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Emotional, affective and biometrical states analytics of a built environment

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ABSTRACT

Personal interests constitute the emphasis of client-centered, personalized marketing, which leads to personalized client fulfillment. Current shoppers are interested in more than simply buying products and services; shoppers are also interested in the surroundings of the shopping site. Everywhere in the world, an analysis of marketing value, with rare exceptions, does not integrate criteria relevant to the emotional, affective and biometrical states, valence and arousal of potential buyers. Such parameters require assessment for implementing an accurate and more effective, client-centered marketing process. This research, which required developing the Emotional, Affective and Biometrical States Analytics of the Built Environment (VINERS) Method, provides a "big picture" of built environment neuromarketing. A multiple-criteria analysis integrated the emotional, affective and biometrical states of potential buyers and the surrounding environment (its physical, economic, social and environmental criteria). Neuro-decision and neuro-correlation matrices analysis constituted its basis. This research involved the accumulation and analysis of over 350 million remote data points, which aimed to ascertain the development of the biometrical, affective and emotional maps and sought to determine over 35,000 of average and strong correlations. The obtained dependencies constituted the basis for calculating and graphically submitting the VINERS circumplex model of affect, which the authors of this article had developed. This model is similar to Russell's circumplex model of affect. However, now, the VINERS Method has provided supplements offering new opportunities. Determination of an integrated emotional market rental (IEMR) value, provision of digital tips and optimization of the IEMR value are made possible by the VINERS Method.

1. Introduction

Many researches confirm that happy persons are more successful in numerous areas of life displaying productivity (DiMaria et al., 2017; Blankson, 2017; Graziotin and Fagerholm, 2019), social support (Findler et al., 2016; Ye et al., 2019; Mérida-López et al., 2019) and inclusion (Fagundes, 2017; Fisk et al., 2018), health (Kubzansky et al., 2016; Zhang et al., 2017a,b; Steptoe, 2019), lower corruption (Kabene et al., 2017; Li and An, 2019; Suhaimi et al., 2019) and environmental sustainability (Kyttä et al., 2016; Musikanski et al., 2017; Musa et al., 2018), wedlock (Grover and Helliwell, 2019; Tao, 2019; Perelli-Harris et al., 2019), friendliness (Wang et al., 2016; Demir et al., 2017; Sanchez et al., 2018), salary (Whillans et al., 2017; Jebb et al., 2018; Oishi et al., 2018) and such.

Analyses about the best (Tan, 2012; Tam, 2015; Urry, 2016) and the worst (Tam, 2015; Xu et al., 2017) retail outlets for shopping places have been ongoing for a number of years. Such studies have employed multiple-criteria analysis as well (Yang et al., 2018). Different sorts of analyses (Zhang et al., 2017a,b) have focused on positive emotions, such as happiness, and the retail environment that generates such emotions to a greater or lesser degree. Scientific literature broadly analyzes consumer behavior on a global basis, paying special attention to the emotional and hedonic aspects of the surrounding environment. The accent of such studies is on entertainment as one of the fundamental, retailing strategies. Various studies have analyzed that buying induces both pleasure and excitement (Yüksel, 2007). Furthermore an emotional bonding to a shopping center arouses positivity and comfort whenever engaged in buying at that site (Kesari and Atulkar, 2016) along with an enjoyment of the emotional bonding (Rintamaki et al., 2006) and a pursuit of novel experiences (Goldsmith, 2016) as well as a reduction of stress and negativity (Rintamaki et al., 2006). Thereby customers find shopping centers to be more than a site for buying needed goods but also as a site of pleasurable and enjoying experiences (Kesari and Atulkar, 2016). However, whenever such customers become disappointed with their buying experience, they can become restrained and angry (Kim et al., 2016).

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The built environment in cities and towns greatly influences the social and cultural lives of their inhabitants, as well as the degree of intercommunication and the values of the real estate market. The growth in the value of housing also increases the real estate tax income for the municipality. Small businesses near public spaces also enjoy an increase in the values of their enterprises. Public spaces encourage residents to walk, to engage in sports and to take pleasure in their environment. They become important meeting places, fostering social interrelationships and forming a cultural identity for the locale. Public spaces are judged based on various aspects, including social, economic, urban, ecological, cultural and even symbolic factors (Cao and Kang, 2019; Mandeli, 2019; Nouri et al., 2019; Benita et al., 2019; Peng et al., 2019). It is important to discuss the relationships between public spaces and their value, quality and benefits to inhabitants. One of the most important indicators of the value of a public space is the number of people who visit it. According to dual process theory, evaluation duality (intuitive/emotional and logical/rational) is characteristic of a public space's value. This is based on a space's assets, type, amount, condition and value to people. The environment, comfort, convenience, accessibility, functionality and possibilities for the beneficial use of a space are criteria that express the level of services provided by the space. However, the connection between the quality of a public space and its value to society is complicated, due to the broad spectrum of benefits it encompasses.

Scholars and practitioners have also investigated emotional values from various perspectives (Ahvenniemi et al., 2018; Scheutz, 2000; Kahneman, 2011; Simon, 1997; Hämäläinen et al., 2013; Damasio, 1994; Russell, 1980; Zawadzki et al., 2017; Mingione et al., 2020; Khan and Mohsin, 2017). These studies are described briefly below.

The buying and selling of real estate is an important process that usually requires a great deal of time and specialized information about laws, the economy and other significant factors. As a rule, this process does not occur spontaneously nor in an emotional way. Nevertheless, emotions can play a considerable role, and often do so when decisions relevant to the buying and selling of real estate are made. Rational choices, as Ahvenniemi et al. (2018) have shown, is not the only factor that plays a role in the decision to buy housing; emotions also contribute. The decision is, therefore, difficult to measure in terms of money. Neurological sciences recognize that emotions affect actions and thoughts, and, in modeling our decisions and actions, are just as important as reason (Scheutz, 2000). It is therefore important to analyze both market value and emotional value in this context, together with the relationship between them.

Nobel Prize laureate Kahneman (2011), who is a founder of behavioral economics, lays out two categories (or systems) of thought processes: the first system is fast thinking and the second system is slow thinking. Impulses, emotions and exaggerated optimism determine the first system. It does not require any significant effort, because everything happens almost involuntarily. Slow thinking, on the other hand, consists of analytical skills prompting control of behavior and thoughts. Evidently, the slow system of thought is relevant to advertising that tends towards the rational, whereas the fast system of thought is relevant to emotional advertising. Emotion can encourage good decision-making, according to Nobel Laureate Simon (1997), who has analyzed emotions as a factor in decision-making and concluded that intrinsic conflict between rationality and emotions is absent. Behavioral operational research (BOR) requires modeling. It then can support humans in their problem-solving efforts, as Hämäläinen et al. (2013) propose, to advance the practice of operational research (OR). These same scholars have illustrated the derivation of opposing results when, for example, we take a certain phenomenon and describe it differently, when questions are posed differently and when different graphs are used. Operational research processes are sensitive to a considerable degree to various behavioral effects. Their sensitivity is suggested by the results of a study by Hämäläinen et al. (2013).

Damasio (1994) conceived the somatic marker hypothesis. The hypothesis suggests that behavior and decision-making are guided by emotional developments. Having in mind that feelings are about the sensations a body experiences, Damasio (1994) gave this phenomenon the name "somatic state" (from "soma", the Greek word for body). Damasio (1994) believes that even in the simplest everyday decisions emotions play a critical role. Whenever an individual, for instance, receives a somatic marker and the somatic marker is linked to a positive result, the individual might feel happy and that sense of happiness might inspire him or her to repeat the same behavior. When the somatic marker, in contrast, is linked to a negative outcome, the individual could feel sad. The sense of sadness acts as an internal alarm and warns the person against that action (Damasio, 1994; Russell, 1980) proposed the circumplex model of affect. This model is a two-dimensional, circular space in which all emotions are distributed along two axes, indicating arousal and valence. The vertical axis (arousal) indicates the level of excitement, where a person can be either aroused or relaxed. The horizontal axis (valence) represents the emotional state, where a person's emotions can be either positive or negative (Russell, 1980). This study contains the application of the somatic marker hypothesis and the circumplex model of affect.

A growing interest in the effect cities make on emotions led to the development of various methods and tools over recent decades. The tools and methods are applied in various studies by many scientists looking at the effect from both subjective and objective perspective. The body of subjective research (questionnaires, self-reports, observations, interviews and diaries, in order to record the subjective involvements of personalities) of emotions includes studies by Kim and Fesenmaier (2015), Solymosi et al. (2015), Resch et al. (2016), Birenboim and Shoval (2016) and Birenboim et al. (2019) while objective studies have been conducted by Sagl et al. (2015), Birenboim (2016, 2018), Birenboim and Shoval (2016), Birenboim et al. (2019), Zeile et al. (2016) and integrated studies by Birenboim et al. (2015), Birenboim and Shoval (2016), Shoval et al. (2011, 2018, 2020), Shoval and Birenboim (2019). Objective research of people experiences and/or emotions in public spaces have included the application of biometric methods and systems (heart and breathing rates, blood pressure, skin conductance, body temperature, pupil size and blinking).

Resch et al. (2016) introduce an interdisciplinary approach called TwEmLab; their system allows tracking emotions of people at different locations in a city. Another solution proposed by researchers is a multi-parametric approach for tweet grouping into emotion classes. In an attempt to examine subjective feelings such as fatigue, hunger and boredom, Loiterton and Bishop (2008) of the Royal Botanic Garden in Melbourne developed questionnaires with a focus on public spaces and then applied the data in their forecasts about people walking around the garden. Shoval et al. (2018) look at a large-scale urban environment and make systematic maps of its emotional characteristics using aggregative measures of emotions (objective and subjective). These maps show which areas of the city are emotionally arousing, highlight emotional 'clusters' and 'boundaries', identify where the emotional space of the city remains continuous and indicate where the space is disrupted by discontinuities. An integrated method introduced by Li et al. (2016) and based on an emotion-tracking technique and geographical information systems (GIS) allows quantifying the relationship between urban spaces and people's emotional responses. The findings suggest that, in urban spaces, both shifting scenario sequences and spatial sequence arrangements can influence people's emotional responses. Lai et al. (2017) discovered that individuals alerted by primary appraisal of resource loss are more likely to experience negative emotions.

An integrated approach has also been used in research examining emotions (Birenboim and Shoval, 2016; Birenboim et al., 2015; Shoval et al., 2011; Pettersson and Zillinger, 2011). Pettersson and Zillinger (2011), for instance, used tracking technologies and questionnaires to examine the feelings (positive and negative) of contributors during the 2008 Biathlon World Championship held in Ostersund, Sweden. Daly et al. (2016) developed the Huss Index that combines ethnographic methods (i.e. sensory mapping and interviews) and biometric technologies. Their goal was to discover the correlations that link the subjective feelings of the participants and their statements about their experiences related to their environment with their objective emotional and physical states tracked in a natural environment in real time (Daly et al., 2016).

Crowding emotions analysis is very important for happiness economics growth. According to Bolonkin (2012), the economics of happiness suggests that along the more traditional economic measures the success of a public policy should be measured by taking into account public happiness as well (Bolonkin, 2012). The promotion of happiness economics leads to increasing GDP and GNP, individual income, social security, employment, relationships, happiness and leisure, economic security (Lyubomirsky et al., 2005; Stutzer and Frey, 2012), relationships and children (Glaeser et al., 2016), religiosity (Ngamaba and Soni, 2018), political stability (Ott, 2010; Malnar et al., 2017; Woo, 2018), economic freedom (Bennett et al., 2016; Kelley and Evans, 2017), democracy (Klar and Kasser, 2009; Barker and Martin, 2011; Bennett et al., 2016), economic development (Stevenson and Wolfers, 2008; Melo et al., 2013).

In the 2017 World Happiness Report, Helliwell et al. (2017) found that the top ten countries in the ranking of emotional wellbeing share six factors primarily relevant to overall happiness: income, health and life expectancy, significant others for emergency assistance, generosity, freedom and trust. However, overall, nation-wide happiness had little correlation with corruption and generosity, as Tofallis (2019) discovered. Other scholars also analyzed the links happiness had with other variables, such as income, psychological well-being, health and the like. For example, Jebb et al. (2018) analyzed the relationship between happiness and personal income. Their evidence indicates a limit to the degree of happiness realized by income levels, which holds true worldwide. The significance estimated by Heizomi et al. (2015) between happiness and mental health was r = 0.48). A positive correlation was found by Subramanian et al. (2005) between health and happiness in their study of individuals as well as communities; education and income indicated strong impacts on realizing happiness. Another study, by Johnston et al. (2013), indicated that work-related stress had a negative impact, whereas an attitude of happiness had a positive effect. Nonetheless, even an attitude of happiness showed a negative correlation with work-related stress despite engagement and pleasure scales. Besides, an ability to adapt to a career can act as an intermediary between an attitude of happiness and work stress. Meanwhile enjoying a social network, social trust and social norms, as per Jung (2020), positively influence the happiness of a workforce. Jung discovered that a social network and social norms statistically significantly affected personal happiness. Meanwhile Taylor and Adams (2020) highlight the complexity of intense happiness by categorizing it according to three areas: time for me, spatial imaginaries and community challenges. Resolving problems, self-control and positive reappraisal correlated positively with happiness (P<0/01), as Rajabimoghaddam and Bidjari (2011) found, while escape-avoidance and responsibility correlated negatively with happiness (P<0/05).

The public looks for new experiences, thus, retailers often upgrade their outlets and product offerings to satisfy their customers (Goldsmith, 2016). Tourism includes shopping as one of the means for experiencing pleasure and excitement, thus, promotions of retail outlets are essential in tourism marketing. Naturally the way a buyer assesses his/her time purchasing different products/services depends to a certain degree on the surrounding environment. Certain empirical studies already exist about shopping centers and how they influence the behavior of the people shopping there, these tend to be limited (Yüksel, 2007). The hypotheses of various studies claimed that the environment where consumers shop affect emotions while buying. Other studies raised hypotheses that the buying itself affects emotions while conducting the buying, thus, influencing the values inherent in shopping along with approach behaviors. This is a consistent result obtained by research in general, which indicated the effect on shopping emotions, values and behaviors by environmental perceptions (Yüksel, 2007). Once people experience pleasantness at some shopping center where they go to do their buying, they tend to become loyal customers who are emotionally linked to that site. Such attachment to a place for shopping relates to a positive evaluation of a retail outlet, positive assessments of customer services and loyalty, which then influence a positive attitude towards the advantages of buying at a mall or shopping center (Kesari and Atulkar, 2016). The outcome of an evaluation by *hedonic* buyers about a shopping center revealed that they believed they could lower stress and any negative emotions they held at that site leading to an emotional bonding and enjoyment (Rintamaki et al., 2006) in the overall process of shopping (Kesari and Atulkar, 2016). These buyers visited shopping centers for reasons other than for purchasing products. They reported feeling pleasure and enjoying the process of going shopping (Kesari and Atulkar, 2016). The opposite side of the coin is that buyers experience restraint and anger whenever their shopping experiences fall short of their expectations (Kim et al., 2016).

A lower degree of happiness and overall satisfaction with life comes from intensified anxiety, and annoyance, which can lead to self-harm, mental disorders and suicide (Zhang et al., 2017a). Air pollution, for one, has been known to lessen happiness. The job of city planners is to concentrate on designs leading to greater positive emotions, which are important to general wellbeing. Thus they seek means for increasing socializing among people, fostering feelings of safety in the public and having more green spaces easily accessible to people (Pfeiffer and Cloutier, 2016). Some researchers such as Zhang et al. (2017a) studied hedonic happiness by employing a country-level survey. The country was China, where these scholars noted daily air quality parameters by date and county and interviewed the public to establish the affect local concentrations of particulate matter have on the happiness of individuals

One of the reasons for an inadequate market value could be due to emotional value, whereas professional real estate valuers must remain objective when determining market value. Market value does not reflect the value to a specific owner or buyer. An assumption is simply made that there is a willing buyer, but not a specific buyer. Thus, personal circumstances and unusual circumstances arising between the parties in a real estate purchase–sales agreement are not considered when establishing market value. A purchase–sales price affected by personal circumstances cannot be established over the scope of an entire market.

