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Integrated Approach to e-Commerce Websites Evaluation with the Use of Surveys and Eye Tracking Based Experiments

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***Abstract*—Due to high availability of e-commerce websites providing similar services and products, the website usability becomes one of the most critical factors affecting online businesses' success. Therefore, website quality and user experience evaluation is an important research task. There are multiple methodologies for performing the evaluation. The proposed in our earlier studies PEQUAL methodology extends the classical eQual method by taking into account different aspects of preference modeling and aggregation derived from Multi-Criteria Decision Analysis (MCDA). This paper extends the PEQUAL methodology further by incorporating eye tracking based measurement and analysis into the criteria set. The results of the conducted empirical verification of proposed approach are presented.**

I. Introduction

IN JANUARY 2017 out of the total world population of 7.5 billion people, 50% were Internet users and 66% used mobile devices [1]. A growth of 482 million users, i.e. 21%, was observed among active social media users since January 2016. According to January 2016 data [2], 79% of UK population searched online for a product or service to buy at least once within a 30-days period and 77% made a purchase. In 2015, the total value of online sales in Europe was 455 billion euro [3], compared to 131.61 billion euro in 2013 and 156.28 billion euro in 2014.

The competition in e-commerce is high. In June 2016 there were 12 million stores online, however only 650 thousands of them (5.4%) sold more than $1,000 per year [4]. With such hot competition, entrepreneurs try to increase their chances by marketing and using analytic tools [5], refactoring the usability of the website and its assessment [6], providing web content accessibility [7] or ascertaining credibility of the website [8]. The credibility is the perception of being trustworthy and believable and it can be built, among other things, by providing great user experience and high levels of usability and quality [8].

With such a tough competition, it is beneficial to evaluate the websites' quality, usability and user experience [9]. There are multiple website and e-commerce evaluation methods, including eQual[10], SiteQual [11], E-S-QUAL [12] to name just a few. The methods differ in the range of possible applications, assessment scale used, their theoretical basis, verification of solution or minimum number of evaluators.

Since the websites quality evaluation is a multi-criteria problem, the Multi-Criteria Decision Analysis (MCDA) methods can be used to approach it, such as TOPSIS [13] or PROMETHEE [14] in their classic or fuzzy variants [15] [16]. Also a hybrid approach is possible that combines the classic methods with MCDA methods, such as PEQUAL [17].

The aforementioned methods are commonly based on survey data, which causes some problems. The number of questions needs to be limited so the survey is manageable for the respondents. Also real users from the target group should be involved in response collecting process [10]. On the other hand, a growing popularity of research tools based on eye tracking can be observed. Originally they were used mainly in medicine, however, currently we can also find studies on user experience [18], website quality [19] and usability evaluation [20] founded on the data collected with these tools [21].

While numerous studies based on eye tracking and survey website evaluation can be found, the lack of integrated eye tracking and MCDA approach is observed. Therefore, the combination of the eye tracking tools' results and the MCDA methods foundations constitue an interesting research gap, which this paper is addressing. The main objective of this paper is to extend the PEQUAL website quality evaluation model of the world most popular e-commerce websites by combining the EQUAL criteria survey data with the perceptual measurements criteria. An eye-tracking device has been used to collect selected metrics and they have been included into the PEQUAL method.

The paper is split into sections. Section II contains literature review. The methodological framework of the proposed approach is presented in section III. Section IV contains

empirical study results. The conclusions and future directions are outlined in section V.

II. Literature Review

A. Website Quality, Usability and User Experience

It has been noted in [32] and [33] that the focus time span of the average human is eight seconds. Therefore, the websites' designers must create the websites in a manner that the user will be able to find all sought data easily within this time. In other terms, the website needs to be characterized by high levels of quality, usability and user experience.

As noted in [34], the quality and usability are terms related to each other. The ISO 9241-11:1998 standard [35] defines usability as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use", and the ISO 25010:2011 standard [36] defines it as "the ability of software to be in intelligible, easy to learn and use as well as attractive to the user in specified circumstances".

The authors of [9] point out that it is beneficial to evaluate the quality, usability and user experience of a website. It is especially important, considered the systems' usability changes over time, depending among other things on the user preferences or software and hardware evolution [34].

The authors of [37] grouped the usability evaluation methods into five groups: user testing, inspection methods, inquiry methods, analytical modeling and simulation methods. The website quality evaluation methods, on the other hand, can be split into three groups [38]: expert evaluation, user traces analysis, interviews and surveys.

B. Classic Website Evaluation Methods

The methods employed in websites evaluation differ in the type, quantity and structure of criteria used. However, they often follow the same procedure, where initially the users' thoughts are obtained by surveys or questionnaires, and later the responses are put on a Likert scale. The actual degree of the scale depends on the method.

The Ahn method utilizes the Technology Acceptance Model (TAM) provided by Davis [39]. It can be used for evaluation of e-banking and e-commerce. It utilizes 54 criteria with assessment scale of 1-7. Consistency reliability of the questionnaires is performed [40]. The SiteQual method [41] is based on the set of 28 criteria, each assessed in the scale of 1-9. It utilizes the SERVQUAL service quality instrument [42] and information quality criteria to allow B2C websites quality evaluation [11]. The E-S-QUAL [12] and E-RecS-Qual methods evolved from the SERVQUAL technique and can be utilized for the evaluation of e-banking and e-commerce. They are based on two sets of 22 and 11 criteria assessed in the scale of 1-5 [43]. The Website Attribute Evaluation System (WAES) method [44] is intended for surveying office and organization sites. It is an expert evaluation method of examining the website quality. The Website Evaluation Questionnaire (WEQ) [45] is a research-tool developed for informational websites evaluation. It uses 18 criteria and additional 8 negative criteria for verification. Web Portal Site Quality (WPSQ) method [46] provides means to evaluate information portals, and the obtained solution is then verified by a set of complex reliability tests. The Website Quality Model (WQM) method [47] uses the Kano quality model, in which there are three levels of clients' desires: essential, execution and energizing.

