

Housing Health and Safety Decision Support System with Augmented Reality

A. Kaklauskas, M. Kutinis, L. Kovachev, P. Petkov, L. Bartkiene, I. Jackute.

Abstract. Integration of augmented reality and decision support systems has a very promising future in scientific research. The authors of this paper participated in two projects: Lifelong Learning Programme project “Learning Augmented Reality Global Environment” (LARGE) and project “Development of national Housing Health and Safety certification model” (DNHHSCM). One of LARGE’s and DNHHSCM’s goals (on the Lithuanian side) was to integrate of augmented reality and decision support systems (to develop a HoUsing health and Safety decision Support system with Augmented Reality (HUSSAR)). HUSSAR consists of a Decision Support Subsystem and an Augmented Reality Subsystem and can create value in the following important ways: search for dwelling alternatives, find out alternatives and make an initial negotiation table, provide augmented reality services, complete a multiple criteria analysis of alternatives, make negotiations based on real calculations, determine the most rational dwelling purchase variant, statistical analysis, groupware decision making and complete an analysis of the loan alternatives offered by certain banks.

1 Introduction

Certain groups of patients included in American Lung Association’s study are those such as asthmatics, atopic patients, patients with emphysema and bronchitis, heart and stroke patients, people with diabetes, pregnant women, and the elderly and children who are especially sensitive to the health effects of outdoor air toxicants [2]. It is estimated that about 20% of the USA’s population suffers from asthma, emphysema, bronchitis, diabetes or cardiovascular diseases and are thus especially susceptible to outdoor air pollution [2]. Outdoor air quality plays an important role in maintaining good human health. Air pollution causes large increases in medical expenses, morbidity and is estimated to cause about 800,000 annual premature deaths worldwide [9]. Much research [3, 6, 15], digital maps and standards [13, 23, 25] on the health effects (respiratory effects, cardiovascular effects, cancer, reproductive and developmental effects, neurological effects, mortality, infection and other health effects) of outdoor air pollution, a premise’s microclimate, and dwelling valuation, has been published in the last decade. The above-mentioned and other problems are related to a built environment’s air pollution, the premise’s microclimate, health effects, and real estate market value, etc. However, a Housing Health and Safety Decision Support System with Augmented Reality (HUSSAR) can analyse the above factors in an integrated way.

The Housing Health and Safety Rating System (HHSRS or the Rating System) is the UK Government’s new approach to the evaluation of the potential risks to health and safety from any deficiencies identified in dwellings. There are 29 hazards in dwellings. These are arranged in four main groups reflecting the basic health requirements. The four groups are sub-divided according to the nature of the hazards [33]:

- Physiological Requirements, including – Hygrothermal conditions and Pollutants (non-microbial).
- Psychological Requirements, including – Space, Security, Light, and Noise.
- Protection against Infection, including – Hygiene, Sanitation, and Water supply.

- Protection against Accidents, including – Falls, Electric shock, Burns and Scalds, and Building related Collisions.

For example, the databases of Protection against Infection contain the following information:

- Domestic hygiene, pests and refuse. Poor design, layout and construction, such that the dwelling cannot be readily kept clean and hygienic; access into, and harbourage within the dwelling for pests; inadequate and unhygienic provision for storing and disposal of household waste. Health effects: stomach and intestinal disease; infection; asthma; allergies; food spoilage; disease from rats and birds; physical hazards.
- Food safety. Threats of infection from poor provision and facilities for storage, preparation and cooking of food. Health effects: stomach and intestinal disease; diarrhoea; vomiting; stomach upsets; dehydration.
- Personal hygiene, sanitation and drainage. Threats of infection and threats to mental health associated with personal hygiene, including personal and clothes washing facilities, sanitation and drainage. Health effects: stomach and intestinal disease, including dysentery; skininfections; depression.
- Water supply for domestic purposes. The quality and adequacy of the water supply within the dwellings for drinking and domestic purposes, including threats to health from contamination by bacteria, protozoa, parasites, viruses and chemical pollutants. Health effects: dehydration; fatigue; headaches; dry skin; bladder infections; stomach and intestinal and respiratory disorders; Legionnaires' disease.

One of the priorities of the Europe 2020 Strategy - smart growth is driven by complex interactions between technical, social, economic, and human factors. The project - Learning Augmented Reality Global Environment (LARGE) - is designed to create a new type of learning environment that support the educational/training institutions in delivering their curriculum in the most attractive and effective for the learners way. Aim of the LARGE is to build a global environment, based on this technology, simplifying the process of augmented reality content creation, allowing all educational/training institutions to benefit from its undoubted advantages. This Global Environment consists of a platform, serving as a basis for the system and an integrated content development tool, which will allow the creation of appropriate educational/training AR content by the target groups. An AR system generates a composite view for the user which combines the real scene and the virtual scene generated by the computer that then augments the scene with additional information. The Learning Augmented Reality Global Environment superimposes graphics, audio, video, 3D objects and other enhancements from computers screens to real time environments expanding users' knowledge, skills and experience.

