Minimizing the influence of coronavirus in a built environment

MICROBE

O2/A1. Formulation of the Research Problem and Goals

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1. Literature rewiev

More than half of the world's inhabitants now reside in towns, making the development of healthy city environments a main policy priority [1]. In the opinion of Shoval et al. [2], individual emotional connections with a city's environment have been of vital importance to city researchers for decades. A city's physical, social and cultural aspects determine a person's emotional involvement with a city environment. Various research studies [3, 4] propose that a city's environment (its architecture, land use mix, public squares, parks, built features, polluted areas, rubbish, the quality of the built environment, manufacturing zones and traffic flow) plays an important role in human emotions, moods and mental health, in conjunction with individual and social factors. Gong et al. [4] hold the opinion that a city's environment affects people on an individual/personal level (based on individual perceptions) and due to the effects of public spaces. Rapoport [5] defines the built environment as a form of "nonverbal communication", and finds that individuals use tools to interpret its meanings. Carmona [6] has emphasized that the perception of an association between humans and their physical environment is a vital constituent of city planning.

Efforts to assess the effect of a city on human emotions, from both a subjective and objective point of view, have involved the development and application of various methods and tools over recent decades. Analyses of human emotions have been undertaken by an entire array of researchers, and subjective studies include those by Kim et al. [7], Solymosi et al. [8], Resch et al. [9] and Birenboim et al. [10] while objective studies have been conducted by Sagl et al. [11], Birenboim [10], Birenboim et al. [12], Zeile et al. [13] and integrated studies by Birenboim et al. [12, 14] and Shoval et al. [15].

Subjective studies of human emotions/experiences in an urban context have been performed by applying qualitative methods such as self-reports, interviews, observations, questionnaires and diaries, in order to register the subjective experiences of individuals in their usual settings. For example, self-reports might encompass methods such as the Ecological Momentary Assessment, the Pleasure–Arousal–Dominance scale and the Experience Sampling Method. Russell's circumplex model of emotion [16] can aid in the evaluation of a self-report (as per the Pleasure–Arousal–Dominance scale), and has been widely used in such studies [7]. Loiterton and Bishop [17] of the Royal Botanic Garden in Melbourne sought to examine subjective feelings such as boredom, fatigue and hunger, and developed questionnaires focusing on public spaces, applying these data to make forecasts about people walking in the garden.

Objective studies of human emotions and/or experiences in a built environment and minimization the influence of coronavirus in a built environment have involved the application of biometric methods and systems (blood pressure, body temperature, heart rate, skin conductance, pupil size, blinking and others). A number of researchers have looked at ways to make ambulatory physiological sensing part of urban planning [10, 13, 14, 18]. In their efforts to integrate ambulatory sensing within urban planning, Nold [19], Sagl et al. [11], Zeile et al. [18] and Resch et al. [20] have relied on fundamental theoretical and methodological approaches. Advanced technologies and tools now offer more effective ways to focus on residents [18]. Data related to emotions can also offer a different way to validate the monitoring of public spaces [20]. Many researchers use wearable electronics (smartwatches, Google Glass, computerized contact lenses, wristband sensors, intelligent textiles, wearable sensor patches) to conduct unbiased affective, emotional and physiological studies. Many of these devices were first imagined in science fiction and mainstream films.

When we know how individuals respond to environments via their emotions, we can begin to understand how people engage and interact with spaces [21]. Based on this, designers, planners and managers of public spaces can measure people's responses to various different stimuli [22] within the built environment [23]. The combined effects of various environmental stimuli produced through interaction, and their power to induce the desired emotions and behaviors, need further study before they can be fully understood [24]. Hence, there is a need to study the emotional reactions of human beings to the everyday stimuli that can affect the senses of people living within and using different spaces [23].

Human emotions have also been studied using an integrated approach [12, 14, 15, 25]. For instance, Pettersson and Zillinger [25] examined the positive and negative feelings of contributors during the 2008 Biathlon World Championship held in Ostersund, Sweden, with the help of tracking technologies and questionnaires. The Huss Index, developed by Daly et al. [23], combines ethnographic methods (i.e. interviews and sensory mapping) with measuring biometric technologies in an attempt to discover correlations between the subjective feelings of the participants and their statements about their environmental experiences, with their objective physical and emotional states tracked in real time and in a natural environment [23].