Last, but not least, one of the most popular websites evaluation methods is the eQual method [10]. It has been successfully used for the evaluation of e-commerce, e-government, university websites and WAP websites. It uses 22 criteria divided into Usability, Information Quality and Service Interaction quality groups. The Usability group is further divided into Usability and Design subcategories, and the Service Interaction quality group is further divided into Trust and Empathy subcategories.

C. Eye Tracking Devices in Website Evaluation

As it was pointed out, the original area of the eye tracking (ET) usage has been significantly expanded with new research areas. The usability testing and user experience (UX) is one of the current, dynamically developing environments. UX is a concept related to usability and it is defined as "a momentary, primarily evaluative feeling (good-bad) while interacting with a product or service" [48]. Literature review provides a broad overview of the use of ET in these fields. In categorizing this area, two groups of the eye tracking applications can be identified in the usability research:

- ET based usability studies,
- ET + surveys based approaches.

The fundamental difference between these groups is that group II includes usability evaluation surveys either before or after the ET study, and in the case of group I, the usability assessment is based only on measurable factors, such as AOI [18], TFF, FBT [22], visits and revisits [19] or the time required to complete a given task [31]. The cited works describe the indicated measures in detail.

When analyzing the first group (see Table I), it can be observed that in many works, even the ET perceptual measurements alone are indicated as an effective tool of website evaluation. It is worth pointing out that the practical areas of the research cover various practical areas of commercial websites, such as e-commerce [18], social commerce [23], online booking [30] or tourism [24]. The principal limitation of these studies is, however, a relatively narrow focus of each of them on the selected measurement aspects, e.g. in [23] the impact of the price level, position and the presentation of the product by a famous person on the fixation time on the website and on the price is analyzed, while in [22] location typicality and efficiency in finding target web objects on the homepages was analyzed.

In the case of the second group, ET + surveys based approaches (see Table II), the vast majority of the analyzed works is oriented towards a wider usability or UX of the analyzed web pages. Thus, the introduction of the survey data into the final assessment extends the scope of the evaluation process.

TABLE I
EYE TRACKING USAGE IN WEBSITES EVALUATION

Ref.	Application	Users	Aim of the research	Data analysis methods and results	Criteria	
[18]	e-commerce websites	21	Study how the site interface affects the end user recommendation process.	Comparison of fixation times for selected AOIs for different structures and fixation times on products. ANOVA analysis was used. The total number of users who selected any product was compared to how many users selected the product in each interface, and from which AOI the highest number of products was selected.	3	number of users who chose a product, average number of products, percentage of products chosen in each AOI
[22]	online shops, online newspapers, company webpages	40	To examine the relation between location typicality and efficiency in finding target web objects on the homepages	Analysis of location typicality, time to first fixation (TFF) and fixations before target (FBT) using Wilcoxon signed-rank tests	2	TFF, FBT
[23]	social commerce	34	Analysis of the impact of the price level and position, and the presentation of the product by a famous person to the fixation time on the website and on the price.	Statistical tests for the time of fixations on the page and price, and gender comparison.	2	fixation time on the page, fixation time on the price
[20]	mobile phone manufacturers' websites	17	Website usability analysis.	ANOVA statistical analysis with the exception of response time that was tested with Chi2	5	fixation times, count, response time, time of task completion, spatial density of fixations
[24]	eTourism 2.0	60	Hypotheses analysis what kind of advertising is more effective.	Statistical analysis, t test. Three separate covariance analyses (ANCOVAs) were computed, with gender, expert level and type of advertisement as independent variables and age as metric covariate.	3	time to first fixation, fixation duration, fixations before
[25]	e-commerce	42	Examination how the website's complexity affects the user's attention and behavior, considering different cognitive loads.	ANOVA analysis was used to measure website complexity.	3	time to first fixation, fixation duration, total time
[26]	clinical guidelines on the Web	14	Study of the usefulness of the sites containing medical guidelines for doctors.	Comparison of the task success evaluation to the user experience. Overall performance of the websites was calculated with the geometric mean of the task execution time.	4	

Additionally, it should be noted that the surveys evaluations in the second group are often based on the methodological patterns from the AHN or eQual group of methods (see subsection II-B). These works have, contrarily to the ones from the first group, a broad domain scope and include the assessment of usability in the e-commerce [27], online banking [28], e-government [29] or online booking systems [30].

When analyzing the methodological aspects of the works contained in Table I and II, one should note the dominant role of the research with strong sociological rigor (oriented on the verification of the selected statistical hypotheses), and as a consequence, their methodological side is based on the statistical analysis elements, such as statistical tests or ANOVA analyzes. However, the statistical analysis techniques (correlation [27], covariance of variables [24] or ANOVA [25]) remain the basic research tool. Also in the case of the second group, the sociological cognitive tone of research remains dominant.

D. MCDA Website Evaluation Methods

Apart from the evaluation methods mentioned above, during the literature review, endeavors at utilizing the MCDA techniques for websites' assessment can be found. The MCDA approach is justified, since the evaluation of websites is a multi-criteria problem, in which multiple dimensions and measurements need to be considered [49]. For example, Chmielarz broadly utilizes scoring method to assess an extensive variety of business oriented websites [50], [51], [52]. Lee and Kozar applied the AHP method to evaluate e-tourist and e-commerce websites [53]. Sun and Lin used the fuzzy TOPSIS method to evaluate e-commerce websites [15]. Del Vasto-Terrientes et al. used the ELECTRE-III-H method on traveler websites [54]. Furthermore, hybrids of different MCDA techniques can be used [16], [55], [56].

The literature review demonstrates that the majority of the MCDA use surveys to collect data for the evaluations. The weights of the criteria are commonly compared pairwise and AHP technique is used. While most of the methods use a predetermined set of criteria, some papers used theoretical bases identifying the need for presenting both specific quality measures and criteria [54], [55].