A saying by Edward Coke (1552–1634) is often quoted: ‘‘The house of everyone is to him as his Castle and Fortress as well for defense against injury and violence..’’.. Homes are expensive personal items for sellers or owners, and they remind them of times spent there with family, various events, pleasant encounters with friends and other powerful memories. A home may therefore have an enormous emotional value, albeit much smaller than its economic value. According to Sheth et al. (1991), ‘‘Emotional value pertains to the products’ capability to stimulate moods or emotional situations’’.

The emotional comfort associated with a property may be an emotional attachment, an emotional regulator, escapism, emotional ‘‘therapy’’, convenience, safety or self-confidence (Dittmar, 1992). Meanwhile, negative emotions, such as the pain of a divorce, can create a lower sales price for the property. The emotional attachment of city dwellers to specific places and natural spaces helps to explain why they will pay a high price for a home (Zawadzki et al., 2017).

For such owners, one of the most complicated aspects of selling a home is the release of emotional attachment, which is often quite painful. The emotional value related to memories can and should be separated from the physical object. If such an attachment is not shaken off, it is difficult to establish a grounded sales price for the property according to its market value rather than its emotional value. Once a decision has been made to sell a piece of property, it becomes simply another unit of real estate, which no longer emotionally belongs to the owner. An owner’s memories related to the history of the property, rather than to the present necessity to sell it, belong to him or her, rather than to the property. Hence, emotional value does not cease to exist when the property has been sold.

A number of researchers have worked and achieved significant success in the neuromarketing field (Sebastian, 2014; Lee, 2016; Vargo and Lusch, 2017; Boz et al., 2017; Koc and Boz, 2018; Lim, 2018; Golnar-Nik et al., 2019; Muñoz Leiva et al., 2019; Kaklauskas et al., 2019a,b,c; Zavadskas et al., 2019). Neuromarketing, also known as consumer neuroscience, is an interdisciplinary marketing research field (Lee, 2016). Vargo and Lusch (2017) predict that future research in neuroscience and neuromarketing will cover the ways in which cognitive assistants/mediators can alter brain activity and affect a multitude of marketing phenomena, such as the adoption of new services ("products"), value assessment and brand choice. They also predict that future scholarship will analyze the behavior of advertising executives, who gradually rely upon intellectual assistants/mediators in terms of their marketing analytics and decision-making support.

Accumulation of over 350 million remote data served the analysis of this research. Development of biometrical, affective and emotional maps and determination of over 35,000 average and strong correlations constituted its objectives. The basis for calculating the graphic submission of the VINERS circumplex model (developed by these same authors) were the obtained dependencies. Although Russell's circumplex model, developed earlier by other scholars, is similar, the VINERS method supplements now offer added opportunities.

A review of neuromarketing studies conducted within the built environment shows that these have never been employed in an integrated manner using non-contact (remote) multimodal biometrics and multiple-criteria analysis methods, Damasio's Somatic marker hypothesis (Damasio, 1994) and Russell's Circumplex model of affect (Russell, 1980). Furthermore, on the grounds of the derived emotional, affective, biometrics and the surrounding environment data, no neuromatrix has ever been compiled, nor has an integrated emotional market rental (IEMR) value been determined using such a matrix. In addition, no researchers have provided digital recommendations or performed multiple-criteria calculations for other rationalizations of the built environment. An effort to compile a multiple-criteria neuromatrix that would comprehensively define the built environment under deliberation necessarily involves gathering different types of data, such as human affective states, emotional and biometrical states, valence and arousal, with physical, economic, social and environmental pollution data. The complexity of the problem under study is therefore greater than in prior studies.

Section 2 of this paper presents the VINERS method. Section 3 discusses the case studies and gives an account of the VINERS method in practice. Section 4 gives an overview of the analysis of correlation matrices. Section 5 presents the VINERS Circumplex Model of Affect. Section 6 presents the results, conclusions and plans for future research.

2. Emotional, affective and biometrical states analytics of the built environment method

Meanwhile real estate advertising only considers affective reactions, biometrical and emotional conditions, arousal and the valence of potential buyers in exceptional cases. However, as far as it is known, not all these factors were viewed as an integrated entity. The research performed here endeavored to view the biometrical and emotional conditions of potential buyers, their affective reactions, arousal and valence along with the physical, economic and social surroundings, including environmental pollution in an integrated manner. The multiple-criteria analysis of sales site neuromarketing alternatives for fairs employed the aforementioned data for this study. Additionally the neuro decision matrices analyzed potential sites for conducting sales at a fair. The contribution of this research includes additional factors to the "big picture" of neuromarketing. Nonetheless, some questions remained unanswered in full while numerous previously unforeseen questions arose.

The development of the Emotional, Affective and Biometrical States Analytics of the Built Environment (VINERS) method was conducted in five stages:

1. Establishment of VINERS problems and formulation of the research problem and goals, i.e., shortages, limitations of former studies on emotional, affective and biometrical states analytics of built environment, and contradictions among earlier studies;
2. Analysis of former concepts, models, methods, and theories of neuroadvertising and neuromarketing based on the Web of Science (Clarivate Analytics) and the ScienceDirect database, and proposing two VINERS hypotheses;
3. Completion of a Data Protection Impact assessment (DPIA);
4. Portrayal of the big picture of the VINERS neuromarketing potential, collection of data in the neuromatrices (trends, variability, links, etc.), biometrical, affective, emotional and the surrounding environment (its physical, economic, social and environmental criteria) maps;
5. Development of the VINERS method.

These five stages are discussed briefly below.

2.1. Formulation of the research problem and goals

The neuromarketing currently executed in cities has not been performed in an integrated manner using remote tools, multiple-criteria analysis methods, Damasio's somatic marker hypothesis (Damasio, 1994) and Russell's circumplex model of affect (Russell, 1980). This research addresses the following problem: improving the efficiency of best shopping places neuromarketing by integrating Damasio's somatic marker hypothesis (Damasio, 1994); Russell's circumplex model of affect (Russell, 1980); emotional, affective, biometrics and the surrounding environment data; neuro-decision and neuro-correlation matrices (Kaklauskas et al., 2019d); neuromarketing, affective computing, and opinion analytics methods, as well as five methods for multiple-criteria analyses developed by the authors. Real-time location emotional, affective and biometric analysis is a very important research topic in modern neuromarketing. The research aim is to create the VINERS method, which analyzes real time potential buyer emotional, affective and biometrical states, arousal, valence, measures how attractive location are and, based on the existing best practice and the results of analysis, provides a "big picture" of built environment neuromarketing.

Therefore, the VINERS research object is extended and developed, similarly to investigations previously conducted by other researchers. The VINERS research object was not documented as being a subject of investigation prior to this investigation. The research problem is, consequently, an enlargement of built environment neuromarketing using the VINERS technique.

2.2. Literature review and hypotheses

The formulation of two hypotheses for this study was based on the experience and intuition of the authors and on an analysis of the scientific literature:

- H1: Pollution (magnetic storms, SO_2, $PM_{2.5}$, PM_{10}, NO_2, CO, O_3) influences emotional states (surprised, sad, disgusted, angry, happy, scared) and biometrical states (respiration and heart rates) as well as arousal, valence and affective states (confusion and interest) (see Sections 4 and 5).
- H2: Influences of emotional and biometrical states, arousal, valence and the surrounding environment (its pollution and physical, economic, social and environmental criteria) on the priority, utility degree and integrated, emotional market value of real estate (see Section 3, "Case Studies").

The VINERS method, developed by the current authors, was used to confirm these hypotheses.

2.3. Data protection impact assessment

The general data protection regulation (GDPR) applies in all European Union (EU) Member States from 25 May 2018 (Consensus, 2019). The GDPR means that EU citizens have more control over their personal data and the measures foreseen in the regulation contribute to better security both online and offline. This research involved analyzing passersby at seven sites in Vilnius and establishing their affective attitudes, emotional and biometrical states, as well as their valence and arousal. To adhere to the GDPR requirements and the applicable laws of the Republic of Lithuania, a data protection impact assessment was necessary for the equipment subsystem before we could launch our data gathering activities (Table 1). Use of this subsystem enabled the gathering of the aforementioned data for this research.

2.4. Portrayal of the big picture of the VINERS neuromarketing potential, collection of data in the neuromatrices and development of the biometrical, affective, emotional and the surrounding environment maps

This stage involved the gathering of twelve quantitative and qualitative layers of data, and subsequently systematically evaluating them. Such actions were needed to acquire an understanding about neuromarketing opportunities and to take advantage of them. The accumulation of these twelve layers of quantitative and qualitative data aimed to reach particularly important goals that affirmatively influence the neuromarketing process. The big picture stage defines the reality of neuromarketing by analyzing the twelve layers of data in the neuromatrices and the biometrical, emotional, affective and the surrounding environment maps. These data were collected and investigated:

- 1^{st} layer: emotional states (happy, sad, angry, surprised, scared, disgusted or neutral), and valence and arousal;
- 2^{nd} layer: affective attitudes (boredom, interest, confusion);
- 3^{rd} layer: biometrical states (average crowd facial temperature, crowd composition by gender and age groups, heart and breathing rates);
- 4^{th} layer: neuro-surveys;
- 5^{th} h layer: circadian rhythm of Vilnius city inhabitants;
- 6^{th} layer: weather conditions (air temperature, relative air humidity, average wind velocity, atmospheric pressure; the data were obtained from the Vilnius Meteorology Station);
- 7^{th} layer: pollution (particulates, nitrogen dioxide, noise, carbon monoxide, sulfur dioxide, magnetic storm; the data were obtained from the Environmental Protection Agency and recalculated by Raimondas Grubliauskas);
- 8^{th} layer: Vilnius built environment and municipal district data;
- 9^{th} layer: real estate characteristics;
- 10^{th} layer: initial neuromarketing data tables;
- 11^{th} layer: assessment of neuromarketing alternatives tables;
- 12^{th} layer: neuromarketing multivariate design tables.

The collection of five layers biometric-emotional data from depersonalized passersby took place from November 6, 2017 until February 19, 2020 at seven specific sites with minimal intrusion in the city of Vilnius. The first five layers were measured using equipment subsystem. The equipment subsystem comprises remote biometrics analysis devices (H.264 Indoor Mini Dome IP Camera, FaceReader 7.1, Respiration Sensor X4M200, Infrared Camera FLIR A35SC). Measurements were taken every second. The first layer concentrated on arousal, valence and emotional states. The second layer covered affective states (boredom, confusion and interest) of passersby. The third layer covered investigating the biometrical states (respiration and heart rates, facial temperature) of passersby.

The 80%/20% rule regarding purchasing decisions is popular worldwide. It purports that purchasing decisions are based 80% on emotions and 20% on logic. The application of neuro-questionnaires on this basis allowed for replies not only to some specifically posed question, but additionally to all their emotional hues. For example, a dweller in a multi-unit building was asked if he would like his housing unit to be renovated. The answer was "yes". Additionally, as the resident replied to this question, the equipment subsystem determined his affective, emotional and biometrical states, which provided a strong supplementation to his simple answer, "yes". In this case, an entire rainbow of colors appeared in conjunction with the "yes" answer, making it very different from the "yes" answers heard from the other residents of that same building. A fourth layer of data was formed by using the web-based neuro-questionnaire. The neuro-survey provides a chance for interested parties to interpret the multifaceted neuromarketing process in this manner, along with the behaviors of potential customers and their involvements and sentiments. A layer of data of the fifth circadian rhythm of Vilnius city inhabitants formed by using 1st–3rd layers of data.

The sixth and seventh layers focused on weather conditions (the data were obtained from the Vilnius Meteorology Station), a magnetic storm and pollution (the data were obtained from the Environmental Protection Agency and recalculated by Raimondas Grubliauskas).

The data gathered for the eight through ninth layers of data included:

- Vilnius' built environment and municipal districts data: obtained from experts in the field;
- real estate characteristics: obtained from experts in the field;

A database for designing alternative neuromarketing variants was also accumulated in the same manner. It consists of the tenth–twelve layers of data: initial neuromarketing information, neuromarketing alternatives and multivariant design tables.

The compilation of biometrical, emotional and affective maps was based on the first five layers of data (Kaklauskas et al., 2019d). Meanwhile, the basis for forming the neuromatrices consisted of all twelve layers of data.

Over 350 million depersonalized records were collected. About 90% of the new, additional data was gained using the first three layers of data and the VINERS method, which leads to more relevant and accurate results. Original scientific research on the neuro-decision matrices was performed as follows:

- Analysis of articles from the Web of Science (Clarivate Analytics) and ScienceDirect databases;
- Analysis of related valuable concepts, models, methods and theories from other fields;
- Data gathering and checking for neuro-decision matrices;
- Development of multidisciplinary neuro-decision matrices; and
- Multidisciplinary analysis of neuro-decision matrices.

Biometrical, emotional, affective and the surrounding environment maps are compiled based on the database of neuro-decision matrices that was developed. VINERS analyzes the emotional, affective and biometrical signals from passersby. Such signals serve as the basis for the VINERS method and create emotional, affective, biometrical and the surrounding environment maps of the location under analysis. Based on these neuro-decision matrices and the emotional, affective, biometrical and the surrounding environment maps, the VINERS method submits recommendations to interest groups on how to increase advertising effectiveness by applying the results to the objective needs of the user groups.

2.5. VINERS method

The development of an integrated system of methods is intended for the purpose of determining useful trends and knowledge from over 350 million items of data, supporting interested parties in making efficient, rational multiple-criteria decisions and determining the most

Table 1
Main conclusions of the Data Protection Impact Assessment report for emotional, affective and biometrical states analytics of the built environment.

Description of threat and nature of an impact on individuals — when necessary, there is also a description of the relevant business risk	Damage likelihood	Damage extent	Overall level of threat
Possible threats to the rights and freedoms of data subjects during the time of recording visuals and their transference into the VGTU[a] computer	Unlikely	Minimal	Low
Possible threats to the rights and freedoms of data subjects during the time of recording breathing frequencies, the recording of such data into the VGTU portable computer and USB flash unit, and their transference into a computer at VGTU	Unlikely	Minimal	Low
Possible threats to the rights and freedoms of data subjects during the transference of visuals from the cameras into the VGTU portable computer and the recording of the facial spots of individuals with the FaceReader™ program (Noldus)	Unlikely	Minimal	Low
Possible threats to the rights and freedoms of data subjects and to the transference of depersonalized data during the time of analysis and while stored in the VGTU server and database	Unlikely	Minimal	Low

[a]VGTU—Vilnius Gediminas Technical University

suitable advertisement for a specific potential buyer. The performance of the VINERS method is presented in graphical diagram in Fig. 1. VINERS method involves integrating Damasio's somatic marker hypothesis (Damasio, 1994); Russell's circumplex model of affect (Russell, 1980); emotional, affective, biometrics and the surrounding environment data; neuro-decision and neuro-correlation matrices(Kaklauskas et al., 2019d); biometric methods (Kaklauskas, 2015; Kaklauskas et al., 2018a); spatial analysis of categorical data by means of neuromarketing analysis and multiple-criteria methods, for example, generation of human affective, emotional, biometrical states and the surrounding environment maps (Kaklauskas et al., 2019d); neuro-questionnaire method (Kaklauskas et al., 2018b); affective computing (Kaklauskas, 2015; Kaklauskas et al., 2018a); and neuromarketing (Kaklauskas et al., 2018a) methods. It also involves statistical analysis (LOGIT, KNN, MBP, RBP), recommender technique (Kaklauskas, 2015) and opinion analytics technique (Kaklauskas et al., 2009), as well as five methods for multiple-criteria analysis (Kaklauskas, 1999, 2015, 2016) (see Fig. 1).