The main aim of project "Development of national Housing Health and Safety certification model" is to improve the quality of public healthcare services and to improve the management of residential environmental health risk factor. The goal of mentioned project was to create the tools of residential environmental health risk factor management.

The structure of this paper is as follows. Following this introduction, Section 2 describes Housing Health and Safety Model and Decision Support System with Augmented Reality. Finally the conclusions appear in Section 3.

2 Housing Health and Safety Model

Based on the world wide healthy housing literature analysis [4, 11, 12, 16, 29, 33, 37, 40] and analysis of healthy housing models [10, 17, 18, 19, 20, 21, 22, 26, 28,

30, 32, 36] a National Housing Health and Safety Certification Model was developed. The latter may be described as follows: a life cycle of a housing health and safety, the parties involved in its design and realization as well as micro, meso and macro environment having a particular impact on it making an integral whole. A complex analysis of the research object formulated was made with the help of methods multiple criteria project analysis developed by authors.

3 Decision Support Subsystem

Based on the analysis of existing expert [5, 38], decision support [1, 8, 27, 34, 39, 41, 44] and knowledge [14, 31] support systems, developed Model, Housing Health and Safety Rating System and in order to determine most efficient versions of HoUsing health and Safety decision Support system with Augmented Reality system (HUSSAR) was developed [24].

Dwelling listings are an interface for a seller to post listings. The system provides forms for sellers or brokers to fill in information about their dwelling. Brokers wishing to present information on their objects must receive permission from HUSSAR administrator. Having this permission the broker inserts all the necessary information about dwelling objects under sale in the HUSSAR databases according to the system's requirements (i.e. system of criteria, values and weights of criteria). Access to the databases developed personally by brokers is provided only to the broker and to the HUSSAR administrator. At present the developed HUSSAR allows for the performance of the following six main functions:

- search for dwelling alternatives;
- finding out alternatives and making an initial negotiation table;
- analysis of alternatives; negotiations;
- determination of the most rational dwelling purchase variant;
- statistical analysis;
- groupware decision making.

In order to throw more light on the HUSSAR, a more detailed description of some of the above-mentioned Subsystem functions follows.

A consumer may perform a search for dwelling alternatives from databases from different brokers. This is possible because the forms of data submissions are standardized at a specific level. Such standardization creates conditions that can be applied to special intelligent agents that are performing a search for the required dwelling in various databases, and the gathering information/knowledge. The databases of housing health and safety assessment contain the evaluation data on building referring to Physiological Requirements:

- Damp mould growth. Health threats due to dust mites, mould or fungal growths, including mental and social well-being health threats associated with damp, humid, mouldy conditions. Health effects: allergies; asthma; effects of toxins from moulds; fungal infections.
- Excess cold. Threats to health from sub-optimal indoor temperatures. Healthy indoor temperature is approximately 21 \pm C. Health effects: respiratory (flu, pneumonia and bronchitis); cardiovascular conditions (heart attacks and strokes); thermoregulatory system impairment (body's temperature control); etc.
- Excess Heat. Threats due to excessively high indoor air temperatures. Health effects: dehydration; trauma; stroke; cardiovascular, respiratory and genitourinary disorders.
- Asbestos and Manufactured Mineral Fibres (MMF). Presence of, and exposure to, asbestos fibres and MMF within dwellings. Health effects: pleural disease; lung cancer; mesothelioma NOTE: Attempting to remove

asbestos which is in good condition and not likely to be disturbed is significantly more hazardous than not removing it. Work on asbestos should be done by a contractor licensed by the Health and Safety Executive.

- Biocides. Threats to health from chemicals used to treat timber and mould growth. Health effects: risk from inhalation; skin contact; ingestion (eating or drinking the chemical)
- Carbon monoxide and fuel combustion products. Hazards due to the presence of excess levels in the atmosphere of carbon monoxide, nitrogen dioxide or sulphur dioxide and smoke within the dwelling. Health effects: Dizziness; nausea; headaches; disorientation; unconsciousness; respiratory disorders; bronchitis and breathlessness.

The databases of Psychological Requirements contain the following information:

- Lead. Health threat from lead ingestion. Lead sources: paint, water pipes, soil, fumes from leaded petrol. Health effects: lead poisoning; nervous disorders; mental health; blood production issues; behavioural problems in children.
- Radiation. Health threats from radon gas and its daughters, primarily airborne, but also radon dissolved in water; Concern expressed about possible health effects of electromagnetic fields (EMFs); Leakage from microwave ovens (rare). Health effects: lung cancer caused by exposure to radon gas. Risk increases with dose and duration of exposure.
- Uncombusted fuel gas Threat from fuel gas escaped into the atmosphere within the dwelling. Health effects: suffocation.
- Volatile organic compounds Diverse group of organic chemicals, including formaldehyde, that are gaseous at room temperature and found in a wide variety of materials in the home. Health effects: allergies; irritation to eyes, nose, skin and respiratory tract; headaches; nausea; dizziness and drowsiness.