The application of the MCDA methods to the websites' evaluation problems has a greater potential than just constructing a ranking. This can be illustrated by a model of a decision

TABLE II
EYE TRACKING COMBINED WITH SURVEYS USAGE IN WEBSITES EVALUATION

Ref.	Application	Users	Aim of the research	Data analysis methods and results	Criteria	
[27]	e-commerce, B2B	25	Study of the difference in perception of B2B sites by different cultural groups.	Calculation of the correlation, to what extend each of the 7 criteria affect the attractiveness of the pages and comparison of two cultural groups.	7	
[28]	online banking	10	Usability study of the electronic banking login interface.	The results consisted of comparison of the numerical data (criteria) obtained during the study and heat maps and AOI trajectory maps. Data obtained during the interview was analyzed.	3	time to first fixation, fixation duration, total time
[19]	e-commerce	38	Study of the impact of the presence of a human brand element on the quality of online shopping decisions	ANOVA statistical analysis.	4	viewers, first view, watched time, revisits
[9]	websites of mobile service providers (telecoms)	44	Comparative evaluation of user experience (UX) and usability.	Basic statistics. Comparison of the obtained results of each criterion for each page (min, max mean, median). For each value: job completion time, time and count of fixations since first click, time to find the target, number of pages viewed during task execution.	3	
[29]	e-government websites	9	Study of usefulness of e-government websites.	Basic statistics of the experiment and comparison of the results from the eye tracker with the results from the survey after the experiment.	3	task completion time, fixation duration, fixations count
[30]	online hotel booking websites	16 valid	The purpose of the study was to analyze the impact of images and the size of selection sets on the decision-making process of hotel reservations online.	Based on the data collected in a combined (eye tracking and surveys) experiment, hypotheses were statistically confirmed by comparing the time and number of fixations.	3	task completion time, fixation duration, fixations count
[31]	e-commerce, Amazon	30	The purpose of this study was to examine the credibility of the seller and to find the factors that influence the choice of payment methods for online purchases.	Confirmation or denial of hypotheses using statistics on the choice of payment method, with each criterion. Data analysis methods: - ANOVA for price and sales criteria in the choice of payment method. - Fixation times in AOI (price, sales) in different product types. - Logistic regression to identify factors influencing the choice of payment method.	2	task completion time, fixation duration

process defined by Guitouni [57], where exploitation and recommendation stages are important steps. On the operation stage, the analysis of the obtained solution can be performed, such as its stability examination [58], [59] or the analysis of the decision-makers' preference.

As demonstrated in [17] and [43], MCDA is an effective multi-aspect data analysis tool. However, in order to use the MCDA methodology properly, the decision support / evaluation model needs to be supplied with the complete domain data set [60], [61], [57]. The aforementioned MCDA requirements, along with the advantages of ET and ET + surveys approaches, motivate the authors' contribution to modify the approach presented in [17] and [43] and to introduce to the evaluation model the ET-based data.

III. METHODOLOGICAL FRAMEWORK

A. PEQUAL Methodological Foundations

The website evaluation procedure presented in this paper is based on the PEQUAL methodology of website quality assessment [17]. The methodology depends on the eQual and PROMETHEE II methods. The eQual method has its foundations in Quality Function Deployment. The PROMETHEE II method is a popular MCDA method that employs pairwise comparison and outranking flows to produce a ranking of best decision variants [43].

Initially, pairwise comparison of the alternatives on particular criterion is considered. The preference of one alternative over another on a criterion j can be expressed with the usage of a preference function $P_j(a, b)$, where a and b belong to the A set of alternatives. For each a and b:

$$0 \leq P_j(a, b) \leq 1 \tag{1}$$

Promethee methods offer six preference functions: usual criterion, U-shape criterion, V-shape criterion, level criterion, v-shape with indifference criterion, Gaussian criterion [14]. Next, aggregated preference index of alternatives is calculated with formula (2).

$$\begin{cases} \pi(a, b) = \sum_{j=1}^{k} P_j(a, b) w_j \\ \pi(b, a) = \sum_{j=1}^{k} P_j(b, a) w_j \end{cases} \tag{2}$$

where w_j is the weight assigned to the j-th criterion. $\pi(a, b) \sim 0$ implies a weak and $\pi(a, b) \sim 1$ implies a strong global preference of a over b.

$P_j(a, b)$, $P_j(b, a)$, $\pi(a, b)$ and $\pi(b, a)$ are real numbers without units, completely independent of the scales of the criteria.

Subsequently, the obtained indices are used to calculate positive and negative outranking flows with formulae (3) and (4) [14]:

$$\phi^{+}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a, x) \tag{3}$$

$$\phi^{-}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(x, a) \tag{4}$$

The $\phi^{+}(a)$ value represents how an alternative a is outranking other alternatives, whereas the $\phi^{-}(a)$ value shows how the alternative is outranked by the others.

Eventually, the net outranking flow is calculated as a difference between the positive and negative outranking flows:

$$\phi(a) = \phi^{+}(a) - \phi^{-}(a) \tag{5}$$

In the Promethee I method, two rankings are produced, based separately on the $\phi^{+}(a)$ and $\phi^{-}(a)$ values. In the Promethee II method, a single ranking is created, based exclusively on the $\phi(a)$ value.

B. Modified PEQUAL Framework Gaze Data Analysis

To perform the empirical research, at first, the survey results from [17] were combined with the data from a perceptual evaluation study. The original PEQUAL result set contained data collected from surveys from 41 users, who were experienced in online shopping.

The experiment result set was obtained from a group of 20 students, using an eye tracking device and GazePoint software. The same set of 10 websites as in [17] was studied: Alibaba, Amazon, Apple, BestBuy, eBay, Macy's, Rakuten, Staples, Target and Walmart. Three slides were prepared for each of the websites:

- home page – the front page of each website, containing, among other things, a product search form and a list of categories;
- product page – the main page of a single product in offer, containing a description, images and price;
- payment page – one of the last steps of the purchase transaction, the page containing the payment method choice.