Mehrabian and Russell [26] determined that environmental perceptions inspire various emotions, and that these emotions affect a person's responses to the environment, either positively or negatively. The aforementioned studies and those presented below have examined different types of emotions (happiness, sadness, anger, surprise, fear, disgust, anxiety, neutral, etc.), moods (e.g. depression) and feelings (psychological stress and distress). Researchers have analyzed the impact of a city's social, built and physical environments on human happiness [9], sadness [9], anger and disgust [9], surprise [7, 11], fear [27], depression [28], psychological distress [29], anxiety [30], mental disorders mixed with anxiety and depression [31] and psychological stress [29]. There have also been several studies analyzing cities and their built environments in terms of the effects of pollution on human emotions, stress and mental health [32]. What should a built environment be like, in order to generate positive experiences for people, reduce the negative emotions of its residents and bring about feelings of emotional comfort? For example, Vischer [33] and Daly et al. [23] hold the opinion that in order to provide psychological comfort within a city or a built environment, there needs to be better satisfaction of basic human needs and individual perceptions and a sense of belonging and satisfaction within existing public spheres.

Current research involves measurements of the integrated objective and subjective dimensions of emotions at two levels (individual perception, and the perception of the city and built environment). Individual affective, emotional and physiological tests [34, 35] have also been conducted previously. The project coordinator and partners have developed an Affect-Based Built-Environment Video System (MICROBE) based on the aforementioned literature sources and their long-term personal experience in this field. Within the framework of the H2020 ROCK (Regeneration and Optimization of Cultural Heritage in Creative and Knowledge Cities) project, the MICROBE method and system were developed. As part of the ROCK project, studies are being carried out with a broader scope from the perspective of public spaces in comparing with previous similar studies [7-15, 17-25].

Significant contact-based biometric investigations are being conducted in built environments, and have also been carried out across the world [8-20]. The term 'contact-based investigations' means that sensors have direct contact with the person under analysis. The analysis of these important investigations [8-20] involves comparing a small amount of data according to the number of metrics.

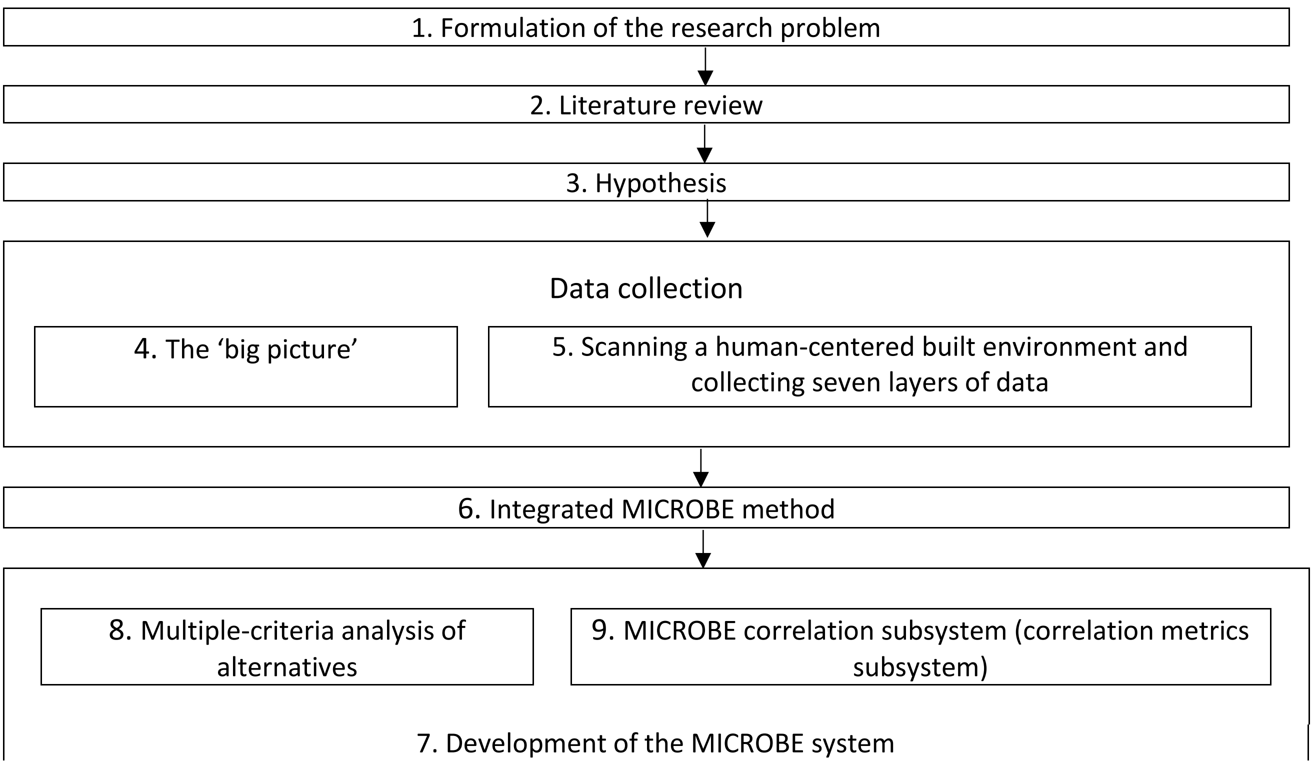
Over the course of the ROCK project, MICROBE (an Affect-Based Built Environment Video Analytics) has accumulated over 500 million anonymized data points by remote means, and this number continues to grow. Several synonyms are used in the literature for contact-free biometric measurements, such as contactless, stand-off, distance or non-contact biometric measurements. MICROBE expands the important investigations of the built environment described above [8-20] by analyzing the large number of variables for a large number of data collected by remote means.