For example, the objective of the integration of neuromarketing method (Kaklauskas et al., 2018a) was to examine the affective and cognitive reactions of buyers to marketing incentives and to forecast their actions. The affective computing method (Kaklauskas, 2015; Kaklauskas et al., 2018a) was integrated in order to understand the emotional states of buyers and to tailor their actions to the neuromarketing process by providing the most rational reaction to those emotions and affective states.

The opinion analytics method (Kaklauskas et al., 2009) analyzes different emotions and affective states (see Fig. 1). The opinion analytics method applies text analytics to determine, extract, measure and evaluate the emotions, affective states and subjective information contained in Google text about built environment under analysis. For an automatic detection of views expressed in comments, reviews, articles, surveys, notices, opinions, papers, studies, research, online forums, blogs, Facebook, Twitter and other social media sites, Opinion Analytics is used. The opinions people hold on issues of built environment can then be visualized. With Opinion Analytics among their tools, city officials can understand and monitor sentiments, thoughts, attitudes, opinions, emotions and preferences of urban citizens better and make better decisions.

Five multiple-criteria analysis methods have been incorporated (see Fig. 1). A brief description of the alternative design and multiple-criteria methods applied in the analysis of neuromarketing alternatives is presented below.

The multi-alternative design of neuromarketing alternatives involved development different alternative video combinations (see Fig. 2). Feasible alternatives could number as many as one million. The perspectives for describing every single alternative can be derived from various data layers described above. This constitutes an incredible amount of information. Therefore, performing a computer-aided design of alternative variants can prove to be a problem. Nonetheless, the situation was resolved by applying the multiple-criteria, multi-alternative project life cycle design method. Performance of this multi-alternative design method involves completing five stages (see Fig. 2).

We calculate the integrated emotional market rental value using the INVAR method(Kaklauskas, 2015, 2016) which composed of stages as shown in Fig. 3. Stages 1–5 of the INVAR method (Kaklauskas, 2016) are the same as in the Complex proportional assessment (COPRAS) method (Kaklauskas, 1999; Zavadskas et al., 1994).

The importance, preferences and the utility degrees (U_j) of the variants under consideration are considered in the first four phases, grounded on data from the neuromatrix.

The neuromatrix and the utility degrees of the variants are used for the execution of Stages 5–10, as follows:

- Calculation of the integrated emotional market rental (IEMR) and market rental (MR) utility degrees of the options (see Section 3.2. Case Study 1);
- Assessment of the IEMR and MR values (see Section 3.3. Case Study 2);
- Optimization of the criteria value by seeking to upgrade the options to be equally competitive on the market compared to the other options (see Section 3.4. Case Study 3);
- Provision of digital recommendations for improving the options (see Section 3.5. Case Study 4);
- Calculation of the IEMR and MR values for an option that would allow this option to become the best of all those under consideration (see Section 3.6. Case Study 5);

Also, the data from the neuromatrices can be used for multiple-criteria analysis, as follows:

- the environment of the fair (color, contours, lighting, scents, sounds; factors relating to the booth at the sales site, including its size and layout; the design of the sales sites and their open spaces);
- sizes and layouts of sales sites;
- alternatives relating to the staff at the fair;
- advertising materials for the products or services being promoted.

Verification identifies whether the VINERS hypotheses match the VINERS method. Validation identifies whether the VINERS method truthfully characterizes the actual reality. First, the VINERS method was verified to assess its accuracy. There was assurance during the verification of the VINERS method that the results disclose the situation as it really is. We wanted to verify all possible states of the method to make sure the desired system's features work as expected and meet our requirements. The second step to assess the accuracy of the VINERS method was validation. Expert assistance was employed both in the validation and the verification of the VINERS method (see Section 4, "Analysis of correlation matrices") with 24 neuromarketing experts asked for their opinions. The experts validated the performed neuromarketing analysis in real-life conditions.

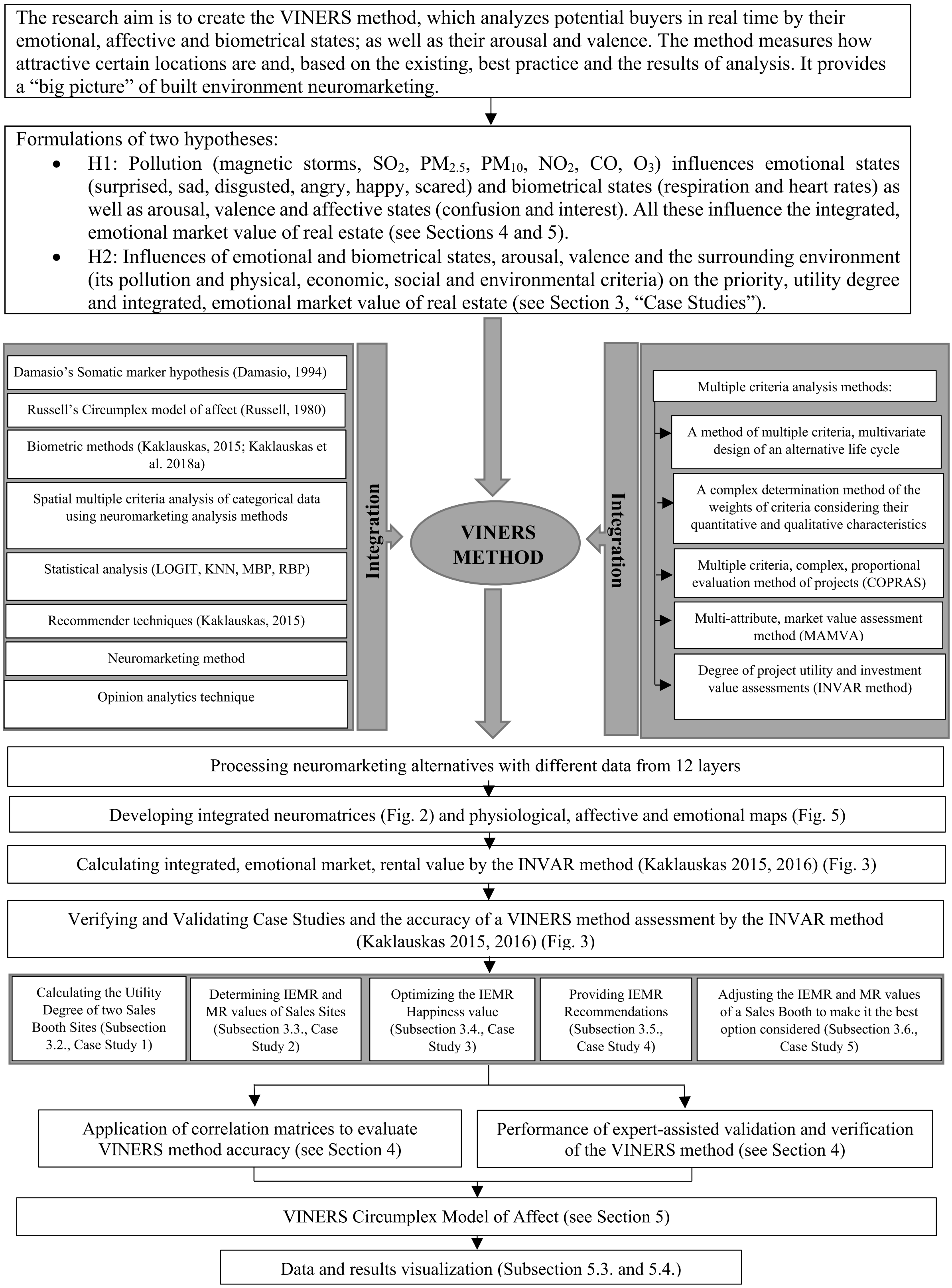

Fig. 1. Graphical diagram of VINERS method.

Certain parts of the VINERS method were evaluated by means of a thorough analysis of five case studies. The studies confirm that the proposed VINERS method is accurate.

VINERS data and results are visualized as multiple-criteria statistics that quantitatively define and analyze twelve layers of gathered data. The first three layers of sensor data are characterized as big data. Visualizations of data and results leads to various ethical issues, as well as issues involved in data analytics and multiple-criteria analysis, which relate to capturing, treating, examining and presenting data. VINERS data and visualizations of results involve quantitative forms (tables,

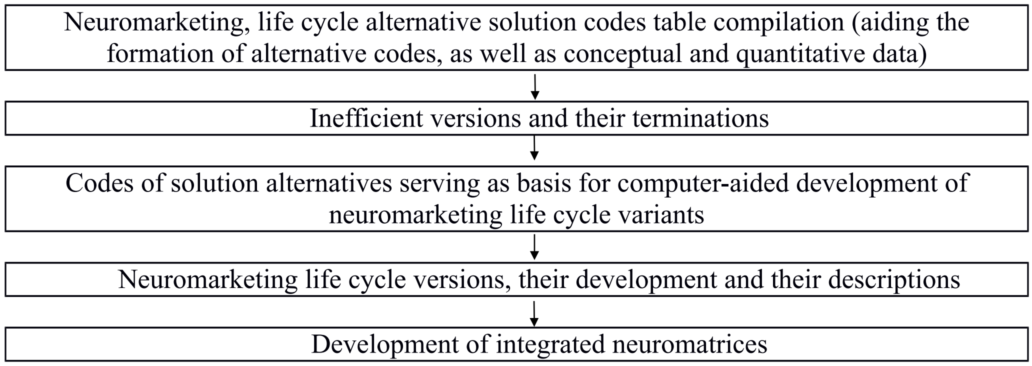

Fig. 2. Neuromarketing life cycle and the main stages of its multiple-criteria, multivariate design.

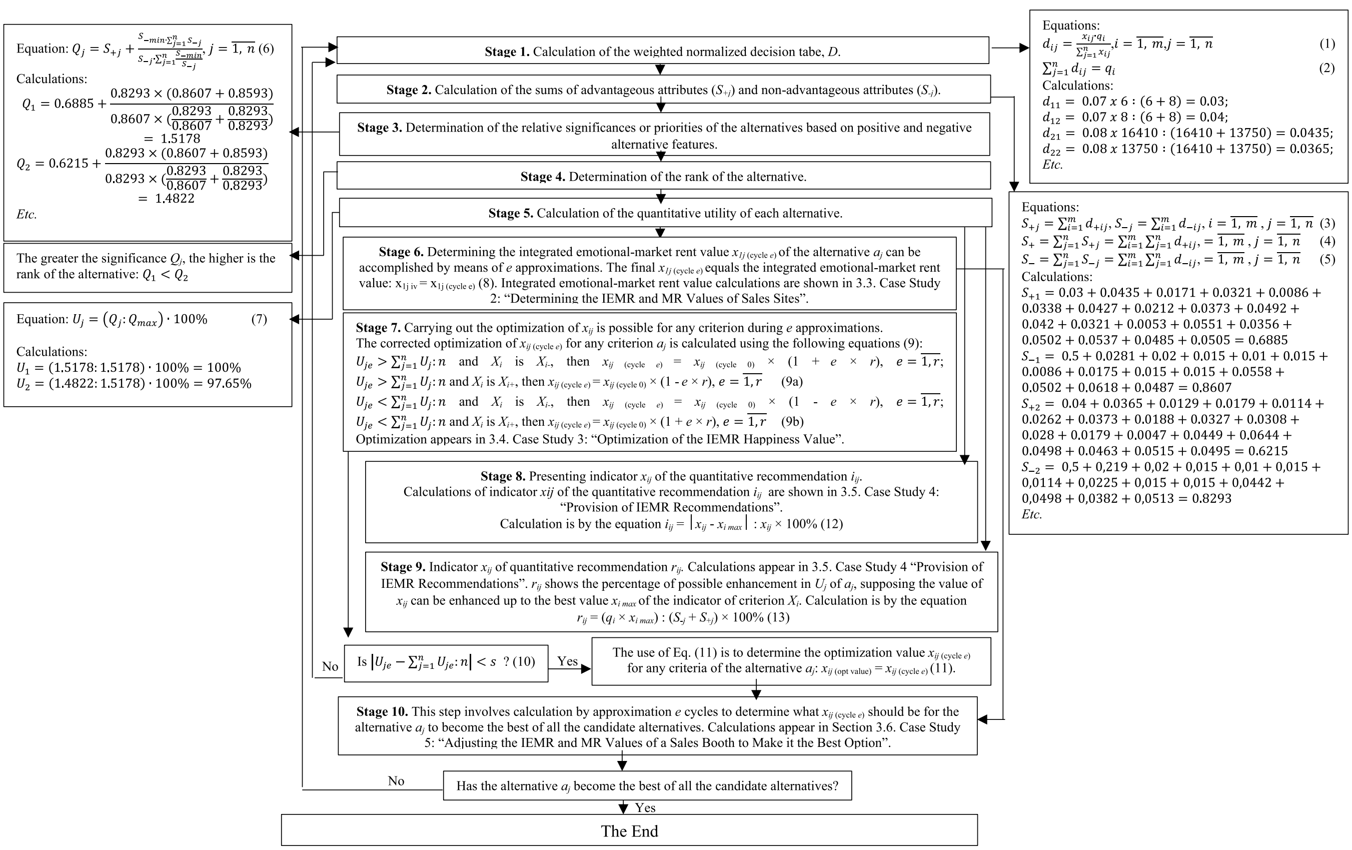

Fig. 3. The key stages of the INVAR method.

charts and circles presenting trends and relationships as well as graphic presentations of evaluations and interconnection) and conceptual forms (written description of the quantitative part and of the comparisons, evidence, multiple-criteria analysis and causality). These serve to present various neuromarketing alternatives from numerous perspectives.

3. Case studies: Multiple-criteria analysis of sales sites at Kaziuko Fair

3.1. System of criteria comprehensively describing the Kaziuko Fair Sales Sites

The experiments took place between November 6, 2017 and February 19, 2020, at seven preselected sites in Vilnius City. This involved the collection of the types of data mentioned above, which then had to be processed, integrated and analyzed. Kaziuko Fair, held on March 2–4 2018, is briefly discussed below as an example.

Kaziuko (Saint Casimir's) Fair is an annual, large-scale exhibition in Vilnius that displays folk arts and crafts, a tradition dating back to the early 17th century. The fair operates in the city center, and displays by hundreds of craftspeople stretch across Gedimino Prospect and into the side streets of äventaragio, B. Radvilaites, Maironio and Pilies. The fair takes place on the Sunday nearest to March 4, which commemorates St. Casimir. In Lithuanian, Kaziuko (or Kaziukas) is the diminutive form of the name Casimir (or Kazimieras in Lithuanian). Today, St. Casimir's Fair also involves music, dance and plays, attracting tens of thousands of visitors and craftspeople from all over Lithuania, as well as from neighboring countries such as Latvia, Russia and Poland. This fair has a unique atmosphere in which tradition and authenticity are particularly important. Kaziuko is not only the largest fair in Vilnius, but is also the oldest event of this type, and has been a tradition for over 400 years (see Fig. 4).