Each slide from the total set of 30 slides was displayed to the participants for a period of 10 seconds, with a 3 seconds pause between slides. An area of interest (AOI) was configured on each of the slides. On the ones presenting home pages, the participants were given the task to locate a piece of electronic - either smartphone or a watch. On the product page slides, the students were supposed to locate the price. Finally, on the payment page slides, they were asked to locate the "PayPal" payment method.

During the experiment, the software collected the following data:

- E1 – viewers – number of people who have visited the configured areas of interest (AOI);
- E2 – first view [s] – time elapsed in seconds before the area was noticed for the first time;
- E3 – watched time [s] – time spent on a given AOI, expressed in seconds;
- E4 – watched time [%] – time spent on a given AOI, expressed in percent;
- E5 – revisitors – the number of participants who returned to the AOI;
- E6 – revisits – number of revisits to the AOI.

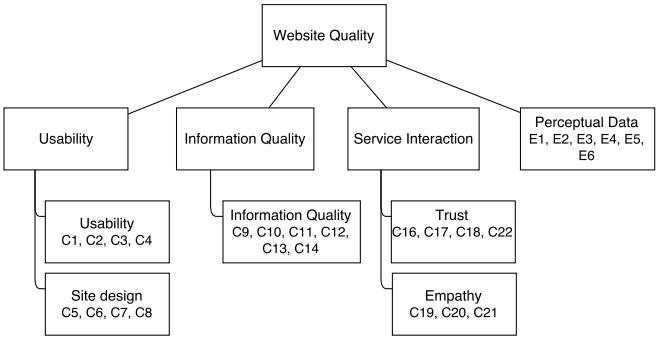

Fig. 1. Combined criteria hierarchy

Eventually, the obtained criteria E1-E6 were combined with the PEQUAL criteria C1-C22. The resulting criteria hierarchy is presented on Figure 1.

The results of the questionnaires from [17] and the empirical data from the experiment were used to build a performance table. Three scenarios were taken into consideration for the perceptual data. In the first scenario, the data regarding the home pages of the websites was used. In the second one, the data from the product pages was utilized. Finally, in the third scenario, the data from the payment pages was used.

The data in each of the scenarios was later aggregated using the Promethee II method and rankings were generated. In the next step, a broad graphical analysis of the received rankings was carried out with the usage of GAIA plane. In the third step, Promethee II and GAIA analysis was performed on the survey data combined with the averaged perceptual data. In the fourth step, sensitivity analysis was performed and stability of the obtained ranking was verified. In the next step, uncertainty analysis was performed. Finally, a comparison of the obtained ranking to a ranking based on the Gaussian preference function was performed. The results were compared to the ones received in the original PEQUAL method [17] on each step of the procedure. The presented approach is depicted in Figure 2.

IV. RESULTS

A. Promethee II Based Analysis

In the first step of the research, the averaged values from [17] were used along with the perceptual data to build a performance table for the Promethee II method. For the C1-C22 criteria, the V-shape preference function was used, with the indifference threshold q=0 and the preference threshold p=7 (maximum value in the 7-degree Likert scale used in the study), to ascertain comparability of the results received.

For the E1-E6 criteria, the V-shape preference function with indifference threshold q=0 was used as well, however, since

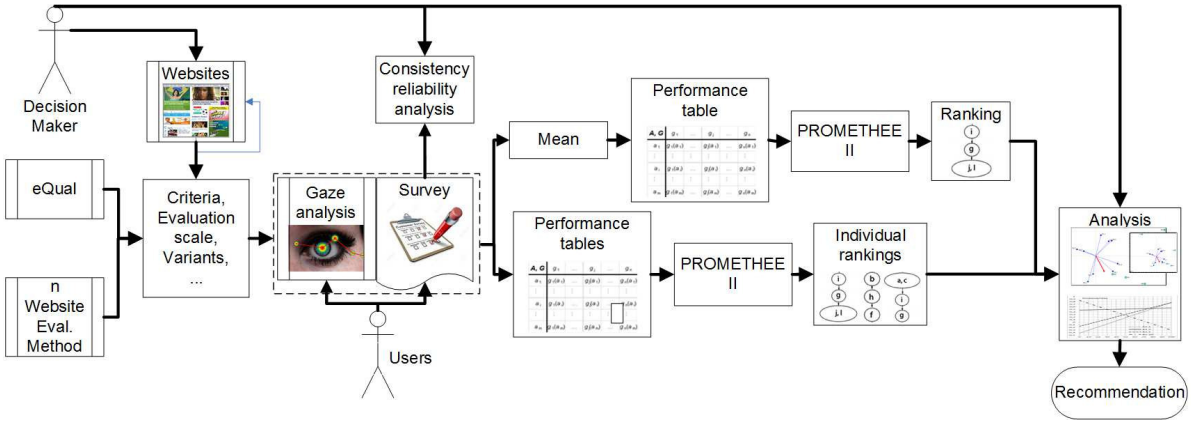

Fig. 2. Website evaluation process using PEQUAL methodology combined with perceptual evaluation criteria.

the perceptual data received is expressed in various units and scales, the preference threshold p was set for the criteria E1, E3, E4 and E5 to the maximum possible value, for the criterion E2 it was set to 5 seconds (a half of the slide display time), and for the criterion E6 it was set to 10 revisits. The preference direction for all criteria but E2 was maximized.

The weights were assigned to the criteria in a manner that the C1-C22 set of eQual survey based criteria total weight was 50% and the E1-E6 set of gaze based criteria total weight was 50%. The weights within the C1-C22 criteria set and within the E1-E6 criteria set were distributed equally, 2.27% for each C criterion and 8.34% for each E criterion. The weights distribution is presented in Table III.