2. Research Design of the MICROBE

The research aim is to create the MICROBE method, which analyzes real time potential buyer emotional, affective and biometrical states, the surrounding environment, possible COVID-19 situation and, based on the existing best practice and the results of analysis, provides a "big picture" of built environment MICROBE. Therefore, the MICROBE research object is extended and developed, similarly to investigations previously conducted by other researchers. The research object will be not documented as being a subject of investigation prior to this investigation. The research problem is, consequently, an enlargement of built environment using the MICROBE technique.

The main objective for the design of MICROBE (see Figure 1) was to compile a framework, a set of methods and a plan of action for collecting, measuring and analyzing data on affective attitudes, emotional and physiological states, valence and arousal, pollution, weather conditions (variables) and COVID-19 data (Deaths, Cases, Tests, Hospitalizations, Vaccinations, Mortality risk, Excess mortality, Policy responses) in a human-centered built environment in order to minimize the influence of coronavirus in a built environment. The integrated quantitative research design developed here concentrates on statistics, while the qualitative research design focuses on descriptions. The variables established during the research design process were quantitatively collected, measured, analyzed and controlled.

The following introduces the 11 stages in the MICROBE research design process.



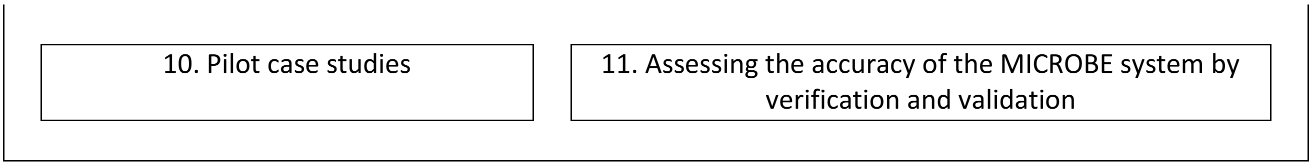


Fig. 1. MICROBE research design and methods

The research problem and topic were formulated at the first stage of the design process of MICROBE. In the third stage, the research hypothesis was formulated based on the available knowledge and a literature analysis, which was performed in the second stage. An overall view of the object under research was presented at the fourth stage. Next, at the fifth stage, scanning took place according to this larger picture of a human-centered, built environment along with the collection of seven layers of data in order to minimize the influence of coronavirus in a built environment. The integrated MICROBE method, developed in Stage 6, serves as the basis for the development of the MICROBE at Stage 7. A multiple-criteria analysis of alternatives with assistance from the MICROBE was performed at Stage 8. The practical application of the correlation subsystem took place in Stage 9 and two pilot case studies were carried out in Stage 10. At the end of the MICROBE research design process, in Stage 11, verification and validation were used to assess the accuracy of the MICROBE (see Figure 1).