In 2018, the Kaziuko Fair took place on March 2–4. The items sold during the fair included handmade goods of national origin, folk arts,

Fig. 4. Kaziuko Fair (photo taken March 4, 2018).

fine crafts, agricultural products and other types of goods made using old-fashioned methods and tools. The locations of the two sites of this fair chosen for this study were at 1 Pilies St. (site a_1) and Lukiskiu Square, at 35 Gedimino Pr. (site a_2). The locations consisted of booths (3 x 3 m) with a rental price of 69.66 for three days. The municipality charged the same price for booths in different locations, and the price was based only on the size of the booth. Thus, the objective of our work was to assess the rental fees for the market of these specific sites, taking into consideration physical, economic, social, environmental and emotional criteria. The designated weight for all of the first four sets of criteria (except for the rental value of a 3 x 3 m sales booth) was one, and this total was the same as the weight for the set of emotional criteria and the rental value of a 3 x 3 m sales booth. Sixteen fair experts in the field (advertisers, built environment experts, fair organizers, sellers) determined a weight factor (weight) of 0.25 for each of the physical, economic (except for the rental value of a 3 x 3 m sales booth), social and environmental criteria groups, reflecting sustainable principles of development and the primary importance of humans and their well-being during the event. They determined the same weight for the set of emotional criteria as for the total weight of previously mentioned four groups.

The location of sales site a_1 was one of the oldest streets in Vilnius, at 1 Pilies St. Vilnius Cathedral, the Palace of Lithuania's Grand Dukes and Bernardinai Garden are no more than a few hundred meters away from this site, and, a little farther away, visitors can find the Tower of Gediminas Castle and the Hill of Three Crosses.

Nearby sales site a_2 was located in Lukiskiu Square, at 35 Gedimino Pr. This has views of the Ministry of Foreign Affairs of the Republic of Lithuania, Lukiskiu Square, the Lithuanian Academy of Music and Theatre, Vilnius Regional Court, Lukiskiu Prison and Holy Apostles Philip and Jacob Church.

The following factors were considered in the set of physical criteria: the accessibility of the site; the number of visitors to this part of the fair; the widths of the street and sidewalk; the surroundings; eye-catching views of buildings with unique features (monuments, memorials, sculptures and other special or unique features, such as a bridge or bandstand); and hard landscaping (benches, bins, railings, paths, etc.).

The set of economic criteria included housing prices, the prices for renting commercial property, real estate tax rates and the attractiveness to small businesses. The housing prices, rental prices for commercial property and level of taxes on real estate are rather high at both sites a_1 and a_2, since these are prestigious locations within Vilnius City where real estate prices are the highest. However, site a_1 is more highly valued, and the experts therefore assigned slightly higher points to this site.

The set of social criteria consisted of the popularity of the site as a meeting place for residents, its popularity among tourists, its popularity as a place for taking walks and the crime rate. Site a_1 is more popular among both townspeople and tourists than site a_2. Thus, experts gave site a_1 a rating of 8, 9 and 9 points for these criteria, respectively, and gave 5, 6 and 5 points, respectively, for site a_2.

The items in the environmental criteria included levels of particulate matter ($KD_{2.5}$, KD_{10}), carbon monoxide (CO), nitrogen oxide (NO_2), sulfur dioxide (SO_2), visual contamination, noise levels, magnetic storms (Kp), atmospheric pressure and soft landscaping (trees, flower beds, meadows, lawns etc.). The indicators for the first four criteria were taken from the Environmental Protection Agency's 2018 data from tests of air quality (http://gamta.lt/cms/index?lang=en). The visual contamination and noise levels were lower at site a_1 than they were at site a_2.

Pilies St. (a_1) data for a multiple-criteria analysis of IEMR and MR alternatives (see Table 2) appear in graphic form in Fig. 5. This illustration also provides an emotional, biometrical and the surrounding environment (its physical, economic, social and environmental criteria) map relevant to the same area under study.

3.2. Case study 1: Calculation of utility degree for two sales booth sites

Stages 1–5 of the INVAR method (Kaklauskas, 2016) are the same as in the Complex proportional assessment (COPRAS) method (Kaklauskas, 1999; Zavadskas et al., 1994).

In the following, we describe the application of the INVAR method in carrying out the IEMR and MR values analysis for sales booths at two sites: Pilies St. (a_1) and Lukiskiu Square (a_2). The division of Table 2 is in two parts — the left side of the table shows IEMR data matrix divided into five groups of criteria: physical criteria, economic criteria, social criteria, environmental pollution criteria and emotional criteria. The right side shows MR data divided into four groups of criteria: physical criteria, economic criteria, social criteria and environmental pollution criteria. Criteria values and weights are equal, both on the right as well as on the left sides of the table. The IEMR and MR alternatives analysis results appear at the end of the table. Experts determined an equal weight of 0.25 for each of the first four groups to reflect the principles of sustainable development. They set the weight of the emotional criteria group as equal to the sum of the weights of the first four groups, since the most important issue at such an event was considered to be the people, their well-being and their positive emotions. All sets of criteria were broken down further, and the experts provided weights for each individual criterion.

Pilies St. (a_1) data for a multiple-criteria analysis of IEMR and MR alternatives (see Table 2) appear in graphic form in Fig. 5. This illustration also provides an emotional, biometrical and the surrounding environment map relevant to the same area under study.

Determination of the IEMR value for the sales sites was performed using Stages 1–10 of the INVAR method (see Fig. 3). Table 2 (see left side) shows the results of the criteria assessment of the IEMR values of

Table 2
Decision matrix and assessment results of IEMR and MR alternatives from Kaziuko Fair (on March 2) using the COPRAS method.

Criteria describing the alternatives	[a]	Units of measure-ment	Weight	Integrated emotional market rental (IEMR) compared alternatives		Market rental (MR) compared alternatives	
				Pilies St. a_1	Lukiskiu Square a_2	Pilies St. a_1	Lukiskiu Square a_2
Physical criteria						**Physical criteria**	
Accessibility of the location	+	Points	0.07	6 0.03	8 0.04	6 0.03	8 0.04
Number of visitors to the fair	+	Number of visitors	0.08	16410 0.0435	13750 0.0365	16410 0.0435	13750 0.0365
Widths of the street and sidewalk	+	m	0.03	28 0.0171	21 0.0129	28 0.0171	21 0.0129
Eye-catching views	+	Points	0.05	9 0.0321	5 0.0179	9 0.0321	5 0.0179
Hard landscaping	+	Points	0.02	6 0.0086	8 0.0114	6 0.0086	8 0.0114
Economic criteria						**Economic criteria**	
Rental value of a 3 x 3 m sales booth	–	Euros for three days	1	69.66 0.5	**69.66** 0.5	69.66 0.5	**69.66** 0.5
Housing prices	+	Points	0.06	9 0.0338	7 0.0262	9 0.0338	7 0.0262
Commercial property rental prices	+	Points	0.08	8 0.0427	7 0.0373	8 0.0427	7 0.0373
Real estate tax rates	+	Points	0.04	9 0.0212	8 0.0188	9 0.0212	8 0.0188
Attractiveness to small business enterprises	+	Points	0.07	8 0.0373	7 0.0327	8 0.0373	7 0.0327
Social criteria						**Social criteria**	
Popularity as a meeting place	+	Points	0.08	8 0.0492	5 0.0308	8 0.0492	5 0.0308
Popularity with tourists	+	Points	0.07	9 0.042	6 0.028	9 0.042	6 0.028
Popularity of the walkways	+	Points	0.05	9 0.0321	5 0.0179	9 0.0321	5 0.0179
Criminality	–	Points	0.05	9 0.0281	7 0.0219	9 0.0281	7 0.0219
Environmental pollution criteria						**Environmental pollution criteria**	
Particulate matter (KD_{10})	–	µg/m3	0.04	25.09 0.02	25.09 0.02	25.09 0.02	25.09 0.02
Carbon monoxide (CO)	–	mg/m3	0.03	0.52 0.015	0.52 0.015	0.52 0.015	0.52 0.015
Nitric oxide (NO_2)	–	µg/m3	0.02	4.55 0.01	4.55 0.01	4.55 0.01	4.55 0.01
Sulfur dioxide (CO)	–	µg/m3	0.03	2.6 0.015	2.6 0.015	2.6 0.015	2.6 0.015
Visual pollution	–	Points	0.02	6 0.0086	8 0.0114	6 0.0086	8 0.0114
Noise level	–	Points	0.04	7 0.0175	9 0.0225	7 0.0175	9 0.0225
Soft landscaping	+	Points	0.01	8 0.0053	7 0.0047	8 0.0053	7 0.0047
Magnetic storms	–	Kp	0.03	3 0.015	3 0.015	3 0.015	3 0.015
Atmospheric pressure at the station level	–	hPa	0.03	993.98 0.015	993.97826 0.015	993.98 0.015	993.97826 0.015

(*continued on next page*)

Table 2 (*continued*).

Criteria describing the alternatives	[a]	Units of measurement	Weight	Integrated emotional market rental (IEMR) compared alternatives		Market rental (MR) compared alternatives	
				Pilies St. a_1	Lukiskiu Square a_2	Pilies St. a_1	Lukiskiu Square a_2
Emotional and biometrical criteria						–	–
Happiness	+	Points	0.1	0.158225 0.0551	**0.129154** 0.0449	–	–
Sadness	–	Points	0.1	0.200443 0.0558	0.158545 0.0442	–	–
Anger	–	Points	0.1	0.108799 0.0502	0.108075 0.0498	–	–
Surprise	+	Points	0.1	0.051358 0.0356	0.092899 0.0644	–	–
Fear	–	Points	0.1	0.042741 0.0618	0.026442 0.0382	–	–
Disgust	–	Points	0.1	0.036638 0.0487	0.038552 0.0513	–	–
Valence	+	Points	0.1	0.905851 0.0502	**0.897404** 0.0498	–	–
Arousal	+	Points	0.1	0.36 0.0537	**0.31** 0.0463	–	–
Respiratory rate	+	Respiration per minute (RPM)	0.1	14.506207 0.0485	15.3982 0.0515	–	–
Heart rate	+	Beats per minute (BPM)	0.1	76.00119 0.0505	74.61746 0.0495	–	–
Normalized weighted maximizing alternative indices, totals				0.6885	0.6215	0.3949	0.3151
Normalized weighted minimizing alternative indices, totals				0.8607	0.8293	0.6442	0.6458
Significance of the alternative				1.5178	1.4822	1.0407	0.9593
Priority of the alternative				1	2	1	2
Utility degree of the alternative (%)				100%	97.65%	100%	92.18%

[a]The sign + (–) indicates that a greater (lesser) value for a criterion corresponds to its greater (lesser) significance to stakeholders

the sales sites under analysis. That the utility degree U_1 = 100% for the Pilies St. Site a_1 is greater than the utility degree U_2 = 97.65% for the Lukiskiu Square Site a_2 is obvious. The difference is equal to 2.35%.

The compilation of an analogical matrix (see right side of Table 2) was an endeavor to calculate the MR value and to prove the influence of emotions on the results. Therefore, the criteria groups of emotions were not included herein (http://iti3.vgtu.lt/vgtu_lomonosov/simpletable.aspx?sistemid=6852).

The results derived by using Stages 1–5 of the COPRAS Method appear on the right side of Table 2. These results indicate that the priority alternative among the alternatives under deliberation had not changed. However, a difference began to appear between it and the "Utility degree of the alternative (%)" indicator. The derived result of the difference between the sites at Pilies St. a_1 U_1 = 100% and Lukiskiu Square a_2 U_2 = 92.18% is equal to 7.82%. A comparison of the difference between the results of IEMR and MR alternatives showed that the difference between the utility degrees of the IEMR alternatives was three times lower. An explanation for the difference between the IEMR and MR alternatives results could be that the assessments by experts and the existing data are more likely to favor the first alternative, whereas the emotional and biometrical states of the passersby indirectly voted for the second alternative.

3.3. Case study 2: Determining the IEMR and MR values of Sales Sites

The objective of Case Study 2 is to decrease the IEMR price for sales site a_2 in Lukiskiu Square to equal the IEMR of other sales sites, using Stages 1–5 of the COPRAS method and Stage 6 of the INVAR method. The aim is to diminish the rent price ($x_{526\ cycle\ e}$) of the sale booth at site a_2 in Lukiskiu Square and the other sales sites on this street to equal the value of those at site a_1 on Pilies St., via minimization of the three-day rent price for a sale booth at site a_2.

Calculations of the IEMR value of a 3 x 3 m booth site are carried out using the data from Table 2 and Stage 6. The goal is to assess the IEMR value $x_{11\ cycle\ e}$ needed for a 3 x 3 m booth at site a_2 in Lukiskiu Square (see Table 3). After revision, the IEMR value should make the booth as competitive as the 3 x 3 m booth at the Pilies St. site a_1. It is possible to determine the negative and positive features of the sales sites by applying Stages 1–9 of the INVAR method.

A decision matrix from the Kaziuko Fair held in March 2018 was compiled (see http://iti3.vgtu.lt/vgtu_lomonosov/simpletable.aspx?sistemid=7852). The three-day rent price for a sale booth at site a_2 in Lukiskiu Square is 69.66, and the site's utility degree is 97.65%. Table 3 is in two parts. The left side of the table shows the change in the IEMR utility degree at Kaziuko Fair upon rationalizing the results of the corrected value, $x_{12\ cycle\ e}$, at Lukiskiu Square Sales Site a_2. Meanwhile, the right side shows the change in the MR utility degree at Kaziuko Fair upon rationalizing the results of the corrected value $x_{12\ cycle\ e}$ at Lukiskiu Square Sales Site a_2.

The left side of Table 3 shows that if the rent price for a sale booth at Lukiskiu Square site a_2 is reduced to 64.90, the utility degree of Lukiskiu Square Site a_2 becomes nearly equal to that of the Pilies St. Site a_1 (with a difference of merely −0.005%). Table 3 indicates that the inequality in Eq. 8 (Fig. 3) is still not satisfied after 436 approximation cycles ($x_{12\ cycle\ 436}$ = 65.3, |−0.10 %| > 0.00%). However, after 478 approximation cycles, the rent price for a sales booth at site a_2 is reduced to 64.88, and the utility degree of this sales site becomes equal

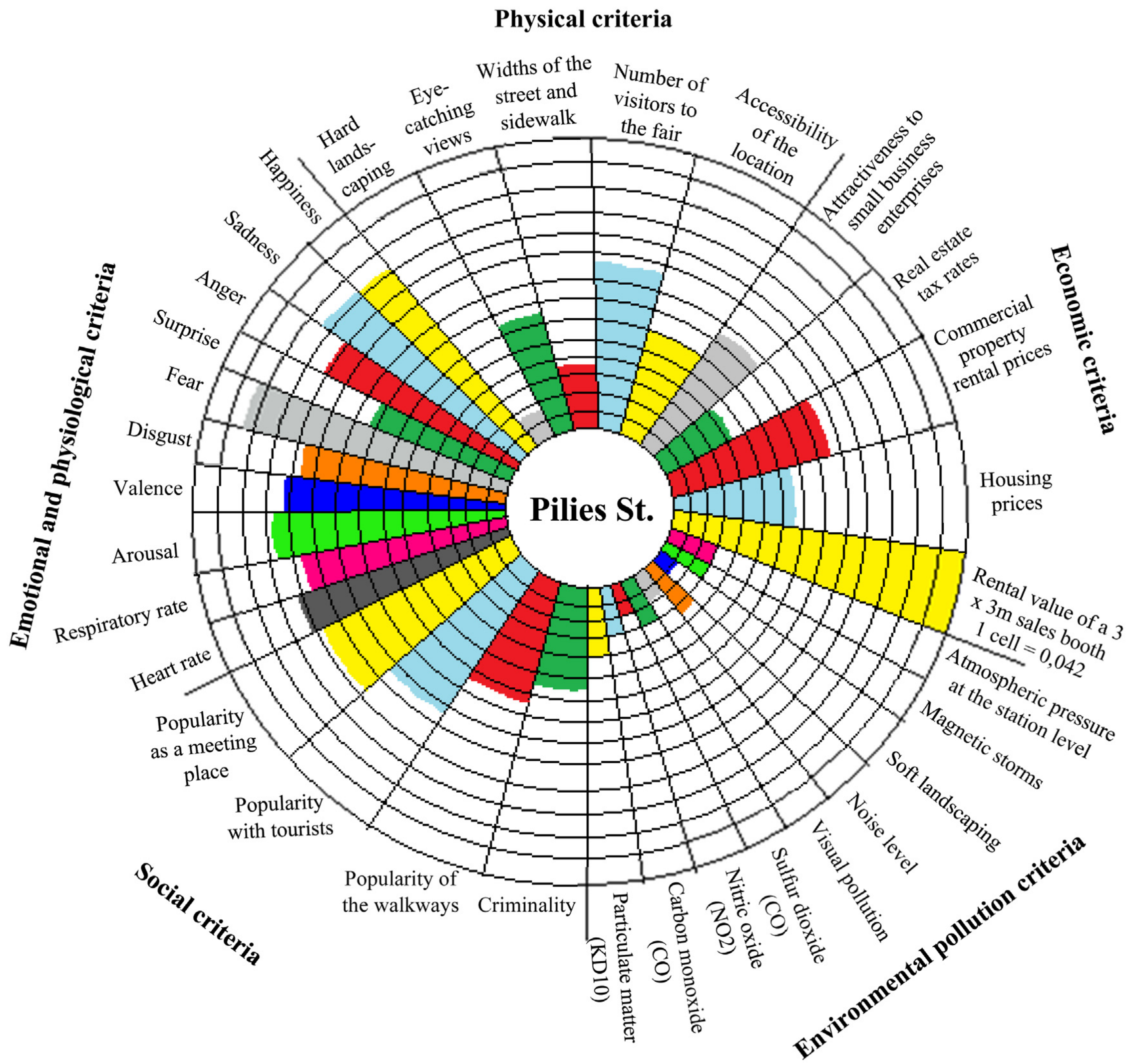

Fig. 5. Pilies St. (a_1) map of emotions, biometrics and the surrounding environment.

to the utility degree of site a_1 ($x_{12\ cycle\ 478}$= 64.88, | 0.00%| = 0.00%). Thus, the utilities of the IEMR values of these sales sites become equal.