For the reasons of brevity, the performance tables for scenarios 1-3 were merged into a single table. The Promethee II method was applied on each of the scenarios and the resulting rankings are presented in Table IV. The results originally obtained in [17] are presented for reference in Table V.

It can be observed that the introduction of perceptual measurements data into the analysis modified the ranking of the websites. However, the three best websites from [17] analysis, i.e. Apple, Amazon, eBay, are still in the group of the first five best websites in the combined criteria rankings. Surprisingly, the Alibaba website has dropped significantly in the new rankings, from the fourth rank to the last four ranks in the new rankings. It is visible, that the ranking varies depending on the page studied in the perceptual research. The differences might be caused by the fact that in the original study, the surveys collected opinions about the website in general. The perceptual evaluation, on the other hand, was performed on three specific pages of the website. This information can be used to find areas requiring improvement in the websites analyzed. For example, when product or payment pages are considered, Amazon receives the first rank. However, in the scenario where the users where asked to locate a piece of electronic on the home page, Amazon ranks much worse, with 5th position in the ranking. This might mean that the layout of the home page of this website does not expose electronic devices enough.

TABLE III
WEIGHTS ASSIGNED TO CRITERIA, GROUPS AND CLUSTERS.

Cluster of criteria	Group of criteria	Criterion	Weight
Usability 18.2%	Usability 9.1%	C1	2.27%
		C2	2.27%
		C3	2.27%
		C4	2.27%
	Site design 9.1%	C5	2.27%
		C6	2.27%
		C7	2.27%
		C8	2.27%
Information quality 15.9%	Information quality 15.9%	C9	2.27%
		C10	2.27%
		C11	2.27%
		C12	2.27%
		C13	2.27%
		C14	2.27%
		C15	2.27%
Service Interaction 15.9%	Trust 9.1%	C16	2.27%
		C17	2.27%
		C18	2.27%
		C22	2.27%
	Empathy 6.8%	C19	2.27%
		C20	2.27%
		C21	2.27%
Perceptual 50%	Perceptual 50%	E1	8.34%
		E2	8.34%
		E3	8.34%
		E4	8.34%
		E5	8.34%
		E6	8.34%

B. Graphical Analysis of Promethee II Solution

The results obtained by the Promethee II method were additionally analyzed using the GAIA planes. Figures 3a-i depict the scores of this analysis separately for individual criteria, groups and clusters for each of the three analyzed criteria.

TABLE IV
RANKING OF WEBSITES BASED ON PROMETHEE II AND A) HOME PAGES, B) PRODUCT PAGES, C) PAYMENT PAGES, D) AVERAGE PERCEPTUAL EVALUATION DATA (V-SHAPE PREFERENCE FUNCTION)

	Website	Alibaba	Amazon	Apple	BestBuy	eBay	Macy's	Rakuten	Staples	Target	Walmart
a	ϕ	-0.0899	0.0266	0.0547	0.0805	0.055	-0.063	-0.0324	-0.0157	0.0369	-0.0528
	Rank	10	5	3	1	2	9	7	6	4	8
b	ϕ	-0.0369	0.0565	0.032	0.0032	0.0371	0.0123	-0.0205	0.0094	-0.0331	-0.06
	Rank	9	1	3	6	2	4	7	5	8	10
c	ϕ	-0.0364	0.1136	0.0782	-0.016	0.0708	-0.0616	-0.095	0.0739	-0.1042	-0.0232
	Rank	7	1	2	5	4	8	9	3	10	6
d	ϕ	-0.0543	0.0656	0.055	0.0227	0.0543	-0.0373	-0.0491	0.0222	-0.0335	-0.0456
	Rank	10	1	2	4	3	7	9	5	6	8

TABLE V
RANKING OF WEBSITES BASED ON PROMETHEE II AND AVERAGE CRITERIA EVALUATIONS AS IN [17]

Website	Apple	Amazon	eBay	Alibaba	Walmart	Macy's	BestBuy	Staples	Rakuten	Target
ϕ	0.1037	0.0822	0.0629	-0.0137	-0.0191	-0.0272	-0.0343	-0.0380	-0.0559	-0.0607
Rank	1	2	3	4	5	6	7	8	9	10

The analysis of Figure 3a shows that the criteria support the five leading variants from ranking in Table IVa, i.e. BestBuy, eBay, Apple, Target and Amazon, in varying degrees. BestBuy, eBay and Target are supported by the perceptual criteria, while Amazon and Apple are supported by the survey criteria. The criteria E1, E5 and E2 have the highest impact on the final ranking. No conflicts are observed between the perceptual criteria, however, they are in strong conflict with the criterion C11, which means that the websites which are highly evaluated with regard to this criterion receive lower evaluation in perceptual study. Because of the length of the C11 criterion vector, the E3, E4 and E6 criteria would be affected mostly. The interpretation of this fact can be that the websites providing timely information, at the same time introduce some distraction which reduces the length of watching and the number of revisits in the AOI.

The analysis of Figure 3d demonstrates that most of the criteria, survey and perceptual alike, support the three leading websites from ranking in Table IVb. It can be observed, that the vectors of the criteria E5 and E6, as well as of the criteria E3 and E4, are pointing in very similar directions. This means that receiving higher score in E5 criterion resulted in getting higher score in E6 criterion, and similarly scoring higher in E3 resulted in better result in E4. The C5 criterion (attractive appearance of the website) is pointing in similar direction as the E1 criterion, which might mean that when the website look was more appealing, the attention of more users was attracted to the AOI. However, the rest of the perceptual criteria are in conflict with the criterion C5, which could mean, that the attractive appearance of the website resulted in smaller number of revisits, shorter watch time, as well as longer time to notice the AOI.

When analyzing the Figure 3g, one can find out that almost all criteria support the four leading websites from the ranking in Table IVc. It is confirmed by the ϕ net outranking flow values. The four leading websites have positive ϕ values, whereas the remaining six websites have negative ϕ values, which means the latter are more outranked by all the criteria.

