5	2	5
A3	5	5	3	6	5	5	6	4	6	5	6	5	5	6	4	5	5	4	4	5	6	5
A4	4	4	5	5	5	6	6	6	7	4	7	4	5	5	4	4	6	6	5	6	5	6
A5	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6	7

TABLE 11. Evaluations of alternative e-commerce websites by decision maker 4.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	4	4	5	5	4	5	5	4	6	5	5	5	4	5	4	5	6	5	5	5	4	5
A2	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	6	6
A3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3
A4	5	6	6	6	5	6	5	6	6	5	7	6	6	5	5	5	6	7	6	7	6	6
A5	7	7	6	6	3	6	5	1	5	4	6	6	7	4	5	5	5	5	2	2	1	5

TABLE 12. Evaluations of alternative e-commerce websites by decision maker 5.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	5	5	3	3	2	5	4	3	4	4	5	5	5	5	5	6	6	6	6	4	4	4
A2	7	7	6	7	7	7	5	4	5	6	6	6	5	6	5	3	4	3	5	3	2	1
A3	6	6	6	6	5	5	6	6	6	6	6	6	6	6	6	6	7	6	7	5	6	7
A4	6	7	4	7	4	6	5	7	4	6	4	7	6	3	4	7	6	4	6	6	5	3
A5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5

TABLE 13. Evaluations of alternative e-commerce websites by decision maker 6.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	6	6	6	7	5	6	6	6	6	6	5	6	5	5	6	4	4	4	7	3	5	7
A2	6	7	6	6	6	6	6	7	6	6	6	6	7	5	6	7	7	7	7	6	6	6
A3	7	7	7	7	5	7	5	7	7	7	4	7	7	7	7	7	7	7	7	5	5	6
A4	2	3	4	5	6	5	5	5	5	4	3	4	4	4	4	5	4	4	3	4	4	6
A5	7	7	7	7	4	4	5	5	7	7	7	7	7	6	6	6	7	6	6	6	6	6

TABLE 14. Evaluations of alternative e-commerce websites by decision maker 7.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	5	5	5	5	4	5	6	4	5	5	6	5	5	6	5	6	6	6	6	4	4	6
A2	7	7	6	7	7	7	7	7	7	7	7	7	7	7	6	7	6	7	6	6	6	6
A3	6	6	6	7	7	7	6	6	5	3	4	4	5	5	4	7	7	6	4	4	4	7
A4	7	7	7	7	7	7	7	7	7	7	5	7	7	7	7	7	7	7	7	7	7	7
A5	7	6	6	6	7	6	7	5	4	3	4	4	4	3	5	5	7	7	5	6	5	4

the assessment indicated the need to develop a new MCGDM method, applicable, among others, in assessing the quality of websites. The PROSA GDSS method was based on the PROMETHEE GDSS and PROSA-C methods, also developing the GAIA graphical method for it. Using the developed methodological tools, a group evaluation of websites operating on the Polish e-commerce market, and at the same time offering the largest range of goods, was performed.

As part of the assessment, it was found that Allegro is the dominant e-commerce website on the Polish market, and Ebay.pl comes second. Amazon.pl and Aliexpress are competing for the third position. Banggood takes the last place

TABLE 15. Evaluations of alternative e-commerce websites by decision maker 8.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	6	6	6	6	5	6	6	6	7	6	5	6	6	6	6	6	6	6	6	5	4	6
A2	6	6	6	6	6	6	6	4	6	6	6	6	6	6	5	7	5	6	5	4	4	4
A3	5	6	5	5	2	6	5	5	6	6	4	4	5	6	5	5	5	4	6	5	5	5
A4	7	4	7	7	5	5	5	5	5	6	7	4	4	5	5	5	5	6	4	4	4	4
A5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5

TABLE 16. Evaluations of alternative e-commerce websites by decision maker 9.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	7	7	7	7	5	3	5	6	7	6	7	7	5	7	5	5	6	6	6	4	4	1
A2	4	5	5	5	6	6	6	4	5	5	6	6	5	6	5	4	5	5	5	4	3	3
A3	6	6	5	6	5	6	4	5	5	5	5	5	4	4	4	5	4	4	4	7	6	4
A4	6	6	6	6	6	6	6	7	7	6	6	6	6	6	6	5	6	6	6	4	4	4
A5	6	6	7	6	7	6	6	7	7	7	6	6	6	6	6	6	6	7	6	7	7	7

TABLE 17. Evaluations of alternative e-commerce websites by decision maker 10.

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	7	7	6	6	7	7	7	5	7	7	7	7	5	5	7	6	6	4	4	3	3	5
A2	5	6	5	6	3	4	3	3	4	4	6	6	5	4	4	6	5	7	7	4	3	4
A3	6	5	5	5	5	6	6	5	6	6	6	6	6	6	5	6	6	6	6	5	5	6
A4	7	6	6	6	5	6	6	5	5	6	4	5	6	5	6	5	6	5	7	5	2	6
A5	6	6	5	5	3	6	5	5	5	6	5	5	6	5	4	6	7	7	6	5	5	5

among the assessed websites. Summarizing these results, it is necessary to point out their high credibility. Allegro is the largest auction website in Poland and one of the largest trading platforms. Ebay.pl has been available on the Polish e-commerce market for a long time and, although it is not able to threaten Allegro, it has had a stable position on the Polish e-commerce market. Amazon.pl entered the Polish market in March 2021 and has not yet manager to achieve a stable market position, while Aliexpress has an established popularity. On the other hand, it should be expected that Amazon.pl, like Allegro and Ebay.pl, will be gaining the market because they are local websites, and thus, among others, more trustworthy and more adapted to the mentality of the local audience. Meanwhile, Aliexpress and Banggood are foreign websites and are associated with, among others, tax risks (goods are shipped from abroad, from outside the euro area). These websites are also adapted to slightly different users (mental differences). At the same time, it should be noted that Banggood is the least popular among the assessed websites in Poland, which was reflected in the results of the assessment.

As for the directions of further work, they will concern the development of the PROSA GDSS method by allowing it to take into account the stochastic and fuzzy uncertainty [67]. In the context of the evaluation of Internet services, this could give, among others, the opportunity to simulate social preferences [63]. At the same time, this would eliminate the basic limitation of the proposed methodology, which is limited to a few, and at most several dozen, decision makers.

APPENDIX A

See Tables 8–17.

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