Stage 1: Formulation of the Research Problem

To date, research performed in a human-centered built environment and Coronavirus Pandemic (COVID-19) analysis has not been accomplished by remote means (i.e. by employing multiple non-contact biometrics). Various types of data (affective attitudes, emotional and physiological states, valence and arousal, pollution and weather conditions, COVID-19 data (Deaths, Cases, Tests, Hospitalizations, Vaccinations, Mortality risk, Excess mortality, Policy responses)) need to be gathered in an integrated manner to serve as the basis for establishing over 50,000 of average and strong correlation coefficients. The larger picture defines the reality of the built environment. The multiple-criteria analysis of the built environment and COVID-19 should use neuro decision tables, and several values should be established (market, investment, synergistic and fair values) and various recommendations prepared for stakeholders. In this way, the scientific problem is broadened and deepened compared with prior research by other scientists. The problem studied via MICROBE has not previously been recognized as a topic for research, and this research study therefore contributes to the body of research on the human-centered built environment via the application of the integrated MICROBE method.

The topic of this study is an analysis of different types of data (human affective attitudes, emotional and physiological states, valence and arousal, pollution and weather conditions, and other data, COVID-19 data (Deaths, Cases, Tests, Hospitalizations, Vaccinations, Mortality risk, Excess mortality, Policy responses)) that are related to a human-centered built environment and minimization of the influence of coronavirus in a built environment. This analysis involves the application of the integrated MICROBE method consisting of multimodal non-contact biometrics, recommenders, statistics (logit, KNN, MBP, Rprop), case studies and four multiple-criteria decision analysis methods developed by the current authors.

Stage 2: Literature Review

A literature review was carried out to determine the state of art in this field. The extant knowledge in the field under study was condensed as part of this literature review to answer the following questions: What aspects have not yet been observed but may be significant? How does this study contrast with research that has already been performed? What is the status of this research? Is there any recognition of the problems that this research addresses? What other outcomes, if any, does this study inspire or broaden?

Stage 3: Hypothesis

The hypothesis posed here is that human affective attitudes, emotional and physiological states, valence and arousal, pollution, the weather conditions and COVID-19 data (Deaths, Cases, Tests, Hospitalizations, Vaccinations, Mortality risk, Excess mortality, Policy responses) in a human-centered built environment are interrelated. In addition, these and other data related to a built environment and COVID-19 can be used for a multiple-criteria analysis and to prepare recommendations for stakeholders with the help of neuro decision tables. This hypothesis will be substantiated by employing correlational research and descriptive research.

When built environment spaces have a positive emotional charge, they are very attractive to stakeholders (developers, communities, architects, businesses, contractors, environmentalists, consultants and landowners), and very popular with inhabitants; such positively charged locations become preferred recreational spots. Places where visitors exhibit high valence tend to attract businesses, which are keen to open outlets there offering a variety of products and services.

Stage 4: The Big Picture

The 'big picture' stage defines the reality of the built environment and possibilities of minimization of the influence of coronavirus in a built environment. This stage involves describing a human-centered built environment and establishing the demands of interested groups.

An attempt to plan and implement an effective life cycle for a public space requires a complex analysis of its composite parts and its participating interest groups, along with their goals and abilities. It is also necessary to consider the built environment surrounding it, and the effects on it due to any events held there. Various interest groups (urban planners, communities, developers, architects, contractors, landowners, environmentalists, consultants, businesses and so on) may participate in these events over the life cycle of the built environment.

One of the most important stages in the life cycle of a public space in a built environment in order to minimize of the influence of coronavirus in a built environment involves establishing the values and weights of the criteria describing alternatives. The utility degrees and priorities of the variants under comparison are established by calculating the values and weights of the criteria and applying methods for planning project variants and for a multiple-criteria analysis. In this way, an exhaustive picture of a built environment can be drawn at this stage.

The 'big picture' stage involves establishing a system of metrics that comprehensively describe a human-centered built environment and minimization of the influence of coronavirus in a built environment. Each metric can be measured both at the individual level and at the public space level.

Stage 5: Scanning a Human-Centered Built Environment and Collecting Data

Biometric/emotional tests were performed on anonymous passersby between November 6, 2017 and October 28, 2018 at specific sites (see Table 1). The MICROBE was used to collect seven layers of data in different formats (see Stage 6), which needed to be processed, integrated and analyzed.