Subsequently, an analysis of GAIA planes with groups (Figures 3b, 3e, 3h) and clusters (Figures 3c, 3f, 3i) of criteria was performed. All the six figures demonstrate that the perceptual criteria are represented on the GAIA planes by axes more-or-less orthogonal to the Service Interaction and Usability survey criteria clusters, which means that these criteria clusters are not related to each others in terms of preferences.

Figures 3b, 3c, 3e, 3f show that the Information Quality axis is less orthogonal to the Perceptual axis than the rest of the groups and clusters on the home pages and the product pages, which means that these clusters are expressing slightly similar preferences. However, figures 3h and 3i show that on the payment pages the Information Quality axis is orthogonal to the Perceptual axis, meaning they are unrelated to each other in terms of preferences. On the payment pages it is the Service Interaction cluster, and, more precisely, the Trust group, that expresses the greatest preferences' similarity to the Perceptual cluster.

C. Promethee II and GAIA Analysis Based on Averaged Perceptual Data

In the next step, the perceptual data from the 3 scenarios was averaged and only then was it combined with the survey data. Subsequently, Promethee II analysis was performed on the received data set. The ranking produced by this analysis is presented in Table IVd. It differs from the rankings calculated with the data from the separate home, product and payment page perceptual evaluations, however Amazon, Apple and eBay websites remain the leaders. It is worth noting, that in the ranking based on the averaged perceptual data, these three websites receive positions most similar to the ranks received in the original PEQUAL ranking (Table V).

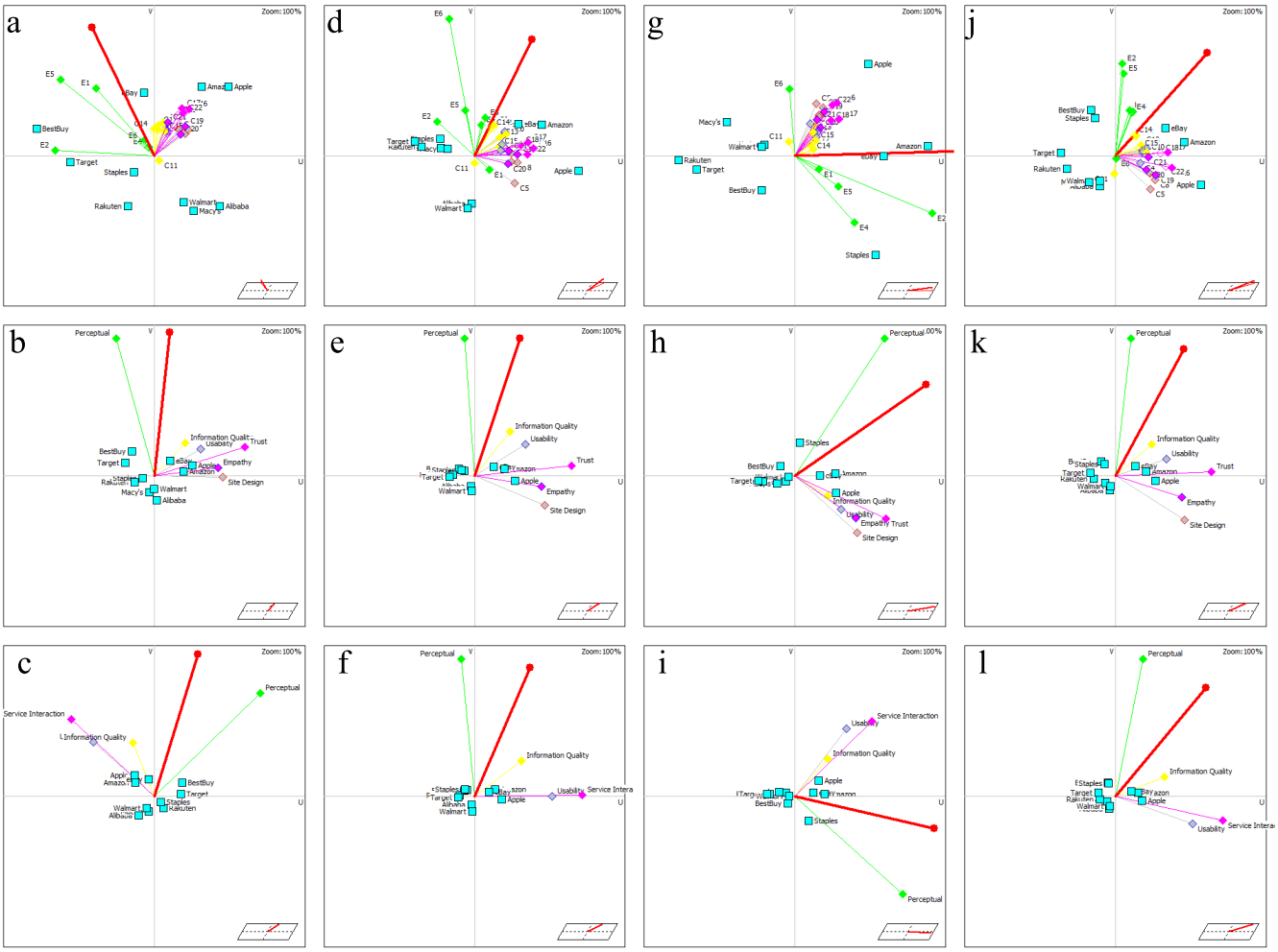

Fig. 3. GAIA analysis for home page scenario: a) criteria, b) groups, c) clusters; product page scenario d) criteria, e) groups, f) clusters; payment page scenario: g) criteria, h) groups, i) clusters; averaged data scenario: j) criteria, k) groups, l) clusters;

GAIA planes analysis was also performed for the new combined data set. Figures 3j-l depict the GAIA planes criteria, groups and criteria respectively. Figure 3j shows that the three leading websites are supported in various degrees by almost all criteria, both perceptual and survey. The websites with rank 4 and 5, i.e. BestBuy and Staples, are supported by the perceptual criteria, which explains why they advanced from ranks 7 and 8 in the ranking based on the survey data exclusively.