The MR values of the sales sites also change due to a change in utility degrees. The objective of this research is to decrease the MR price for sales site a_2 in Lukiskiu Square to equal the MR of other sales sites, using Stages 1–5 of the COPRAS method and Stage 6 of the INVAR method. The aim is to change the price ($x_{526\ cycle\ e}$) of the sale booth at site a_2 in Lukiskiu Square and the other sales sites on this street — that is, to increase it to equal the value of those at site a_1 on Pilies St., via minimization and maximization of the relevant criteria. The three-day rent price for a sale booth at site a_2 in Lukiskiu Square is 69.66, and the site's utility degree is 92.18% (Table 3). As shown on the right side of Table 3, a reduction in the rental price for a sale booth at Lukiskiu Square Site a_2 to 59.22 results in the utility degree of Lukiskiu Square Site a_2 becoming nearly equal to that of the Pilies St. Site a_1 (with a difference of merely −0.02%). Table 3 indicates that the inequality in Eq. 8 (Fig. 3) is still not satisfied after 1044 approximation cycles ($x_{12\ cycle\ 1044}$ = 59.22, |−0.02 %| > 0.00%). However, after 1048 approximation cycles, the rent price for a sales booth at site a_2 is reduced to 59.18, and the utility degree of this sales site becomes equal to the utility degree of site a_1 ($x_{12\ cycle\ 1048}$ = 59.18, | 0.00%| = 0.00%). Thus, the utilities of the MR values of these sales sites become equal.

The results show that a reduction in the rental price for an IEMR sale booth at Lukiskiu Square Site a_2 to 64.88 causes the utility degree of Lukiskiu Square Site a_2 to become nearly equal to that of Pilies St. Site a_1 after 478 approximation cycles. Meanwhile, a reduction in the rental price for an MR sale booth at Lukiskiu Square Site a_2 to 59.18 causes the utility degree of Lukiskiu Square Site a_2 to become nearly equal to that of the Pilies St. Site a_1 after 1048 approximation cycles. An explanation for the difference between the IEMR and MR analysis results could be that the emotional and biometrical states of the passersby indirectly increase the value of a sales site.

As seen, a system of criteria that adequately describes a 3 x 3 m booth and the sizes of the criteria values and weights make a direct and proportionate impact on the IEMR value of the booth. Furthermore, the IEMR value of a 3 x 3 m booth makes the booth as competitive as a comparative alternative. The second hypothesis – "Influences of emotional and biometrical states, arousal, valence and the surrounding environment (its pollution and physical, economic, social and environmental criteria) on the priority, utility degree and integrated, emotional market value of real estate" – was confirmed in the same way in this case study, by assessing the set of positive and negative characteristics of the alternatives.

3.4. Case study 3: optimization of IEMR happiness value

We can optimize the value of each selected criterion at Stage 7 of the INVAR method (Kaklauskas, 2016) (see Fig. 3). One example is the happiness value (x_{24}) derived on March 2, 2018 at the Lukiskiu Square

Table 3
Revised changes for assessing the IEMR and MR alternatives for a sale booth at the Lukiskiu Square sales site a_2.

Approximation cycle	[a]	Change in integrated emotional market rental utility degree in Kaziuko Fair by rationalizing the corrected value $x_{12\ cycle\ e}$ of Lukiskiu Square sales site a_2				Change in market rental utility degree in Kaziuko Fair by rationalizing the corrected value $x_{12\ cycle\ e}$ of Lukiskiu Square sales site a_2			
		Utility degree U_{1e}	Utility degree U_{2e}	[b]	[c]	Utility degree U_{1e}	Utility degree U_{2e}	[b]	[c]
1	2	3	4	5	6	3	4	5	6
0	69.66	100%	97.65%	98.83%	$\|-1.18\%\| > 0.00\%$	100%	92.18%	96.09%	$\|-3.91\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
66	69	100%	97.97%	98.99%	$\|-1.02\%\| > 0.00\%$	100%	92.62%	96.31%	$\|-3.69\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
436	65.3	100%	99.79%	99.89%	$\|-0.10\%\| > 0.00\%$	100%	95.22%	97.61%	$\|-2.39\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
466	65	100%	99.93%	99.97%	$\|-0.04\%\| > 0.00\%$	100%	95.43%	97.715%	$\|-2.285\%\| > 0.00\%$
...	...	...	...	...	...				
476	64.9	100%	99.99%	99.99%	$\|-0.005\%\| > 0.00\%$	100%	95.5%	97.75%	$\|-2.25\%\| > 0.00\%$
...	...	...	...	...	...				
478	64.88	100%	100%	100%	$\|0.00\%\| = 0.00\%$	100%	95.52%	97.76%	$\|-2.24\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
700	62.66	–	–	–	–	100%	97.2%	98.6%	$\|-1.4\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
1000	59.66	–	–	–	–	100%	99.6%	99.8%	$\|-0.2\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
1040	59.26	–	–	–	–	100%	99.92%	99.96%	$\|-0.04\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
1044	59.22	–	–	–	–	100%	99.96%	99.98%	$\|-0.02\%\| > 0.00\%$
...	...	...	...	...	...	...	...	...	...
1048	59.18	–	–	–	–	100%	100%	100%	$\|0.00\%\| = 0.00\%$

[a]Revised changes in market rental value $x_{12\ cycle\ e}$ (in euros for three days) for Lukiskiu Square sales site a_2.
[b]$(U_{1e} + U_{2e})$: 2.
[c]This inequality determines whether a revised value $x_{12\ cycle\ e}$ for a booth at Lukiskiu Square sales site a_2 is sufficiently accurate.

site a_2. The goal for optimizing the happiness value at this site was to bring the sales booth at this site to an equal level of competitiveness on the market to that of the Pilies St. site a_1. This meant that the happiness value $x_{24\ 2}$ at site a_2 needed to be increased until its degree of utility was equal to that of site a_1. The calculations were carried out in accordance with Stages 1–5 of the COPRAS method and the equations (9, 10) used in Stages 7 and 10 of the INVAR method.

The results are shown in Table 4, from which it can be seen that the happiness value x_{24} is 0.129154 ($x_{24\ 2\ cycle\ 0} = 0.129154$), and the utility degree $U_{2\ cycle\ 0} = 97.65\%$ at site a_2. Completion of 135 approximation cycles caused the happiness value $x_{24\ 2}$ to reach 0.243364, or 1.88 times greater than the previous $x_{24\ 2\ cycle\ 0} = 0.129154$ at site a_2, while its utility degree $U_{2\ cycle\ 135} = 99.72\%$. However, the required result was still not achieved, and an effort was therefore made to achieve an even higher happiness value$x_{24\ 2}$. After 162 cycles, the happiness value $x_{24\ 2}$ at the Lukiskiu Square site a_2 reached 0.266206, and its utility degree reached $U_{2cycle\ 162} = 100\%$, meaning that the sales booth at site a_2 was equally competitive as site a_1.

3.5. Case study 4: provision of IEMR recommendations

While analyzing the sales sites at Kaziuko Fair, we formulated digital recommendations for each sales site to improve certain criteria values and to determine the influence that these new values will have on the general assessment of their sales sites, as per Stages 8 and 9 of the INVAR method (Kaklauskas, 2016) (see Fig. 3). Table 5 presents the recommendations matrix. For example, Tables 2 and 5 show that the Lukiskiu Square site a_2 has a lower valence ($x_{30\ 2} = 0.897404$) than the Pilies St. site a_1 ($x_{30\ 1} = 0.905851$). Assuming that our goal is to optimize the valence (x_{30}) for site a_2, the valence of site a_2 must be increased by 0.94% ($i_{30\ 2} = 0.94\%$). This value was calculated using the INVAR method (Stage 8; see Table 5). The calculations (INVAR method, Stage 9; see Table 5) show that the significance of site a_2 would increase by 0.0314% ($r_{30\ 2} = 0.0314\%$).

We can analyze ways to improve the rate of arousal in the same way. As shown in Tables 2 and 5, site a_1 shows greater arousal ($x_{30\ 1} = 0.36$) than site a_2 ($x_{30\ 2} = 0.31$). Assuming that our goal is to achieve the same level of arousal (x_{31}) as site a_1, the arousal at the Lukiskiu Square Site a_2 must be increased by 16.13% ($i_{30\ 2} = 16.13\%$), as calculated in Stage 8 of the INVAR method (see Table 5). In this way, the significance of the Lukiskiu Square Site a_2 would increase by 0.5376% ($r_{30\ 2} = 0.5376\%$, as calculated in Stage 9 of the INVAR method shown in Table 5). We can analyze ways to improve the other criteria values in the same way.

The calculations for digital recommendations presented in this case study indicate how many percentage points the alternative a_j of the IEMR value of a sales booth has to increase for the indicator value x_{ij} to become equal to value $x_{i\ max}$ of the best indicator X_i. In this way, the second hypothesis – "Influences of emotional and biometrical states, arousal, valence and the surrounding environment (its pollution and physical, economic, social and environmental criteria) on the priority, utility degree and integrated, emotional market value of real estate" – was confirmed in this case study upon performing the multiple-criteria analysis of alternatives for providing recommendations.

3.6. Case study 5: adjusting the IEMR and MR values of a sales booth to make it the best option

The purpose of this section is to optimize the IEMR and MR sales booths to become the best of the possible sites considered here, using

Table 4
Optimization of IEMR happiness value at Lukiskiu Square sales site a_2 to make the sales booth equally competitive on the market as sales booth at Pilies St. site a_1.

Approximation cycle	*	Utility degree U_{1e}	Utility degree U_{2e}	**	***
1	2	3	4	5	6
0	**0.129154**	100%	97.65%	98.83%	$\|-1.18\%\| > 0.00\%$
...	...	...	...	...	...
76	0.19345	100%	98.98%	99.49%	$\|-0.51\%\| > 0.00\%$
...	...	...	...	...	...
135	0.243364	100%	99.72%	99.86%	$\|-0.14\%\| > 0.00\%$
...	...	...	...	...	...
151	0.2569	100%	99.89%	99.945%	$\|-0.055\%\| > 0.00\%$
...	...	...	...	...	...
156	0.26113	100%	99.95%	99.975%	$\|0.025\%\| > 0.00\%$
...	...	...	...	...	...
161	0.26536	100%	99.99%	99.995%	$\|0.005\%\| > 0.00\%$
162	0.266206	100%	100%	100%	$\|0.00\%\| = 0.00\%$

Stages 1–5 of the COPRAS method and Stage 10 of the INVAR method. Optimization of the IEMR value $x_{12\ cycle\ e}$ of the Lukiskiu Square site a_2 was obtained using the INVAR method (see Table 6). Table 6 appears in two parts. The left side shows the IEMR value $x_{12\ cycle\ e}$ (over 3 days). The right side shows the MR value $x_{12\ cycle\ e}$ (over 3 days). The left side of Table 6 shows that his occurred after 478 approximation cycles: $U_1 = U_2 = 100\%$. Thus, the Lukiskiu Square Site a_2 can become the most effective of the sales sites considered, for an IEMR value $x_{12\ cycle\ e}$ of site $a_2 = 64.88$ over three days.

Next, it is necessary to optimize the MR sales booth to become the best of the possible sites considered here, using Stages 1–5 of the COPRAS method and Stage 10 of the INVAR method. Optimization of the MR value $x_{12\ cycle\ e}$ of Lukiskiu Square site a_2 was conducted using the INVAR method. The right side of Table 6 shows that this occurred after 1048 approximation cycles: $U_1 = U_2 = 100\%$. Thus, the Lukiskiu Square Site a_2 can become the most effective of the sales sites considered, for an MR value $x_{12\ cycle\ e}$ of site $a_2 = 59.18$ over three days.

These results indicate that the assessment of emotions has a significant impact when endeavoring to suitably assess the market rental values of both sales sites. If there is no assessment of emotional parameters, the three-day rental price for a booth at Lukiskiu Square Site a_2 decreases by 8.78%. An explanation for the differences between the IEMR and MR analysis results could be that the emotional and biometrical states of passersby indirectly increase the value of that sales site.

The determination of the IEMR value of a sales booth to make it the best of the options under consideration occurred during this stage after calculating 478 cycles (upon assessing environmental pollution and human arousal, valence and emotional states criteria values and weights). In this way, the second hypothesis – "Influences of emotional and biometrical states, arousal, valence and the surrounding environment (its pollution and physical, economic, social and environmental criteria) on the priority, utility degree and integrated, emotional market value of real estate" – was confirmed in this case study upon assessing the set of positive and negative characteristics of the alternatives.

4. Analysis of correlation matrices

The VINERS method was first verified to assess its accuracy and to prove that the results of the VINERS method reflected the real situation by applying correlation matrices. All possible states of the VINERS method had to be tested, in order to check whether the desired features of the method produced satisfactory results. The accuracy of the VINERS method was then also assessed by means of validation. The next step was the expert-assisted validation and verification of the VINERS method. Twelve real estate evaluators and twelve property development experts took part in this assessment. These experts expressed their opinions and validated the analysis of the IEMR of rental spaces in terms of the affective, emotional and biometrical states, valence and arousal of passersby, and the physical, economic, social and ecological environment characterizing the built environment in question.

Two variables were needed for this statistical examination, and more than 35,000 average and strong correlations were established. The number of data used is presented in Table 7. Table 8 shows a compiled containing matrix.

Before finalizing the correlation matrix, an important task was to establish if the correlations were positive (↑), negative (↓) or both (↑↓). A positively surprised person, for instance, experiences positive emotions, while unpleasant surprises lead to negative emotions. In terms of emotions, valence indicates an intrinsic averseness/"badness" (negative valence) or attractiveness/"goodness" (positive valence) of an object, situation or event (Frijda, 1986).