Table 1. Data measured at seven sites in Vilnius City

	Measured data		

Where and when measurements were taken	Emotional states (happiness, sadness, anger, surprise, fear, disgust and a neutral state), valence and arousal	Heart rate	Affective attitudes (boredom, interest and confusion) (Action Unit Module)	Crowd composition by gender and age group	Breathing rate	Average crowd facial temperature	COVID-19 data
1. Pilies St. 1	2017 11 07 – present	2018 12 05 –present	2018.05.11 – present	2017 11 07 –present	2017 11 10 –2018 06 01	2017 11 07 – 2018 06 01	
2. Gedimino Avenue 1	2017.11.22 – 2018.01.25	2017.11.22 – 2018.01.25	-	2017.11.22 – 2018.01.25	2017.11.10 - 2018.01.25	-	
3. Gedimino Avenue 35	2018.01.25 –present	2018.01.25 – present	2018.05.28 – present	2018.01.25 –present	2018.01.25 – 2018.06.01	-	
4. Santariškių St. 2	2018.03.27 – present	2018.03.27 – present	2018.09.21 –present	2018.03.27 – present	2018.03.27 – present	-	
5. Kalvarijų St. 143	2018.03.27 – present	2018.03.27 – present	2018.09.21 –present	2018.03.27 – present	2018.03.27 – present	-	
6. Žygimantų Str. 1 2018.03.13 – present	2018.03.27 – present	2018.03.27 – present	2018.09.21 –present	2018.03.27 – present	2018.03.27 – present	-	
7. Islandijos Str. 6 2018.05.27 – present	2018.05.28 – present	2018.05.28 – present	2018.05.28 – present	2018.05.28 – present	-	-	

At this stage of scanning a human-centered built environment in Vilnius City, specific cultural events were designated for focus. These events were Christmas (December 24 and 25), New Year (December 31), Flag Day (January 1), the birthday of Vilnius (January 25), Lithuania's Restoration of Independence Day (February 16), Lithuanian Independence Day (March 11), Kaziuko Fair (March 2-4), Europe Day (May 9), Culture Night 2018 (Jun 15 and 16), Lithuania's Centenary Song Celebration (July 1-6) and the start of the new academic year (September 3). First five layers of data (see Stage 7 "Development of the MICROBE") were measured based on these selections since November 6, 2017, during 18 months.

Stage 6: The Integrated MICROBE Method

The integrated MICROBE method combines various methods of data gathering and analysis, such as case studies, recommenders, statistical means (logit, KNN, MBP, Rprop), big data analytics, four multiple-criteria decision analysis methods and biometric methods.

This stage presents the original integrated MICROBE method for collecting data on affective attitudes, emotional and physiological states and valence, arousal, and COVID-19 data (Deaths, Cases, Tests, Hospitalizations, Vaccinations, Mortality risk, Excess mortality, Policy responses) in a built environment, and develops an innovative method by examining the interconnections between the above factors and pollution, apparent temperature and other dimensions of a public space. This method also provides techniques for recognizing the range of subjective experiences of passersby in a built environment.

However, rather than concentrating on measurements of emotions and physiological data as previous research [7-15, 17-25], the present investigation implemented an integrated remote method focusing on sensing and analytics data relating to a built environment (pollution, noise, weather, COVID-19 data (Deaths, Cases, Tests, Hospitalizations, Vaccinations, Mortality risk, Excess mortality, Policy responses) and so on) and its users (their emotional and physiological states, valence, arousal, affective attitudes).

Stage 7: Development of the MICROBE

The MICROBE was developed at this stage, based on the results from the first five stages.

Seven layers of data were collected over the period of scanning of this human-centered built environment at the aforementioned sites (see Table 1) since November 6, 2017.

The first layer focused on emotional states, that is, whether the passersby were happy, sad, angry, surprised, scared, disgusted or in a neutral state. Valence and arousal were also mapped, and records were analyzed. The second layer involved the range of affective attitudes of passersby: boredom, interest or confusion. These were collected and investigated. The third layer involved examining the physiological states of the passersby, in terms of the average crowd facial temperature, crowd composition by gender and age groups, heart rates and breathing rates.

The fourth layer focused on the weather conditions, and involved collecting and studying the air temperature (°C), relative air humidity (%), average wind velocity (m/s), atmospheric pressure (hPa) and apparent temperature (°C).

The fifth layer focused on collecting and analyzing data on a magnetic storm and information on several different pollution particulates ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and sulfur dioxide (SO_2).