The analysis of the clusters in Figure 3l shows that when the averaged perceptual data from the three scenarios is used, the Service Interaction cluster is not related to the Perceptual cluster in the terms of preferences, and the Information Quality cluster expresses slightly similar preferences to the Perceptual cluster. A very small conflict can be noticed between the Usability and Perceptual clusters' preferences. The analysis of Figure 3k allows to observe that it is the Site Design group of the Usability cluster that is conflicted with the Perceptual cluster, whereas the Usability group is expressing slightly similar preferences to the Perceptual cluster.

D. Sensitivity Analysis

Apart from GAIA analysis, sensitivity analysis of the rankings, taking into account changes in weights of criteria, was performed. Table VI presents the ranges of stability for the weights of the criteria clusters.

It can be observed, that the stability of the ranking depends on the perceptual data scenario chosen. The ranking based on the payment page scenario appears to be the most stable one, and the home page scenario ranking seems to be the least stable one. It is important to notice, that the weight of the Perceptual cluster criteria cannot be reduced below some determined value.

When the results of the stability analysis are compared to the PEQUAL's one, it can be observed that the rankings based on the combined criteria are more sensitive to the weights' changes. This might be caused by the fact that only 6 perceptual criteria were added, so a change in the weight of

each of them results in more significant changes than in the case of the original 22 PEQUAL criteria.

E. Uncertainty Analysis

In the subsequent step of the analysis, the influence of the uncertainty of the partial evaluations on the sequence of the rankings was verified. The preference function was modified to V-shape with indifference area, where the preference threshold p remained unchanged and the indifference threshold was set to q=1 for the C1-C22 criteria, to remain comparable with the PEQUAL analysis in [17], and to q=10 for E1, q=9 for E2, q=1 for E3, q=10 for E4, q=10 for E5 and q=1 for E6. The obtained ranking is presented in Table VII.

There was a shift in the ranking between Amazon and Apple, also Staples received a higher rank of 2, whereas BestBuy dropped from position 4 to position 6. This is in contrast to the results obtained for the ranking based on survey data only, and is probably caused by the fact that while survey data is based on a subjective Likert scale, the perceptual data is collected with a very high precision by the eye tracking device.

F. Comparison to Gaussian Preference

In the final step of the analysis, the preference function of each of the criteria was changed to a Gaussian type, with s=3 for the criteria C1-C22, s=10 for E1 and E5, s=8 for E2, s=5 for E3 and E6 and s=50 for E4. The resulting ranking is presented in Table VIII. It is very similar to the ranking obtained with the use of V-shape function with no indifference, except the shifts on positions 1-2 and 6-7. However, the ranking obtained with the Gaussian preference function is much more stable, which fact is presented in Table IX.

V. Conclusions

E-commerce is one of the most important sectors of online business. Considering the tough rivalry in the sector and continuous evolution of software, hardware and users' preferences, it is important to perform a systematic evaluation of e-commerce websites and their comparison to the ones owned by the competitors.

The prior MCDA methods were based on data collected from surveys or interviews. Some work has been done in the area of perceptual evaluation data usage, from eye tracking or EEG devices, in websites' evaluation. The authors' contribution in this paper was to extend the preexistent MCDA methods by the application of a combined survey and perceptual evaluation criteria set. In the proposed approach, a unique multistage construction of the model was realized. A new cluster of 6 perceptual evaluation criteria was added to the set of 22 eQual survey criteria.

An experiment was conducted to investigate the top 10 most popular e-commerce sites. Survey data from PEQUAL [17] was used to allow comparative analysis between results obtained by a Promethee II analysis based on survey-only criteria and combined criteria sets. Sensitivity and uncertainty analyses of the obtained rankings was performed. A study was performed on the influence of the preference function chosen on the ranking order and its stability. The GAIA analysis allowed to examine mutual dependencies between the survey and perceptual criteria.

The survey data allows researchers to learn about users' subjective opinions on the evaluated websites. The perceptual evaluation performed with the devices such as an eye tracker, on the other hand, provides palpable, measurable data. The extension of the survey data with the perceptual evaluation data from particular websites' parts, such as the home, product or payment page, allows to create rankings of quality of those websites with special emphasis on those parts. Nevertheless, survey data provides a more general view of the evaluated websites. Therefore, it is beneficial to combine the advantages provided by the both aforementioned kinds of data.

During the research, possible areas of improvement and future work directions were identified. It would be beneficial to increase the diversity of the perceptual criteria combined to the model. Also, more areas of the website could be evaluated with the use of eye tracking devices to provide more general metrics of the website quality. In the proposed approach, all perceptual criteria were grouped into a single cluster. Further research could be performed to introduce a more comprehensive structure of the perceptual evaluation criteria.

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TABLE VI
SENSITIVITY ANALYSIS – THE RANGES OF STABILITY FOR CRITERIA CLUSTERS FOR HOME, PRODUCT AND PAYMENT PAGES AND FOR THE AVERAGED SCENARIO

Cluster of criteria	Weight	Home		Product		Payment		Average	
		Min	Max	Min	Max	Min	Max	Min	Max
Usability	18.20%	0.00%	29.26%	0.00%	45.22%	0.00%	52.25%	0.00%	32.55%
Information quality	15.90%	0.00%	40.46%	0.00%	79.85%	0.00%	89.51%	0.00%	70.46%
Service Interaction	15.90%	0.00%	25.54%	0.00%	61.69%	0.00%	69.18%	0.00%	44.54%
Perceptual	50.00%	42.15%	100.00%	23.42%	82.30%	18.93%	74.69%	33.56%	78.35%

TABLE VII
RANKING OF WEBSITES BASED ON PROMETHEE II AND AVERAGE PERCEPTUAL EVALUATION DATA FROM HOME, PRODUCT AND PAYMENT PAGES, WITH INDIFFERENCE AREA