Surprise may be associated with several different valences (negative/positive, unpleasant/neutral/pleasant). These numbers are correlation values. For each correlation, V=Values in parentheses show the number of days analyzed. The correlation coefficients presented in the studies conducted by these and other authors have matching signs.

Fig. 6A illustrates the dependency between anger and O_3 (ozone) tracked over a period of 118 days ($r = 0.549712$). Fig. 6B shows the correlation among arousal and magnetic storms, monitored over a period of 45 days ($r = 0.563468$). Fig. 6C demonstrates the dependency between arousal and heart rate observed over a period of 447 days ($r = 0.51$).

For a broader comparison, studies by other authors in this field are also shown in Table 8. These studies emphasize the interdependencies that link pollution and magnetic storms with positive/negative moods, emotions (anger, happiness, etc.) and heart rate. Similar trends were observed in the current research.

Tian et al. (2018) have noted that several indicators of bad weather and air quality (pollution, etc.) are associated with negative moods. Lundberg (1996) found that air pollution could affect individual's moods and evoke emotional depression, because it can trigger negative and pessimistic cognitive biases. Prior studies have also demonstrated the impact weather parameters (especially air quality, temperature and sunlight) can have on individual's state of mind. Low levels of sunlight, excessive heat or cold and considerable air pollution may trigger negative moods (Tian et al., 2018). When the sense of smell is considered, pollution may also be associated with disgust (Krueger, 2017). The "amplification effect" typical of the perception of air pollution can be a cause of higher mental harm (e.g. fear, anxiety and other negative feelings) (Geng et al., 2019).

Worsening air quality, a typical consequence of economic growth in less developed countries, can make people feel less happy, as demonstrated by Zhang et al. (2017a). These authors show a significant drop in hedonic happiness caused by air pollution, and suggest that attempts to improve people's happiness should include important policy measures aimed at reducing air pollution (Du et al., 2018). The adverse effects of air pollution on happiness have also been reported by Xu and Li (2016). They analyzed the World Values Survey 2007 (happiness

Table 5
Quantitative recommendations for IEMR sales sites a_1(Pilies St.) and a_2(Lukiskiu Square).

Criterion	[a]	Unit	Weight	Compared alternatives Analyzed criterion, possible improvement, % Alternatives, possible integrated emotional market rental value growth, %. Considering the first impact by the criterion's value growth	
				Pilies St. site a_1	Lukiskiu Square site a_2
Particulate matter (KD_{10})	–	μg/m3	0.04	$x_{15\ 1} = 25.09$ (0%) (0%)	$x_{15\ 2} = 25.09$ (0%) (0%)
Carbon monoxide (CO)	–	mg/m3	0.03	$x_{16\ 1} = 0.52$ (0%) (0%)	$x_{16\ 2} = 0.52$ (0%) (0%)
Nitric oxide (NO_2)	–	μg/m3	0.02	$x_{17\ 1} = 4.55$ (0%) (0%)	$x_{17\ 2} = 4.55$ (0%) (0%)
Sulfur dioxide (CO)	–	μg/m3	0.03	$x_{18\ 1} = 2.6$ (0%) (0%)	$x_{18\ 2} = 2.6$ (0%) (0%)
Visual pollution	–	Points	0.02	$x_{19\ 1} = 6$ (0%) (0%)	$x_{19\ 2} = 8$ ($i_{19\ 2} = 25\%$) ($r_{19\ 2} = 0.1667\%$)
Noise level	–	Points	0.04	$x_{20\ 1} = 7$ (0%) (0%)	$x_{20\ 2} = 9$ ($i_{20\ 2} = 22.22\%$) ($r_{20\ 2} = 0.2963\%$)
Soft landscaping (trees, flower beds, meadows, lawns, etc.)	+	Points	0.01	$x_{21\ 1} = 8$ (0%) (0%)	$x_{21\ 2} = 7$ ($i_{21\ 2} = 14.29\%$) ($r_{21\ 2} = 0.0476\%$)
Magnetic storms	–	Kp	0.03	$x_{22\ 1} = 3$ (0%) (0%)	$x_{22\ 2} = 3$ (0%) (0%)
Atmospheric pressure at the station level	–	hPa	0.03	$x_{23\ 1} = 993.98$ (0%) (0%)	$x_{23\ 2} = 993.97826$ ($i_{23\ 2} = 22.51\%$) ($r_{23\ 2} = 0.7503\%$)
Happiness	+	Points	0.1	$x_{24\ 1} = 0.158225$ (0%) (0%)	$x_{24\ 2} = 0.129154$ ($i_{24\ 2} = 22.51\%$) ($r_{24\ 2} = 0.7503\%$)
Sadness	–	Points	0.1	$x_{25\ 1} = 0.200443$ ($i_{25\ 1} = 20.9\%$) ($r_{25\ 1} = 0.6968\%$)	$x_{25\ 2} = 0.158545$ (0%) (0%)
Anger	–	Points	0.1	$x_{26\ 1} = 0.108799$ ($i_{26\ 1} = 0.67\%$) ($r_{26\ 1} = 0.0222\%$)	$x_{26\ 2} = 0.108075$ (0%) (0%)
Surprise	+	Points	0.1	$x_{27\ 1} = 0.051358$ ($i_{27\ 1} = 80.89\%$) ($r_{27\ 1} = 2.6962\%$)	$x_{27\ 2} = 0.092899$ (0%) (0%)
Fear	–	Points	0.1	$x_{28\ 1} = 0.042741$ ($i_{28\ 1} = 38.13\%$) ($r_{28\ 1} = 1.2711\%$)	$x_{28\ 2} = 0.026442$ (0%) (0%)
Disgust	–	Points	0.1	$x_{29\ 1} = 0.036638$ (0%) (0%)	$x_{29\ 2} = 0.038552$ ($i_{29\ 2} = 4.96\%$) ($r_{29\ 2} = 0.1655\%$)
Valence	+	**Points**	**0.1**	$\mathbf{x_{30\ 1} = 0.905851}$ **(0%)** **(0%)**	$\mathbf{x_{30\ 2} = 0.897404}$ ($\mathbf{i_{30\ 1} = 0.94}$%) ($\mathbf{r_{30\ 1} = 0.0314}$%)
Arousal	+	**Points**	**0.1**	$\mathbf{x_{31\ 1} = 0.36}$ **(0%)** **(0%)**	$\mathbf{x_{31\ 2} = 0.31}$ ($\mathbf{i_{31\ 2} = 16.13}$%) ($\mathbf{r_{31\ 2} = 0.5376}$%)
Respiratory rate	+	RPM	0.1	$x_{32\ 1} = 14.506207$ ($i_{32\ 1} = 6.15\%$) ($r_{32\ 1} = 0.205\%$)	$x_{32\ 2} = 15.3982$ (0%) (0%)
Heart rate	+	BPM	0.1	$x_{33\ 1} = 76.00119$ (0%) (0%)	$x_{33\ 2} = 74.61746$ ($i_{33\ 2} = 1.85\%$) ($r_{33\ 2} = 0.0618\%$)

[a]The sign + (–) indicates that either higher or lower value of the criterion corresponds to its higher or lower significance to visitors.

measures) and subjective perceptions of air pollution. Repeated exposure to environmental stressors (noise, pollution, crowded areas) causes behavioral issues (e.g. attention deficits, stress, depression and anger) (Kanjo et al., 2018). As the baseline models show, four pollutants (SO_2,

Table 6
Calculation of the IEMR and MR value of $x_{12\ cycle\ e}$ to allow Lukiskiu Square site a_2 to become the best of the sites under consideration.

Approximation cycle	Rent value $x_{12\ cycle\ e}$ (over 3 days)	Integrated emotional market rental value $x_{12\ cycle\ e}$ (over 3 days)		Market rental value $x_{12\ cycle\ e}$ (over 3 days)	
		Utility degree		Utility degree	
1	2	3	4	3	4
0	69.66	100%	97.65%	100%	92.18%
...	...	...	...	...	...
66	69	100%	97.97%	100%	92.62%
...	...	...	...	...	...
306	66.6	100%	99.12%	100%	94.27%
...	...	...	...	...	...
376	65.9	100%	99.48%	100%	94.78%
...	...	...	...	...	...
396	65.7	100%	99.57%	100%	94.91%
...	...	...	...	...	...
416	65.5	100%	99.68%	100%	95.06%
...	...	...	...	...	...
436	65.3	100%	99.79%	100%	95.22%
...	...	...	...	...	...
466	65	100%	99.93%	100%	95.43%
...	...	...	...	...	...
476	64.9	100%	99.99%	100%	95.5%
...	...	...	...	...	...
478	**64.88**	100%	**100%**	100%	95.52%
...	...	...	...	...	...
500	64.66	–	–	100%	95.68%
...	...	...	...	...	...
700	62.66	–	–	100%	97.2%
...	...	...	...	...	...
1000	59.66	–	–	100%	99.6%
...	...	...	...	...	...
1040	59.26	–	–	100%	99.92%
...	...	...	...	...	...
1044	59.22	–	–	100%	99.96%
...	...	...	...	...	...
1047	59.19	–	–	100%	99.98%
1048	**59.18**	–	–	100%	**100%**

NO_2, $PM_{2.5}$, PM_{10}) push life satisfaction notably down in Beijing; in Shanghai, however, NO_2 is the only pollutant that makes a notable bad effect on life satisfaction (Du et al., 2018). Anand (2016) points out that life satisfaction refers to how people show their feelings (moods) and emotions, and the way they feel about their future directions and options.

Air pollutants affect heart rate when inhaled. A study of 21 Bostonians looked at the relationship between cardiovascular function and ambient particles, and determined that when people are exposed to $PM_{2.5}$ and ozone, heart rates decrease (Sanidas et al., 2017). Bourdrel et al. (2017) reported a link between reduced heart rate and exposure to particulate air pollution (both short and long term).

Scientists have also noticed that people's moods correlate with solar (magnetic) storms. Such storms can cause mood swings, palpitations, headaches and a general feeling of being unwell (Tango and Blackwood, 2017). Severe geomagnetic disturbances (magnetic storms) amplify an individual's negative emotional background (Babayev and Allahverdiyeva, 2007). Our research results are consistent with these findings (see Table 8).

Table 7
Number of records for emotional states.

Emotional states	Number of records
Neutral	28295270
Happiness	28295042
Sadness	28294977
Surprised	28294864
Anger	28294915
Scared	28294815
Valence	28282914
Arousal	28282857
Disgust	28294757
Interest	6792839
Confusion	6792839
Boredom	4297334
Heart rate	6155732
Gender	1159194
Age	1159239
Respiratory rate	10457649

5. Visualization for decisions in VINERS circumplex model of affect

5.1. Data for analysis

Correlations were measured between 13 features characterizing emotions, biometrical states and environment: angry, valence, arousal, sad, scared, disgusted, surprised, confusion, interest, happy, heart rate, respiration per minute (RPM) and magnetic storm. The peculiarities of the experiments were as follows:

- in most cases, the correlation between a particular pair of features was measured independently from other features,
- the number of experiments was different for different pair of features.

In a result, we got a correlation matrix of these features. The correlation matrix of features, characterizing emotions and biometrical state, is presented in Table 9.

5.2. Method for visualization of correlations

Analysis of the correlation matrix of 13 features characterizing emotions, biometrical states and environment was performed by means of visualization of multidimensional data.

Let us introduce the idea and mathematical concepts of such analysis in brief. We have 13 features characterizing emotions, biometrical

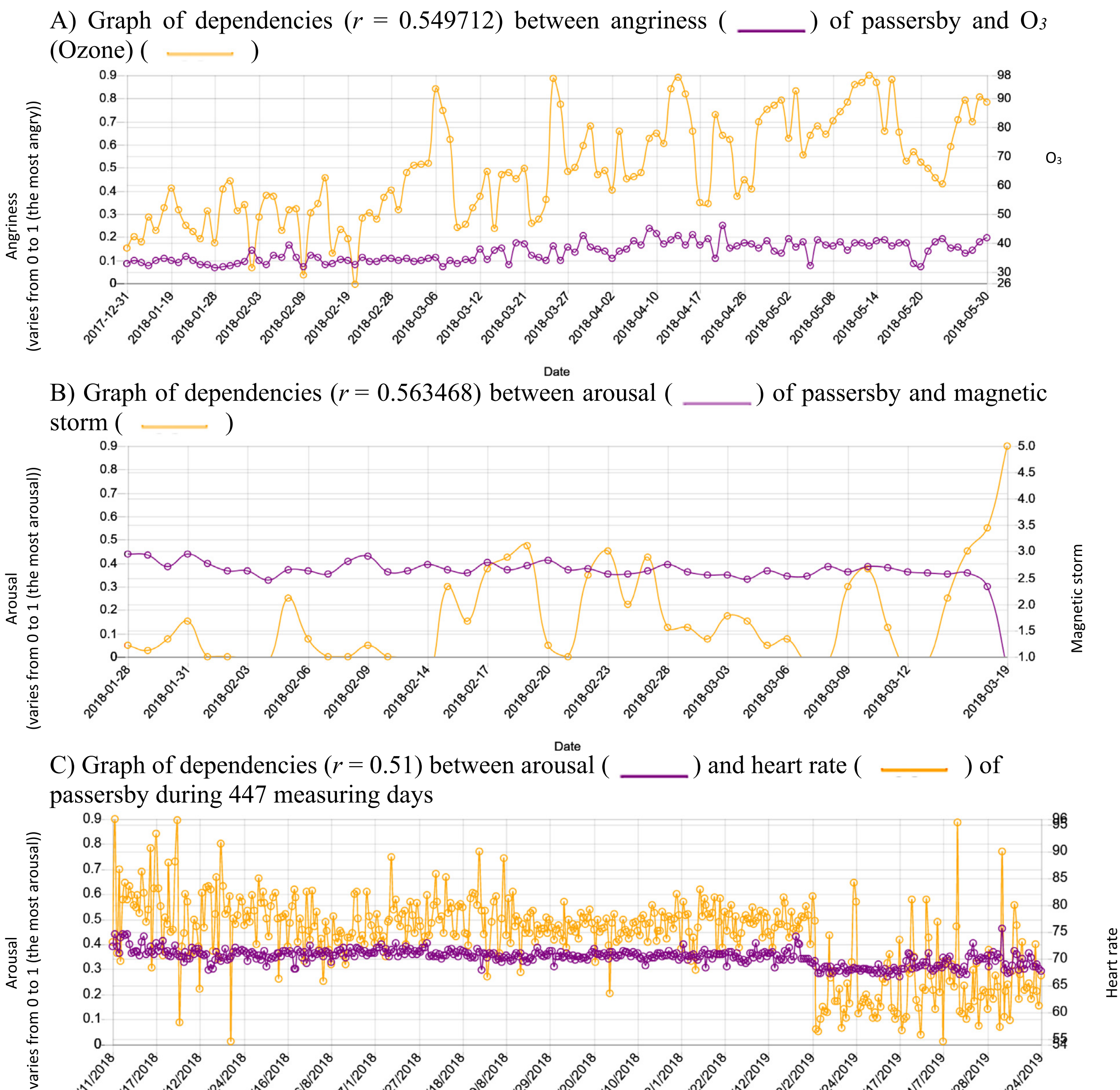

Fig. 6. Charts illustrating the correlations among metrics under analysis: A) anger ( ) and O_3 (Ozone) ( ), B) arousal ( ) and magnetic storms ( ) and C) arousal ( ) and heart rate ( ).

states and environment were measured: angry (x_1), valence (x_2), arousal (x_3), sad (x_4), scared (x_5), disgusted (x_6), surprised (x_7), confusion (x_8), interest (x_9), happy (x_{10}), heart rate (x_{11}), RPM (x_{12}), magnetic storm (x_{13}). The values obtained by any feature x_k among these characterizing emotions and biometrical states can be determined by the values of other features (x_i, $j = 1, \ldots, n$, $k \neq i$). The features are, therefore, correlated. Different properties of emotional states can be characterized by different groups of features. Individual features can be similar, but the problem is to determine the similarities shared by groups of features. A visual analysis of the features would help. The target result is to take a plane and orient a set of points on the plane each corresponding to one feature. Then, the decisions about the similarities of the features may be made when observing where each point is located on the plane and what clusters the points form.