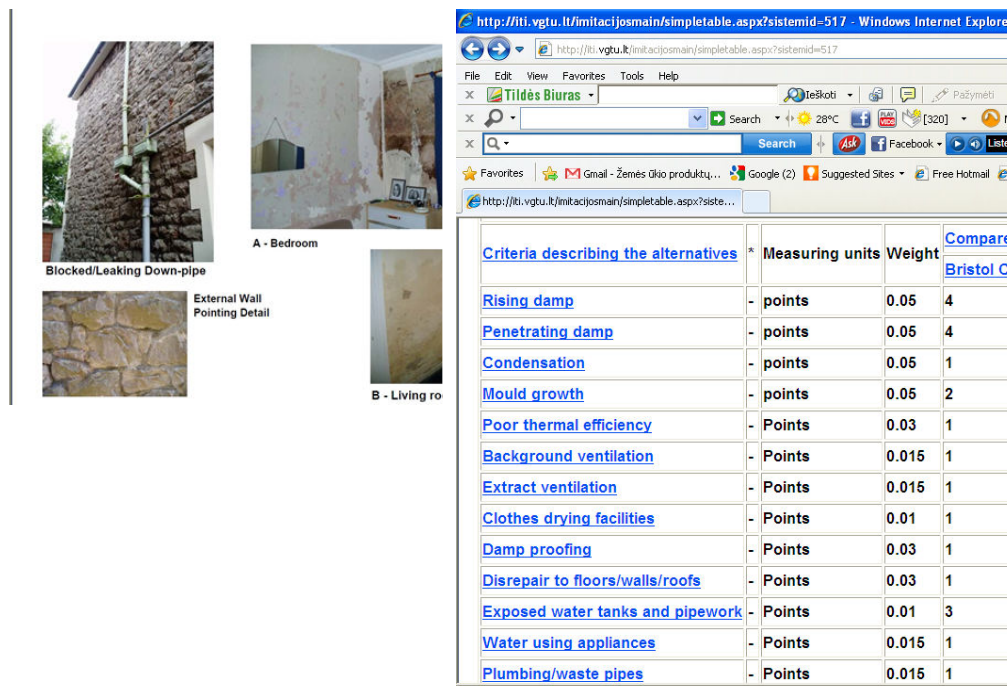


Fig. 1. Search results for a specific dwelling are submitted in: textual, photo/video and graphical information on the dwelling (left); fragment of expert and quantitative description of the dwelling's (damp and mould growth criterion) alternatives (right) [19, 20, 21]

Consumers specify requirements and constraints and the system queries the information of a specific dwelling from a number of online brokers. The system performs the tedious, time-consuming, and repetitive tasks of searching databases, retrieving and filtering information/knowledge, and delivering it back to the user. Search results for a specific dwelling are submitted in a textual, photo/video and graphical information on the dwelling's alternatives (see Fig. 1), which may include direct links to a Web page of brokers. When submitting such a display, the multiple criteria comparisons can become more effectively supported. By clicking the link "Expert and quantitative description of variants", the expert and quantitative description of private houses' alternatives is presented (see Fig. 1 (right)). Each alternative described by the quantitative information (system of criteria, weights of criteria and values) has a number (see Fig. 1) that coincides with the verbal and photographic information describing the mentioned alternative (see Fig. 1).

While going through the purchasing decision process a customer should examine a large number of alternatives, each of which is surrounded by a considerable amount of information/knowledge (physiological (hygrothermal conditions and pollutants), psychological (space, security, light, and noise), protection against infection (hygiene, sanitation, and water supply), protection against accidents (falls, electric shock, burns and scalds, and building related collisions), economic, quality-architectural, aesthetic, comfort, infrastructure, technical, legal, technological), and other factors. Following on from the gathered information and knowledge, the multiple criteria analysis is then carried out.

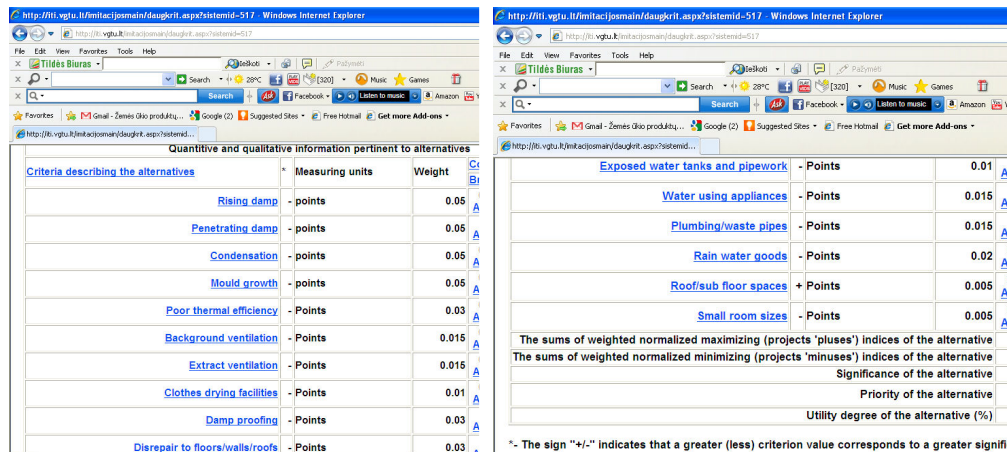


Fig. 2. Fragment of results of multiple criteria evaluation of the dwelling's (damp and mould growth criterion) alternatives: upper part of the matrix for obtained results (left); lower part of the matrix for obtained results (right)