Website	Apple	Staples	Amazon	eBay	Macy's	BestBuy	Rakuten	Target	Walmart	Alibaba
ϕ	0.0115	0.0049	0.0047	0.0019	-0.0003	-0.0017	-0.0034	-0.0035	-0.0057	-0.0085
Rank	1	2	3	4	5	6	7	8	9	10

TABLE VIII
RANKING OF WEBSITES BASED ON PROMETHEE II AND AVERAGE PERCEPTUAL EVALUATION DATA FROM HOME, PRODUCT AND PAYMENT PAGES, WITH GAUSSIAN PREFERENCE FUNCTION

Website	Apple	Amazon	eBay	BestBuy	Staples	Macy's	Target	Walmart	Rakuten	Alibaba
ϕ	0.0232	0.0201	0.0134	0.0024	0.0017	-0.0104	-0.0105	-0.0125	-0.013	-0.0145
Rank	1	2	3	4	5	6	7	8	9	10

TABLE IX
SENSITIVITY ANALYSIS FOR THE RANKING OBTAINED WITH GAUSSIAN PREFERENCE FUNCTION

Cluster of criteria	Weight	
	Min	Max
Usability	7.96%	100.00%
Information quality	0.00%	60.80%
Service Interaction	0.00%	100.00%
Perceptual	0.00%	64.92%

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APPENDIX: PERFORMANCE TABLE FOR PROMETHEE II BASED ON MEAN VALUES OF CRITERION EVALUATIONS

Group of criteria	Criterion	Website									
		Alibaba	**Amazon**	**Apple**	**BestBuy**	**eBay**	**MacyâĂŹs**	**Rakuten**	**Staples**	**Target**	**Walmart**
Usability	C1	4.902	5.610	5.683	5.000	6.024	5.049	4.976	4.927	4.854	5.049
	C2	4.951	5.707	5.415	4.878	5.951	4.976	5.098	4.927	4.756	5.220
	C3	5.000	5.317	5.610	5.000	5.610	4.854	4.805	4.829	4.683	4.829
	C4	4.829	5.390	5.585	4.878	5.634	5.049	4.854	4.659	4.854	5.244
Site design	C5	4.829	5.024	5.976	4.341	4.683	4.707	4.268	4.512	4.220	4.927
	C6	5.098	5.488	6.024	4.561	5.341	5.049	4.707	4.927	4.707	4.805
	C7	4.829	5.366	5.829	4.537	4.878	4.756	4.439	4.732	4.415	4.805
	C8	4.634	5.146	5.415	4.049	4.512	4.585	4.024	4.220	3.683	4.268
Information quality	C9	5.000	5.537	5.049	5.073	5.634	4.780	4.805	4.780	4.756	4.537
	C10	4.902	5.537	5.902	5.098	5.683	4.902	5.024	4.805	4.902	4.805
	C11	5.585	5.268	5.488	5.122	5.415	5.512	5.488	5.146	5.561	5.317
	C12	4.951	5.463	5.341	5.268	5.537	4.902	4.732	4.854	5.049	4.610
	C13	4.732	5.537	5.561	5.244	5.512	4.878	4.756	4.707	4.902	4.976
	C14	4.854	5.488	5.171	5.098	5.220	4.634	4.659	4.854	5.024	4.488
	C15	4.927	5.390	5.293	4.854	5.488	4.732	4.512	4.829	4.756	4.951
Trust	C16	4.927	5.829	5.927	4.244	5.878	4.512	4.415	4.488	4.195	4.927
	C17	4.732	5.805	6.000	4.537	5.659	4.512	4.293	4.927	4.317	4.951
	C18	4.732	5.610	5.805	4.707	5.561	4.659	4.390	4.780	4.220	4.902
	C22	4.683	5.610	6.171	4.634	5.268	4.756	4.220	4.683	4.220	4.902
Empathy	C19	3.951	4.927	4.878	3.537	4.049	3.976	3.659	3.756	3.366	3.951
	C20	3.878	4.683	4.293	3.366	3.488	3.439	3.463	3.610	3.146	3.756
	C21	4.780	5.268	5.561	4.829	5.293	4.610	4.268	4.390	4.610	4.732
Home pages	E1	10	15	14	18	16	10	12	16	17	10
	E2	5.210	5.00	4.64	1.85	3.27	4.41	3.35	3.91	3.32	3.65
	E3	0.390	0.53	1.06	0.98	0.60	0.41	0.62	0.65	0.81	0.43
	E4	3.870	5.27	10.57	9.83	6.04	4.06	6.24	6.45	8.11	4.27
	E5	6	13	9	18	13	6	10	11	16	6
	E6	1.800	2.50	5.10	3.40	2.50	3.80	3.10	2.50	4.90	2.80
Product pages	E1	20	20	20	20	20	20	18	18	19	20
	E2	1.990	2.04	2.73	1.47	1.67	1.39	1.60	1.25	1.94	1.91
	E3	2.030	2.70	3.22	2.83	1.84	2.55	2.31	3.14	1.85	0.80
	E4	20.280	21.70	32.25	28.27	18.41	25.49	23.15	31.45	18.48	7.98
	E5	17	19	15	18	18	19	18	18	16	16
	E6	2.300	5.50	3.50	4.60	5.40	5.10	5.50	5.30	6.50	2.90
Payment pages	E1	20	20	19	20	18	17	17	20	16	20
	E2	2.350	0.32	1.96	2.93	1.15	2.85	4.54	0.32	3.22	2.88
	E3	0.990	3.67	2.57	2.93	3.86	0.90	2.01	4.97	0.97	1.83
	E4	9.890	36.72	25.69	29.26	38.61	8.96	20.10	49.70	9.70	18.30
	E5	17	20	18	18	18	14	16	20	15	18
	E6	4.20	4.30	6.30	4.30	4.00	6.40	4.50	3.90	4.20	4.80