This method gives a theoretically grounded possibility for a special view of the analysis of correlations, in particular, of the visualization of data stored in correlation matrices. The correlation matrix $R = \{r_{ij},\ i, j = 1, \ldots, n\}$ of features $x_1,\ x_2, \ldots, x_n$ can serve as a basis for analysis. Here, r_{ij} is the correlation coefficient of x_i and x_j. In our case, x_i and x_j are particular features among 13 ones listed above. One of the latest applications of this method is in the field of economics when visualizations are employed to analyze the efficiency of regional economic development and see how the economic results reflect regional resources (Dzemyda et al., 2019).

However, this instrument for the visual analysis of correlations cannot be applied in our case due to peculiarities of the experiments given in Section 5.1. The reason for this is that the matrix presented in Table 9 does not meet the formal definition of the correlation matrix: it is not positively defined or semi-defined, and we cannot apply methods for the analysis of correlation matrices directly.

Multidimensional scaling (MDS) is another option for the analysis of the correlation matrix. This method is the most popular visual representation when data is multidimensional (Dzemyda et al., 2013). It has a number of realizations using neural networks and in combinations with neural networks. In general, when solving real-world data analysis problems, the analyzed objects (items) $X_1, X_2, \ldots, X_m$ are

Table 8
Correlations of the emotional and biometrical characteristics and the level of pollution in Vilnius City.

		SO_2	$KD_{2.5}$	KD_{10}	NO_2	CO	O_3	Magnetic storm
		1	2	3	4	5	6	7
Anger	1	0.511260 (19) 0.504656 (19) (Zeidner and Shechter, 1988)	0.504475 (23) 0.510240 (22) (Zeidner and Shechter, 1988)	0.506290 (20) 0.530235 (20) (Zeidner and Shechter, 1988)	0.626449 (35) 0.615722 (35) (Zeidner and Shechter, 1988)	0.593090 (30) 0.502503 (30) (Zeidner and Shechter, 1988)	0.549712 (118), see Fig. 6a 0.555535 (117) (Zeidner and Shechter, 1988)	0.556367 (17) 0.502638 (16) (Myles, 2018)
Valence	2	−0.605495 (8) −0.678923 (7) (Cho et al., 2014; Zijlemaa et al., 2016)	−0.653784 (16) −0.692911 (15) (Yang et al., 2018; Zhang et al., 2017b)	−0.534061 (13) −0.557741 (12) (Yang et al., 2018; Zhang et al., 2017b)	−0.532537 (17) −0.519185 (17) (Zijlemaa et al., 2016; Chen, 2017)	−0.535466 (18) −0.541394 (17) (Zijlemaa et al., 2016)	−0.713499 (17) −0.531620 (17) (Cho et al., 2014; Zijlemaa et al., 2016)	−0.502754 (10)
Sadness	3	0.712097 (19) 0.642047 (19) (Cho et al., 2014; Zijlemaa et al., 2016)	0.506284 (19) 0.515298 (18) (Zhang et al., 2017b; Chen, 2017)	0.515015 (11) (Zhang et al., 2017b; Chen, 2017)	0.517171 (16) 0.517333 (17) (Cho et al., 2014; Zijlemaa et al., 2016)	0.540982 (12) 0.541788 (11) (Zijlemaa et al., 2016; Chen, 2017)	0.696938 (9) 0.664885 (8) (Cho et al., 2014; Zijlemaa et al., 2016)	0.566308 (17) 0.529572 (12) (Myles, 2018; Whittaker, 2015)
Arousal	4	0.671539 (17) 0.722840 (17) (Yang et al., 2018; Zhang et al., 2017b)	0.605056 (18) 0.617199 (17) (Yang et al., 2018; Zhang et al., 2017b)	0.577526 (17) 0.553815 (17) (Yang et al., 2018; Zhang et al., 2017b)	0.700401 (17) 0.698358 (20)	0.528843 (17) 0.546955 (18) (Yang et al., 2018; Zhang et al., 2017b)	0.673900 (11) 0.782173 (10) (Yang et al., 2018; Zhang et al., 2017b)	0.563468 (45), see Fig. 6b −0.530303 (17) −0.624154 (16)
Fear	5	0.510347 (7)	0.508688 (18) 0.522793 (17)	0.567538 (17) 0.645983 (16)	0.500626 (16)		0.589853 (10) 0.549706 (9)	0.739526 (19) 0.636893 (18)
Disgust	6	0.549904 (17) 0.533903 (20)	0.519883 (16)	0.585304 (20) 0.596887 (20)	0.716605 (18) 0.539508 (18)	0.605611 (18) 0.544852 (18)	0.513348 (20) 0.510420 (17)	0.526499 (19) 0.506750 (19)
Heart rate	7	0.502375 (12) (Skerrett, 2017; Park et al., 2008)	0.781790 (8)	0.551654 (18) 0.530120 (17) (Skerrett, 2017)	0.517080 (26) (Park et al., 2008; Chang-Chuan et al., 2005)	0,682372 (8)0,590707 (9)	0.520806 (11) 0.564503 (11) (Skerrett, 2017; Park et al., 2008)	0.621027 (9) 0.549770 (9) (Cornelissen et al., 1999)
Happiness	8	−0.513045 (7) −0.762701 (6) (Levinson, 2012; MacKerron and Mourato, 2009)	−0.643680 (16) −0.523741 (20) (Yang et al., 2018; Chen, 2017)	−0.619946 (13) −0.562833 (13) (Zijlemaa et al., 2016; Levinson, 2012)	−0.5654459 (20) (Zhang et al., 2017b; Talhelm, 2017)	−0.718863 (6) (Zijlemaa et al., 2016; Levinson, 2012)	−0.678451 (8) −0.667679 (7) (Cho et al., 2014; Zijlemaa et al., 2016)	−0.568019 (20) −0.517522 (21)

Table 9
Correlation matrix of 13 features.

	Features	Angry	Valence	Arousal	Sad	Scared	Disgusted	Surprised	Confusion	Interest	Happy	Heart Rate	RPM	Magnetic storm
1	Angry	1.0000	−0.7301	0.6038	0.5629	0.3716	0.6096	−0.5706	0.5590	0.5532	−0.6758	0.5577	0.0488	0.5828
2	Valence	−0.7301	1.0000	0.5820	−0.8281	−0.3504	−0.5638	0.5211	−0.5244	−0.5027	0.8319	0.7257	0.6730	0.4913
3	Arousal	0.6038	0.5820	1.0000	0.6502	0.4857	0.6296	0.8232	0.6294	0.8048	0.5356	0.5600	0.5575	0.5696
4	Sad	0.5629	−0.8281	0.6502	1.0000	0.6419	0.3952	0.5415	0.6595	−0.5638	−0.7001	0.5992	0.1282	0.3014
5	Scared	0.3716	−0.3504	0.4857	0.6419	1.0000	0.4867	0.5768	−0.4069	−0.7511	0.4490	0.5566	0.6252	0.6176
6	Disgusted	0.6096	−0.5638	0.6296	0.3952	0.4867	1.0000	0.7176	0.5049	−0.5158	−0.4422	0.5315	0.4945	0.2754
7	Surprised	−0.5706	0.5211	0.8232	0.5415	0.5768	0.7176	1.0000	0.2856	0.5683	0.5006	−0.1036	0.5563	−0.2531
8	Confusion	0.5590	−0.5244	0.6294	0.6595	−0.4069	0.5049	0.2856	1.0000	0.5790	−0.5115	0.5642	0.6306	−0.5915
9	Interest	0.5532	−0.5027	0.8048	−0.5638	−0.7511	−0.5158	0.5683	0.5790	1.0000	0.5551	0.6279	0.5144	−0.5399
10	Happy	−0.6758	0.8319	0.5356	−0.7001	0.4490	−0.4422	0.5006	−0.5115	0.5551	1.0000	0.5443	0.6208	−0.5680
11	Heart Rate	0.5577	0.7257	0.5600	0.5992	0.5566	0.5315	−0.1036	0.5642	0.6279	0.5443	1.0000	0.7359	0.6466
12	RPM	0.0488	0.6730	0.5575	0.1282	0.6252	0.4945	0.5563	0.6306	0.5144	0.6208	0.7359	1.0000	0.5714
13	Magnetic storm	0.5828	0.4913	0.5696	0.3014	0.6176	0.2754	−0.2531	−0.5915	−0.5399	−0.5680	0.6466	0.5714	1.0000

characterized by certain features $x_1, x_2, \ldots, x_n$, where n is the number of featuresand m is the number of objects. The features $x_1, x_2, \ldots, x_n$ can achieve certain values (numerical). These values can be combined into sets that characterize a particular object $X_i = (x_{i1}, x_{i2}, \ldots, x_{in})$, $i \in \{1, \ldots, m\}$. If the objects are described by more than one feature, the data characterizing the objects are called multidimensional data. A visual analysis of such data makes it possible to get deeper insights into the data and opens up possibilities for direct interactions with the data. In our case, objects are individuals for which 13 features characterizing emotions, biometrical states and environment were measured: angry (x_1), valence (x_2), arousal (x_3), sad (x_4), scared (x_5), disgusted (x_6), surprised (x_7), confusion (x_8), interest (x_9), happy (x_{10}), heart rate (x_{11}), RPM (x_{12}), magnetic storm (x_{13}). Due to a large number of individuals, our starting data are correlations between features. These correlations may be used to evaluate the proximity between particular features.

Low-dimensional visualization requires holding proximities between features $x_1, x_2, \ldots, x_n$ as much as possible. MDS ensures such objective. MDS requires estimating the coordinates of new points $Y_i = (y_{i1}, y_{i2})$, $i = 1, \ldots, n$, in a lower-dimensional space R^d ($d = 2$) by minimizing some stress function. Example of the stress function may be as follows:

$$E_{MDS}(Y) = \sum_{i<j} \left(d\left(Y_i, Y_j\right) - d\left(x_i, x_j\right) \right)^2 \quad (1)$$

Here $d(x_i, x_j)$ is the proximity between two features x_i, x_j, $Y = (Y_1, Y_2, \ldots, Y_n)$ is a variable set; $d(Y_i, Y_j)$ is the Euclidean distance between the points Y_i, Y_j. More stress functions are available in Dzemyda et al. (2019). The optimization problem is quite complicated because of the number of variables, which is equals $2n$. Moreover, the Stress function is multimodal. Usually, gradient-based optimization methods are applied. One of the commonly used algorithm is Scaling by MAjorizing a COmplicated Function (SMACOF), which is based on iterative majorization guaranteeing a monotonic convergence. Here the optimization process is started from initial values of $Y_1, Y_2, \ldots, Y_n$. A particular rule changes these. Finally, such values find that the value of the Stress function is as minimal as possible. Two ways are usually applied to the selection of the initial values of $Y_1, Y_2, \ldots, Y_n$. In the simplest way, the values are random numbers from interval $(0, 1)$.

Proximity $d(x_i, x_j)$ between two features $x_i$and x_j may be derived from the correlation coefficient r_{ij} between them. Correlation coefficient means some product of two n-dimensional vectors $Y_i$and Y_j of unit length. This product may take values in the range [-1, 1]. Geometrically, this product may be interpreted as a cosine between two corresponding vectors $Y_i$and Y_j. If so, then the length of arc between points Y_i and Y_j may be applied to evaluate the proximity:

$$d\left(x_i, x_j\right) = \arccos\left(r_{ij}\right) \quad (2)$$

13 × 13 matrix of proximities of features $x_1, x_2, \ldots, x_{14}$ is computed using (2) and presented in Table 10.

5.3. Visualization results

Results of visualization of features are presented in Fig. 7A and B. Dots in the figure correspond to the features characterizing emotions, biometrical states and environment: angry, valence, arousal, sad, scared, disgusted, surprised, confusion, interest, happy, heart rate, RPM and magnetic storm. The names of features are given at the corresponding dot. We can evaluate visually the similarities of features and their relations. More similar features are located closer on the plain. The visual of features on the plane is invariant to the angle of rotation of all points and to the representation's mirror-image. Therefore, we chose such perpendicular axes: abscise goes through valence and ordinate goes through arousal.

Difference in Fig. 7A and Fig. 7B is that:

- in Fig. 7A, we observe similarities and relations of emotions $x_1, x_2, \ldots, x_{10}$;
- in Fig. 7B, we observe all 13 emotions, biometrical states and environment features $x_1, x_2, \ldots, x_{13}$.

5.4. Visualization: VINERS and Russell's Circumplex models of affect

Visualization of correlations of the features characterizing emotions, biometrical states and environment on one plot allows us to disclose and fix relations among them. VINERS Circumplex Model of Affect.

Fig. 7A and B has many analogies when compared with well-known graphical representations of Russell's circumplex model of affect of emotions for acoustic stimuli, presented in Fig. 7C (Russell, 1980; Posner et al., 2005; Meyerding and Mehlhose, 2018). The vertical axis represents arousal and the horizontal axis represents valence.

Moreover, we can evaluate visually the dependence of emotions and biometrical states on hearth rate, RPM and magnetic storm. The features make some cluster. Arousal appears in the center of this cluster. This state may be interpreted as some transition from other states, e.g. from happy to sad or angry. We observe strong relation among arousal, hearth rate and RPM. The greatest influence of magnetic storm is to scared and hearth rate.

A comparison of the obtained results with the results from the Russell study(Russell, 1980) illustrates the correspondence of numerous indicators. The Y axis at the top corresponded with the emotions of confusion, anger and disgust. Meanwhile, at the bottom, the correspondence was with sadness. The Y axis at the right side, at its top, corresponded with the emotions surprise, arousal, happiness and valence.

The first Hypothesis, "Pollution (magnetic storms, SO_2, $PM_{2.5}$, PM_{10}, NO_2, CO, O_3) influences emotional states (surprised, sad, disgusted, angry, happy, scared) and biometrical states (respiration and heart rates) as well as arousal, valence and affective states (confusion and interest)"; – was confirmed in this and above Sections 4 and 5.

6. Discussion and conclusions

Studies performed worldwide indicate that the happiness experienced by people positively impact their achievements in various spheres of life such as earned wages (Whillans et al., 2017; Jebb et al., 2018; Oishi et al., 2018), productivity (DiMaria et al., 2017; Blankson, 2017; Graziotin and Fagerholm, 2019), friendliness (Wang et al., 2016; Demir et al., 2017; Sanchez et al., 2018), wedlock (Tao, 2019; Perelli-Harris et al., 2019), social support (Findler et al., 2016; Ye et al., 2019; Mérida-López et al., 2019) and inclusion (Fagundes, 2017; Fisk et al., 2018), health (Kubzansky et al., 2016; Zhang et al., 2017a,b; Steptoe, 2019), environmental sustainability (Kyttä et al., 2016; Musikanski et al., 2017; Musa et al., 2018) and lower corruption (Kabene et al., 2017; Li and An, 2019; Suhaimi et al., 2019).

Worldwide investigations indicate that present customers not only purchase products and services but also pay interest to their surroundings. Entertainment thus becomes one of the main retailing strategies.