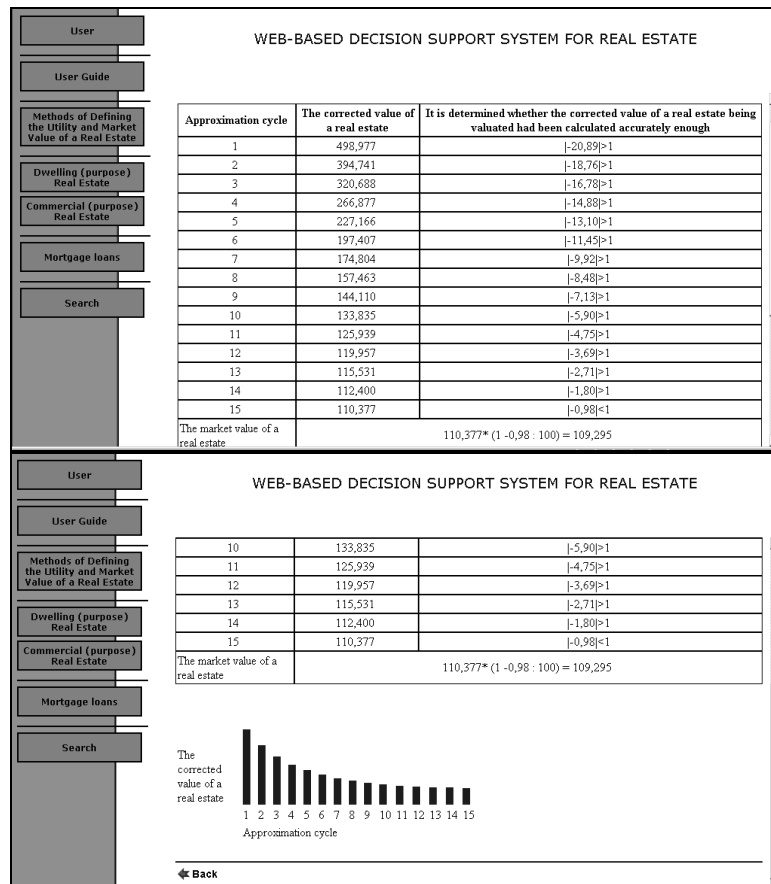


Fig. 3. Calculation of the market value: presentation of the market value's calculations in numerical form (top); presentation of the market value's calculations in graphic form (bottom)

By using multiple criteria methods as was developed by the authors, the buyer (broker) determines the initial priority, utility degree and market value of the

analyzed dwelling's alternatives during this analysis. Clicking the link "Results of Multiple Criteria Evaluation", the results of the multiple criteria evaluation of the private house's alternatives are thus demonstrated (see Fig. 2). In the lower part of the obtained result's matrix the calculated significance of the dwelling's alternatives, their priority and utility degree are presented (see Fig. 2). The upper part of the obtained result's matrix shows the numbering of the dwelling's alternatives (see Fig. 2 (left)). By clicking these blue underlined numbers it is possible to calculate the market value of a certain alternative (see Fig. 3). The table presented in Fig. 3 (top) shows the iterations made during the calculation of the dwelling's market value. The same information, only in graphical form is presented in Fig. 3 (bottom). And by moving a mouse above any column of the graphical part, the numerical value of the column can be seen. For example, the market value of the eighth alternative was calculated by making 15 iterations (see Fig. 3 (top)).

A buyer performing a multi-criteria analysis of all dwelling alternatives selects the objects for starting the negotiations. For that purpose he/she marks (ticks a box with a mouse) the desirable negotiation objects (see Fig. 4). A negotiations email are created by the Letter Writing Subsystem and sent to all dwelling sellers after the selection of the desired objects is made and then *Send* is clicked. During negotiations the buyer and the seller with the help of HUSSAR may perform real calculations (the utility degree, market value and purchase priorities) of the dwelling. These calculations are performed on the basis of characteristics describing the dwelling's alternatives obtained during negotiations (explicit and tacit criteria system, criteria values and weights). According to the results received, the final comparative table is then developed. Following on from the developed final comparative table the multiple criteria analysis and selection of the best dwelling buying version is carried out by using HUSSAR.

After a variant of the dwelling is selected, most often a purchaser has to borrow part of money from a bank. The Loan Analysis Subsystem is created for this purpose (see Fig. 4).