The data accumulated during the period of collection of the seventh layer of data were related to the municipal districts in Vilnius, and included:

- economic data (average property price, number of jobs per 1,000 residents)
- social data (number of educational institutions (except kindergartens), number of places in kindergartens, number of healthcare institutions per 1,000 residents, recreational facilities in the neighborhood per 1,000 residents, annual crime rate per 1,000 residents)
- COVID-19 data (Deaths, Cases, Tests, Hospitalizations, Vaccinations, Mortality risk, Excess mortality, Policy responses)
- environmental protection criteria (air pollution, noise, distance from the city center and green spaces such as maintained large parks and small green urban spaces)
- historical heritage value data involving direct use value (direct benefits: income/revenue, residential space, commercial space, industrial space, circulation space, economic activity and so on) and indirect use value (indirect benefits: community image, environmental quality, aesthetic quality, valorization of existing assets and social interactions).

This new set of addtional multi-layered data can assist stakeholders (e.g. communities, urban planners, architects, developers, contractors, environmentalists, consultants, landowners and businesses) with their decision making. An inhabitant-centric and sustainable approach to the built environment in order to minimize of the influence of coronavirus leads to effective decisions.

Stage 8: Multiple-Criteria Analysis of Alternatives

At this stage, the level of effectiveness of the built environment in order to minimize of the influence of coronavirus is analyzed in terms of the composite parts of the built environment, the external environment and the level of change in achieving various goals by different stakeholders. In this case, it becomes possible to resolve the desired objectives together with the financial resources needed to implement these objectives in order to optimize resources. In other words, once the possible scenarios for developing the built environment in order to minimize of the influence of coronavirus are analyzed, the most rational combination of objectives under pursuit and existing possibilities can be established. An example of this stage of the process is provided in Case Study 2.

Stage 9: The MICROBE Correlation Subsystem (**Correlation Metrics Subsystem**)

The MICROBE correlation subsystem is a suitable tool for assessing a human-centered built environment in order to minimize of the influence of coronavirus in a built environment. The analyses presented here are based on various metrics for a human-centered built environment, according to the values of the correlation coefficients (e.g. average, strong, very strong) and their influence on the inhabitants.

The MICROBE correlation subsystem is a non-experimental research design technique that can discover the connections among related variables. Two different groups are required to conduct this research design method. A statistical analysis is applied to compute the correlation between two variables by employing a correlation coefficient. The value of the correlation coefficient may be equal to zero (no link), a positive value between 0 to less than 0.2 (very weak), between 0.2 to less than 0.5 (weak), between 0.5 to less than 0.7 (average), between 0.7 to less than 1 (strong) or +1 (very strong). Negative correlation coefficient values can be equal to −1 (very strong), or may range between greater than −1 and −0.7 (strong), between greater than −0.7 and −0.5 (average), between greater than −0.5 and −0.2 (weak) and between greater than −0.2 and 0 (very weak). The closer the value of the correlation coefficient to +1, the more it indicates a positive relationship between the two variables, whereas a value of −1 indicates a negative relationship between them. It is expected that future research will establish which of these metrics and correlations indicate a high, medium or low importance for inhabitants. Those parameters measured in Vilnius with strong correlations and substantial influence on the inhabitants should be analyzed in detail, and specific decisions will then need to be made rapidly in order to avoid problems and to gain advantage from the existing situation.

Stage 10: Pilot Case Studies

Using two case studies, we thoroughly analyze specific tasks in order to evaluate certain parts of the integrated MICROBE method. These case studies confirm the accuracy of the proposed integrated MICROBE method.

Stage 11: Assessing the Accuracy of the MICROBE Through Verification and Validation

An assessment of the accuracy of the MICROBE (the Affect-Based Built Environment Video Analytics) system was made via verification, which ensured that the results from the system reflected the actual situation. The aim was to test all possible states of the MICROBE and identify if the objectives of this research are achieved. An assessment of the accuracy of the MICROBE was also conducted by applying validation. Both the validation and the verification of the MICROBE were conducted with expert assistance. The results of the assessment of the accuracy of the MICROBE along with the possibilities for utilizing the system were presented at two meetings of the ROCK project and the H2020 program to experts in this field as well as to other interested groups.

One element of the validation and verification process was that expert opinions were sought from eight facilities managers and eight property development experts. These experts validated our analysis of above seven layers of data in real-world conditions.

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