In the 2017 World Happiness Report, Helliwell et al. (2017) found that the top ten countries in the ranking of emotional wellbeing share six factors primarily relevant to overall happiness: income, health and life expectancy, significant others for emergency assistance, generosity, freedom and trust. However, overall, nation-wide happiness had little correlation with corruption and generosity, as Tofallis (2019) discovered. Other scholars also analyzed the links happiness had with other variables, such as income, psychological well-being, health and the like. For example, Jebb et al. (2018) analyzed the relationship between happiness and personal income. Their evidence indicates a limit to the degree of happiness realized by income levels, which holds true worldwide. The significance estimated by Heizomi et al. (2015) between happiness and mental health was r = 0.48). A positive correlation was found by Subramanian et al. (2005) between health and happiness in their study of individuals as well as communities; education and income indicated strong impacts on realizing happiness. Another study, by Johnston et al. (2013), indicated that work-related stress had a negative impact, whereas an attitude of happiness had a positive effect. Nonetheless, even an attitude of happiness showed a negative

Table 10
Table of proximities for multidimensional scaling.

	Features	Angry	Valence	Arousal	Sad	Scared	Disgusted	Surprised	Confusion	Interest	Happy	Heart rate	RPM	Magnetic storm
1	Angry	0.0000	2.3893	0.9226	0.9729	1.1901	0.9153	2.1781	0.9776	0.9846	2.3128	0.9792	1.5220	0.9486
2	Valence	2.3893	0.0000	0.9496	2.5464	1.9288	2.1698	1.0226	2.1229	2.0976	0.5882	0.7587	0.8325	1.0572
3	Arousal	0.9226	0.9496	0.0000	0.8630	1.0637	0.8898	0.6038	0.8900	0.6354	1.0056	0.9764	0.9794	0.9648
4	Sad	0.9729	2.5464	0.8630	0.0000	0.8738	1.1645	0.9986	0.8506	2.1698	2.3463	0.9283	1.4423	1.2647
5	Scared	1.1901	1.9288	1.0637	0.8738	0.0000	1.0625	0.9560	1.9899	2.4205	1.1052	0.9805	0.8954	0.9051
6	Disgusted	0.9153	2.1698	0.8898	1.1645	1.0625	0.0000	0.7704	1.0415	2.1127	2.0288	1.0105	1.0535	1.2918
7	Surprised	2.1781	1.0226	0.6038	0.9986	0.9560	0.7704	0.0000	1.2811	0.9664	1.0465	1.6746	0.9808	1.8267
8	Confusion	0.9776	2.1229	0.8900	0.8506	1.9899	1.0415	1.2811	0.0000	0.9532	2.1077	0.9714	0.8885	2.2037
9	Interest	0.9846	2.0976	0.6354	2.1698	2.4205	2.1127	0.9664	0.9532	0.0000	0.9823	0.8919	1.0304	2.1411
10	Happy	2.3128	0.5882	1.0056	2.3463	1.1052	2.0288	1.0465	2.1077	0.9823	0.0000	0.9953	0.9010	2.1749
11	Heart rate	0.9792	0.7587	0.9764	0.9283	0.9805	1.0105	1.6746	0.9714	0.8919	0.9953	0.0000	0.7437	0.8677
12	RPM	1.5220	0.8325	0.9794	1.4423	0.8954	1.0535	0.9808	0.8885	1.0304	0.9010	0.7437	0.0000	0.9626
13	Magnetic storm	0.9486	1.0572	0.9648	1.2647	0.9051	1.2918	1.8267	2.2037	2.1411	2.1749	0.8677	0.9626	0.0000

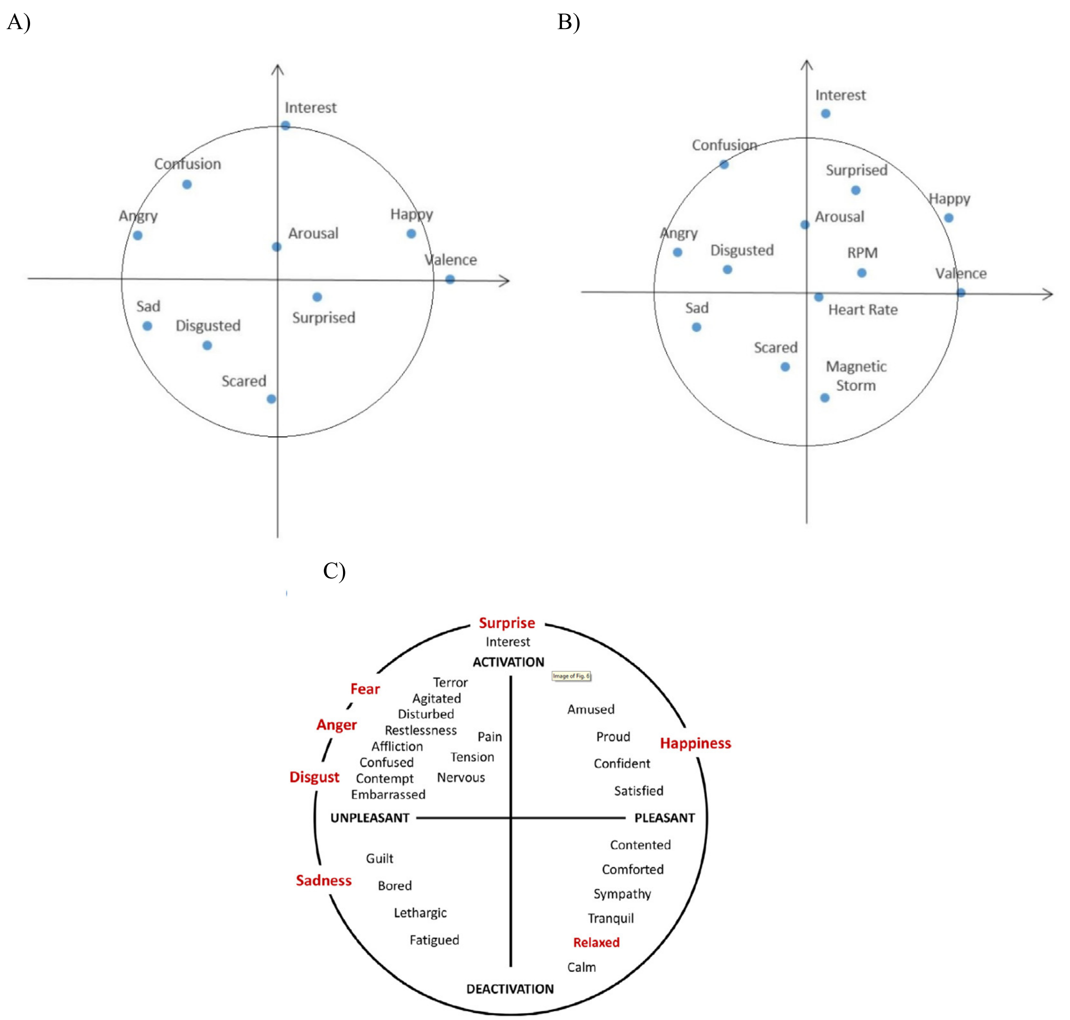

Fig. 7. (A) Visualization of emotions $x_1, x_2, \dots, x_{10}$; (B) visualization of emotions and biometrical states and environment features $x_1, x_2, \dots, x_{13}$; (C) and Russell's (1980) circumflex model of emotions.

correlation with work-related stress despite engagement and pleasure scales. Besides, an ability to adapt to a career can act as an intermediary between an attitude of happiness and work stress. Meanwhile enjoying a social network, social trust and social norms, as per Jung (2020), positively influence the happiness of a workforce. Jung discovered that a social network and social norms statistically significantly affected personal happiness. Meanwhile Taylor and Adams (2020) highlight the complexity of intense happiness by categorizing it according to three areas: time for me, spatial imaginaries and community challenges. Resolving problems, self-control and positive reappraisal correlated positively with happiness (P<0/01), as Rajabimoghaddam and Bidjari (2011) found, while escape-avoidance and responsibility correlated negatively with happiness (P<0/05).

Many scholars have investigated various aspects of the influence of emotions on public spaces (Scheutz, 2000; Kahneman, 2011, Simon, 2011, Hämäläinen et al., 2013; Russell, 1980; Zawadzki et al., 2017), and several neuromarketing studies have been carried out (Meyerding and Mehlhose, 2018). Although these scientists have achieved considerable successes, no researchers have yet integrated analyses of the emotional and biometrical states of potential buyers, their valence and arousal and their affective states into research on the neuromarketing process. It is important to consider the relationships among public spaces and their values, qualities and utilities for people. According to dual process theory, evaluation dualism (intuitive/emotional and logical/rational) is characteristic of public spaces, and is primarily determined by the value of the public space itself – its type, size and environment – as well as by the utility value of the space. However, the relationship between the quality of a public space and its value to a community is complicated, as this encompasses a broad spectrum of benefits.

Explanations about the possible outcropping of disadvantages, inherent in previous studies, which did not use biometrical, affective and emotional factors, appear next. This neuromarketing method can serve as the basis for a more thorough understanding of the actual preferences and requirements of shoppers. It then allows effective consideration regarding the composition of a personalized marketing plan aimed at them and the analysis aiming to enhance a richer relationship with such customers.

– The multiple-criteria method proposed is rational to use in Big Data analytics for arriving at a final decision. For example, Stanley Marcus has pronounced, "Consumers are statistics; customers are people''. The authors of this article have accumulated over 350 million bits of data on affective attitudes, emotional and biometrical states, valence and arousal. Such data can be the basis for identifying previously unknown relations and reacting to these data and trends. The goal for doing so is effective satisfaction of the needs of potential buyers while, in parallel, increasing company profits.
– This method is cost-effective, when applying mass marketing in real time, for analyzing numerous potential buyers and composing a Big Picture of purchaser desires.
– The application of this proposed method makes it possible to humanize and optimize an advertisement better. It also permits better interactions with a customer by responding, in real time, to the reactions of even the smallest buyers to any nuances of an offered product.

Over 350 million remote data points were accumulated and analyzed for this research. Compilations of the neuromatrices, biometrical, emotional and the surrounding environment maps were based on these twelve layers of data. These layers of data were accumulated for the validation of the two hypotheses. This study examined the following factors:

- Emotional states (happy, sad, angry, surprised, scared, disgusted or a neutral state); valence and arousal; affective states (boredom, interest and confusion); biometrical states (heart rate and breathing rate, facial temperature) (data gathered at seven Vilnius City sites employing the equipment subsystem) and neuro-surveys; and
- Weather conditions and pollution; data on Vilnius' built environment and municipal district; real estate characteristics; circadian rhythm of Vilnius city inhabitants; initial neuromarketing data tables; tables assessing neuromarketing alternatives; tables of multi-alternative design neuromarketing (data gathered from the Vilnius Meteorology Station, Environmental Protection Agency and recalculated by Raimondas Grubliauskas, Vilnius Municipality and experts in the field).

An integrated system of methods is compiled to determine the most suitable advertisement for a specific potential buyer. This research involves integrating Damasio's somatic marker hypothesis (Damasio, 1994); Russell's circumplex model of affect (Russell, 1980); biometric methods (Kaklauskas, 2015; Kaklauskas et al., 2018a); spatial multiple-criteria analysis of categorical data using neuromarketing analysis methods, for example, generation of human affective, emotional, biometrical states and the surrounding environment maps (Kaklauskas et al. 2019, (Dauvier et al., 2019); neuro-questionnaire method (Kaklauskas et al., 2018b); affective computing (Kaklauskas, 2015; Kaklauskas et al., 2018a); neuromarketing method (Kaklauskas et al., 2018a); statistical analysis (LOGIT, KNN, MBP, RBP); recommender technique (Kaklauskas, 2015); and opinion analytics technique (Kaklauskaset al. 2009); as well as five methods for multiple-criteria analyses developed by Kaklauskas (2015, 1999, 2016).

The research objectives were to develop biometrical, affective, emotional and the surrounding environment maps (see Section 3.2, Fig. 5) and to determine over 35,000 average and strong correlations (see Sections 4 and 5, Figs. 6 and 7). The dependencies we obtained provided the basis for calculating the graphic submission of the VINERS circumplex model of affect (developed by these same authors). VINERS is similar to the Russell's circumplex model of affect (developed by different authors). The VINERS Method provides supplements for advanced needs.

The two proposed hypotheses validated the accuracy of the VINERS method by verification and validation of case studies (see Sections 3–5):

- H1: Pollution (magnetic storms, SO_2, $PM_{2.5}$, PM_{10}, NO_2, CO, O_3) influences emotional states (surprised, sad, disgusted, angry, happy, scared) and biometrical states (respiration and heart rates) as well as arousal, valence and affective states (confusion and interest) (see Sections 4 and 5).
- H2: Influences of emotional and biometrical states, arousal, valence and the surrounding environment (its pollution and physical, economic, social and environmental criteria) on the priority, utility degree and integrated, emotional market value of real estate (see Section 3, "Case Studies").

This affirmed the posed hypothesis that the neuromarketing of shopping requires an integrated approach. Thereby alternative retail outlets can be considered along with the surroundings for engaging in shopping by their physical, economic and social aspects. Furthermore such a study must look at environmental pollution, the emotions, biometrical states of the buyers and their valence and arousal as well as affective attitudes.

Such research can serve as a basis for determining the integrated emotional market rental value (see Case Study 2). An integrated neuro multiple-criteria analysis and neuro-correlation analysis on the built environment and provisions for digital recommendations (see Case Study 4) also has yet to be performed. Optimization of IEMR happiness value (see Case Study 3) and adjusting the IEMR and MR values of a sales booth to make it the best option (see Case Study 5) also was performed.

One of the main contributions of our results is that we obtained formal estimates of similarities of emotions, biometrical states and environment features by using their correlations, which were evaluated using big data. In this case, our methods, drawn from computer science and artificial intelligence, may serve as a means for the automatic quantification and recognition of emotions and the evaluation of their dependence on environmental features.

The practical significances of the results achieved by these authors for personalized marketing are the following:

– As data was being gathered for this study, the issue of the privacy of passersby arose. Nonetheless, completion of the Data protection impact assessment confirmed that performance of this research had upheld all the established, European Union and Lithuanian, official requirements, thereby eliminating this problem.

– An increase in the integrated emotional market rental (IEMR) value of a product constitutes a substantial aspect for attracting customers. Therefore organizations will achieve value by applying the method developed by these authors.
– This developed method can provide the basis for increasing the effectiveness of marketing retail-shopping outlets. To achieve such results, data on affective attitudes as well as emotional and biometrical states, valence and arousal, which deliberate some certain, potential buyer, must accumulate, in real time,

In its current form, the proposed VINERS method is not ideal and has certain limitations. We have identified three directions for future research. Firstly, data from the property, construction and service industries will be used to enlarge the VINERS database about monuments, buildings (residential areas, theaters, museums, city fortresses, libraries), public spaces (public archeological sites, squares, streets, courtyards), and events (workshops, seminars, conferences, exhibitions, concerts, festivals). Secondly, eye tracking and brainwave sensors and device measuring the electric field present in humans will be incorporated into the system. Emotional, affective, biometrical and the surrounding environment mapping may improve the accuracy of the maps of built environment and that, in turn, may make the tips on ways to make the built environment more efficient more appropriate. The recommending process can also be made more rational by using the existing states of the crowd and the best global practices.

The correlation analysis of emotions and biometric tests produced good results. This makes the approach a promising tool that can offer comprehensive conclusions on the dependencies that link biometric features. The visual analysis of correlations can be done using special methods (Dzemyda, 2001; Dzemyda et al., 2013) that combine multidimensional scaling and neural networks.

Additionally, further work conducted for this study included the uncertainties and their analysis of load reduction possibilities, additional case studies and assessment of the VINERS method's accuracy by verification and validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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