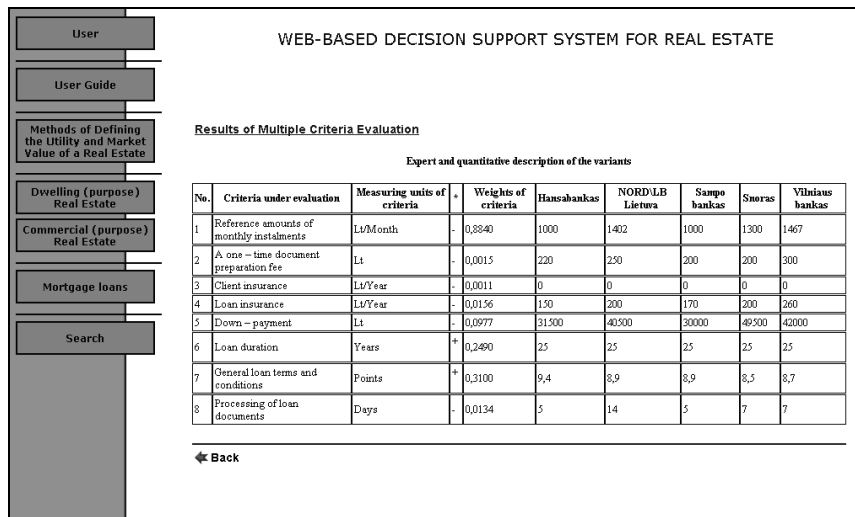


Fig. 4. Analysis of the loan alternatives offered by certain banks

Over the past three years the Statistical Model has accumulated information about client navigational activities and his/her decision making. Concrete statistics about clients' navigational activities - number of concrete real estate alternative

visitors, time period of analysing this alternative and decision making -selection of criteria system, criteria values and weights, was collected in the Statistical Model. The statistical information can be used to determine the most marketable real estate, and the most important criteria and their weights. The received statistical information reflects the navigational purposes of clients. The ability to statistically measure the clients' navigational activities allows one to statistically generate the average criteria system and criteria weights for a typical real estate seeker. This solution improves the accuracy of the development of the criteria system and criteria weights for the client. The above statistical information can also be applied so as to better adapt the searching process to the client's needs.

Currently, intelligent systems for real estate have been mostly looked at from a single-buyer's perspective, where only the purposes of a single client are taken into account. The cooperative decision making subsystem considers the circumstances where a group of interested parties are planning a common real estate development (with special emphasis on pollution and health effect), purchase and other activities, and therefore can include many potentially conflicting objectives that have to be analysed and dealt with. The cooperative decision making subsystem allows different stakeholders to solve common tasks in collaborative ways, e.g. the development of a joint criteria system, the estimation of criteria weight and qualitative criteria values. For example, HUSSAR can help interested parties to achieve a cooperative decision on Web-based real estate's search, analysis, negotiation and in decision making. This is done by transforming individual client models (individual decision making matrix) to the collaborative (medium) client model (collaborative integrated decision making matrix) and by using the collaborative client model to mediate, a group discussion aiming at arriving at a compromise that is acceptable to all the group's members. The cooperative decision making subsystem also allows stakeholders by using expert's methods to develop collaborative integrated decision making matrix. The developed integrated collaborative decision making matrix helps to decrease mistrust problems between stakeholders and to select most appropriate solution to satisfy all interested parties.

4 Augmented Reality Subsystem

A number of academics and practitioners in the world [35, 42, 43] analyzed the Augmented Reality Subsystem in real estate.

Home Spotter is an augmented reality real estate platform that allows brokers to find properties in a neighbourhood that are for sale, property details like number of bedrooms, square footage and price, and provide a "radar view" of others for sale in the neighbourhood, all by pointing their mobile phone cameras. A version for homebuyers is in the works [42].

Sawbuck Reality's Homesnap, an app launched on iOS in 2012 on Android, seeks to make some aspects of home searching a bit more fun. Homesnap seems simple on the surface: take pictures of the houses you want to know more about, and compare them side-by-side. Under the hood, though, things are pretty complicated. The app relies on in-phone sensors like the GPS, magnetometer, accelerometer, and gyroscope. With these, Homesnap is able to figure out where your phone is pointing the moment you take a picture. After the picture is taken, the app uses a number of advanced algorithms to serve up additional data, such as the value and for-sale status of nearby properties. An Explore tab that provides information about nearby homes, neighborhood price trends, and even the quality of surrounding schools. The interface isn't anything to write home about - it's identical to the iOS version - but the functionality is impressive. Layar is derived

from location based services and works on mobile phones that include a camera, GPS and a compass. Layar is first available for handsets with the Android operating system. It works as follows: Starting up the Layar application automatically activates the camera. The embedded GPS automatically knows the location of the phone and the compass determines in which direction the phone is facing. Each partner provides a set of location coordinates with relevant information which forms a digital layer. By tapping the side of the screen the user easily switches between layers. This makes Layar a new type of browser which combines digital and reality, which offers an augmented view of the world [43].

Developed by Netherlands Architecture Institute (NAI) in partnership with IN10 Communicatie and Layar, Sara is the world's first augmented reality architecture application. Users of the technology simply hold up their smartphone to see photos, video, 3D models, scale models and other details about buildings currently in situ as well as those from the past and any planned for the future. Although it's still under construction, those with the app can view a 3D model of how the finished building will look. SARA also allows users to add their own information about any building or map tours of their favourite architecture. The technology was launched on December 2009 on the Layar platform and will be downloadable from the Apple App Store and Android Market beginning next month. The world's first building to appear in three dimensions on the smartphone via augmented reality is the eye-catching Market Hall which is currently under construction in Rotterdam's Blaak area. Within the next 5 years, SARA is expected to have evolved into a complete national architecture guide [35].

Any user with a Google account may access Google Maps at <https://maps.google.com/>. The site's feature My Places lets you personalise its maps with your information. Use the Placemarks tool to mark a location defined by specific coordinates in a map (e.g. to mark a building). Each placemark may have a unique title and may be linked to additional information, such as URLs, photos, HTML code, etc. Our titles refer to a building's address or a company that uses the building for its business. The additional information we provide is a link to the initial data matrix with the building's properties for refurbishment multiple criteria analysis (see Fig. 1-4) and the building's photo. Google's Street View technology lets you take a virtual tour and explore the building's environment.

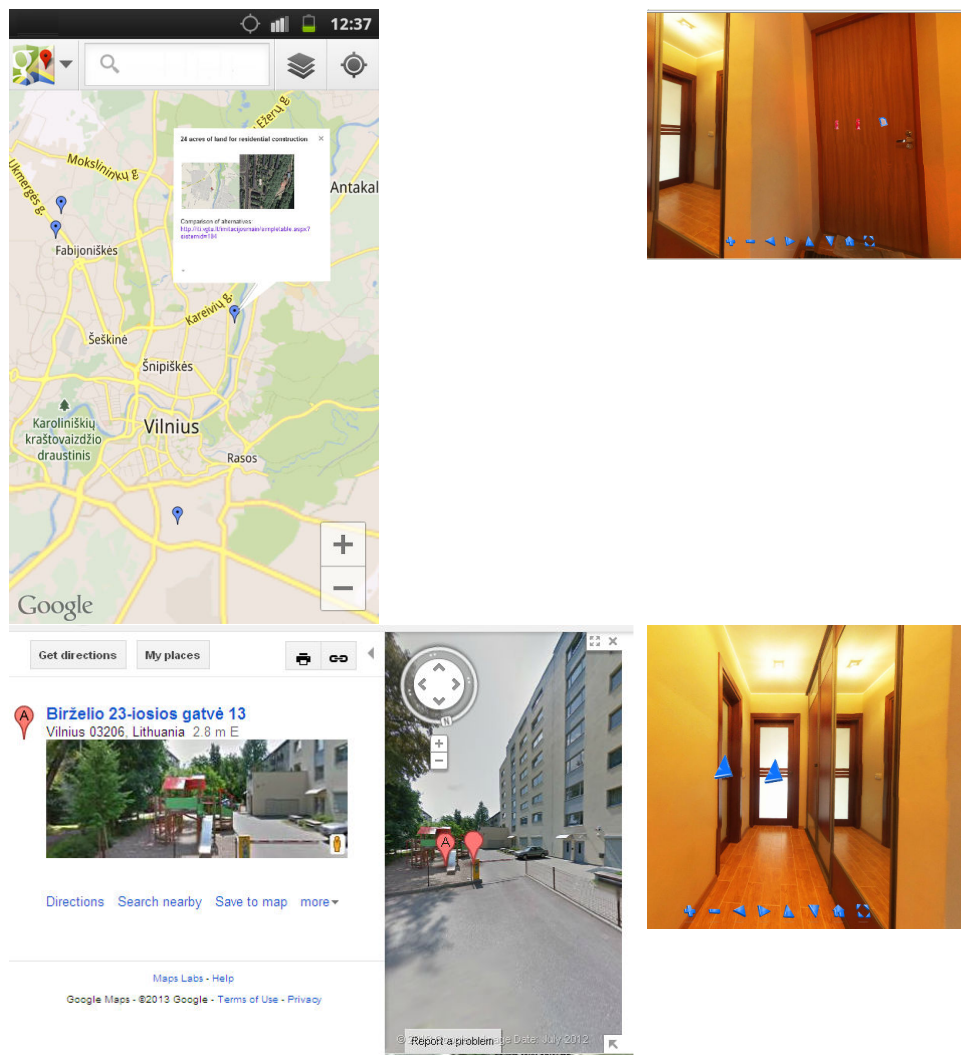


Fig. 5. Links to the multiple criteria analysis matrix that compares the alternatives have been created with the Google Maps tools; a Google Street View image of the location is shown alongside and virtual tour

The Augmented Reality Subsystem offers real-time additional information about a piece of property (see Fig. 2, 3, 4). All property details in the databases are linked to the Google Maps service. The digital map is a convenient tool to display the pieces of property of interest to users and make intuitive choices of a property for further analysis. Once a user has selected the property of interest, the Decision Support Subsystem opens. A user equipped with GPS coordinates and a palmtop may retrieve information about the object in which the user is at present, and compare it with other alternatives pinned in the digital map.

Google Maps tool “My places” is used to pin in a map the address of each piece of property with a marker. Each marker shows some extra information about the property such as its name, address, image, and a link to the Decision Support Subsystem that compares alternative variants of the properties marked in the map.

A mobile device with Android OS and the Maps application offers access to the map in Google Maps. An active GPS receiver in the mobile device pins the user’s

actual location on the map. Thus any nearby alternative variants of real estate objects are shown in the map with some extra information about them. Street View, a service by Google Maps, offers a possibility to take a virtual tour to check out what is in the vicinity of a piece of property.

Using the Google Maps mapping tool, the location of each alternative described in the initial-data table for the multiple criteria analysis is marked on the map. Each property is pinned on the city's map (blue markers on the map). The details (a link to the Decision Support Subsystem, the property's image, a link to Google Street View) of a property you are interested in can be viewed by clicking on its marker.

5 Conclusions

The authors of the research presented in this article have suggested the idea of integrating augmented reality and decision support systems. In order to demonstrate the integration of the above systems in the real estate sector, a HoUsing health and Safety decision Support system with Augmented Reality (HUSSAR) have been developed during the projects LARGE and DNHHSCM as example of such research. HUSSAR developed by these authors determines an utility degree of housing health and safety based on the Physiological Requirements, Psychological Requirements, Protection against Infection, Protection against Accidents parameters. It then generates thousands of alternative recommendations and selects out the most rational of these for the housing health and safety specific situation. The plans for the next stage of the HUSSAR System's development involves integrating this system with biometrics systems, which the authors herein have also developed.

References

1. Ahmed A., Korres N. E., Ploennigs J., Elhadi H., Menzel K. Mining building performance data for energy-efficient operation. *Advanced Engineering Informatics* 25 (2), pp. 341-354 (2011)
2. American Lung Association. American Lung Association, State of the Air 2005(2005)
3. Atkinson, R.W., Anderson, H.R., Sunyer, J. Acute effects of particulate air pollution on respiratory admissions: results from the APHEA2 study. *Am. J. Respir. Crit. Care. Med.* 164, pp. 1860–1866 (2001)
4. Battersby, S. Are Private Sector Tenants Being Adequately Protected? A study of the Housing Act 2004, Housing Health and Safety Rating System and Local Authority Interventions in England. (2011). Available from Internet: <http://www.sabattersby.co.uk/documents/HHSRS_Are%20tenants%20protected.pdf>.
5. Botia J. A., Villa A., Palma J. Ambient Assisted Living system for in-home monitoring of healthy independent elders. *Expert Systems with Applications* 39 (9), pp. 8136-8148 (2012)
6. Brook, R.D., Franklin, B., Cascio, W., Hong, Y., Howard, G., Lipsett, M., et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the expert panel on population and prevention science of the American Heart Association, *Circulation*, vol. 109, pp. 2655–2671 (2004)
7. Carnegie, D. How to stop worrying and start living. Pocket Books. New York, pp. 302 (2004)
8. Chlela F., Husaunndee A., Inard C., Riederer P. A new methodology for the design of low energy buildings, *Energy and Buildings* 41, pp. 982–990 (2009)

9. Cohen, A.J., Ross Alexander, H., Ostro, B., Pandey, K.D., Kryzanowski, M., Kunzail, N., et al. The global burden of disease due to outdoor air pollution. *J. Toxicol Environ. Health A* 68, pp. 1–7 (2005)
10. Csóka J., Deszpoth I., Gáti A., Maros Zs., Pap J., Pap I., Szabó S., Mokry Zs. J. The technology level quality control model system of house-like components. *Control Engineering Practice* 1 (2), pp. 412. (1993)
11. Davidson M., Roys M., Nicol S., Ormandy D., Ambrose P. The real cost of poor housing. ISBN 978-1-84806-115-6. (2010)
12. English Housing Survey. Homes Report 2010. (2010) Available from Internet: <<https://www.gov.uk/government/publications/english-housing-survey-homes-report-2010>>.
13. Environmental Management Centre, 2006. Environmental Management Centre, A comparison of ambient air quality standards applied worldwide (2006)
14. Fazio P., Zmeureanu R., Kowalski A. Select-HVAC: knowledge-based system as an advisor to configure HVAC systems. *Computer-Aided Design* 21 (2), pp. 79-86 (1989)
15. Grossman, C.M., Nussbaum, R.H., Nussbaum, F.D. Cancers among residents downwind of the Hanford, Washington, plutonium production site. *Arch. Environ. Health* 58, pp. 267–274 (2003)
16. Guidance for Landlords and Property Related Professionals. 72 pp. (2006)
17. Hashim, A., Dawal, S. Z. Kano Model and QFD integration approach for Ergonomic Design Improvement. *Procedia - Social and Behavioral Sciences* 57, pp. 22-32 (2012)
18. Hayashi M., Enai M., Hirokawa Y. Annual characteristics of ventilation and indoor air quality in detached houses using a simulation method with Japanese daily schedule model. *Building and Environment* 36 (6), pp. 721-731 (2001)
19. HHSRS worked examples. Bristol CC examples (2007a)
20. HHSRS worked examples. CLG Worked examples (2007b)
21. HHSRS worked examples. IDeA Worked examples (2007c)
22. Howarth P., Reid A. Sunbury Healthy House, Mitchell Beazley, pp. 118-123 (2000)
23. Hubbell, B.J., Hallberg, A., McCubbin, D.R., Post, E.: Health-related benefits of attaining the 8-hr ozone standard. *Environ. Health Perspect.* 113, 73–82 (2005)
24. HUSSAR. HoUsing health and Safety decision Support system with Augmented Reality system (2013). Available from Internet: <http://iti.vgtu.lt/imitacijosmain/simpletable.aspx?sistemid=517>.
25. US Environmental Protection Agency (EPA), US Environmental Protection Agency (EPA), Revisions to the National Air Ambient Air Quality Standards for particulate matter, *Fed. Regist.* 52, pp. 24634–24669 (1987)
26. Kaklauskas A., Rute J., Zavadskas E. K., Daniunas A., Pruskus V., Bivainis J., Gudauskas R., Plakys V. Passive House model for quantitative and qualitative analyses and its intelligent system. *Energy and Buildings* 50, pp. 7-18 (2012)
27. Körner O., Van Straten G. Decision support for dynamic greenhouse climate control strategies. *Computers and Electronics in Agriculture* 60 (1), pp. 18-30 (2008)
28. Laporte P.B., Elliott E., Banta J. Prescriptions for a Healthy House: A Practical Guide for Architects, Builders & Homeowners, Baker-Laporte & Associates (2003)
29. Living in Wales Survey. (2006) Available from Internet: <<http://wales.gov.uk/about/aboutresearch/social/ocsropage/living-wales/?jsessionid=1mX2NT1dhhzgXvNbVkCpH80DYQ5j0kKsp0kGTpMSzLXS82phGddw!-1726265782?lang=en>>

30. Mahdavinejad M., Mansoorim S. Architectural Design Criteria of Socio-Behavioral Approach toward Healthy Model. *Procedia - Social and Behavioral Sciences* 35, pp.475-482 (2012)
31. Matsumoto H., Toyoda S. A knowledge-based system for condensation diagnostics in houses. *Energy and Buildings* 21 (3), pp. 259-266 (1994)
32. Office of the Deputy Prime Minister. Housing Health and Safety Rating System. Operating Guidance. Office of the Deputy Prime Minister: London. (2006) [Cited 4 March 2013]. Available from Internet: <<http://www.nchh.org/Portals/0/Contents/HH%20Standards.UKHHRSooperatingguidance.pdf>>
33. Operating Guidance - Housing Act 2004. Guidance about inspections and assessment of hazards given under Section 9. pp. 185 (2006)
34. Parker D.S. Very low energy homes in the United States: perspectives on performance from measured data, *Energy and Buildings* 41 (5), pp. 512–520 (2009)
35. Sara. World's First Augmented Reality Architecture Application. (2010). Available from Internet: <<http://freshome.com/2010/01/19/world%E2%80%99s-first-augmented-reality-architecture-application-sara/>>.
36. Schoenwetter, W. F. Building a Healthy House. *Annals of Allergy, Asthma & Immunology*, 79 (1), pp. 1-4 (1997)
37. Scottish House Condition Survey. (2011) Available from Internet: <<http://www.scotland.gov.uk/Topics/Statistics/SHCS>>.
38. Soyguder S., Alli H. An expert system for the humidity and temperature control in HVAC systems using ANFIS and optimization with Fuzzy Modeling Approach. *Energy and Buildings*, 41 (8), pp. 814-822 (2009)
39. Thiers S., Peuportier B. Thermal and environmental assessment of a passive building equipped with an earth-to-air heat exchanger in France, *Solar Energy* 82 (9), pp. 820–831 (2008)
40. Wales - Housing Demolitions and Hazards 2011-12. (2011). Available from Internet: <<http://wales.gov.uk/docs/statistics/2013/130131-housing-demolitions-hazards-2011-12-en.pdf>>.
41. Wang L., Gwilliam J. Case study of zero energy house design in UK, *Energy and Buildings* 41, pp. 1215–1222. (2009)
42. Webb, D. Mobile devices are more than handsets. (2013). Available from Internet: <<http://www.itworldcanada.com/news/mobile-devices-are-more-than-handsets/147008>>.
43. Wiggers, K. Real Estate Agent Tools. (2012). Available from Internet: <<http://www.androidpolice.com/2013/05/07/hands-on-homesnap-for-android-augmented-reality-real-estate/>>
44. Yakubu G.S. The reality of living in passive solar homes: a user-experience study, *Renewable Energy* 8, pp. 177–181 (1996)