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Housing Health and Safety Decision Support System with Augmented Reality

Arturas Kaklauskas[a,]*, Edmundas Kazimieras Zavadskas[a], Justas Cerkauskas[a], Ieva Ubarte[a], Audrius Banaitis[a], Mindaugas Krutinis[b], Jurga Naimaviciene[a]

[a]*Vilnius Gediminas Technical University, Sauletekis ave. 11, LT-10223, Vilnius*
[b]*Vilnius University, University str. 3, LT-01513, Vilnius*

Abstract

Europe's residents spend more than 90% of their time in an enclosed environment. Hence generating conditions for a healthy lifestyle and bettering the quality of life in enclosed facilities take on special meaning because these can increase the work productivity of the residents, improve their quality of life, lower the rates of illnesses and save on expenses designated for medical treatments. The above-mentioned issues are related to a built environment's air pollution, the premise's microclimate, health and safety effects, climate change, real estate market value and the like. However, the Housing Health and Safety Decision Support System with Augmented Reality (HUSSAR) can analyse the above factors in an integrated way. The following models of HUSSAR are aimed to perform this function: Pollution Assessment and Recommender Model, Housing Health and Safety Analysis Model, Advisory Model, Augmented Reality Model and Healthy Homes Living Spaces Certification Model.

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Keywords: Pollution Assessment, Housing Health and Safety Analysis, Passive House, Climate change, Augmented Reality, Decision Support System

* Corresponding author. Tel.: +370-5-2745234; fax: +370-5-2745235.
E-mail address: Arturas.Kaklauskas@vgtu.lt

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1. Introduction

Cleaner production is the continuous application of an integrated preventative environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment [1]. Resource Efficient and Cleaner Production continuously applies integrated and preventive strategies to processes, products and services. This increases efficiency and reduces risks to human development by minimizing risks to people and communities and by supporting their development [2].

Worker health and safety and environmental protection are not always considered simultaneously when attempting to reduce or eliminate hazardous materials from our environment. Cleaner Production-Pollution Prevention (CPPP), as the primary means of prevention, has the ability to shift worker health and safety strategies from control to prevention, where exposure prevention precedes exposure control [3]. Standardization of management systems for the environment, quality, safety and health should be aimed at continuous improvement, like cleaner production programs as a starting point. Standards should also favour synergy between the three management systems—quality, environment and working conditions—and the learning processes necessary for proactive approaches [4].

Many Asian cities have encountered severe challenges responding to environmental pollution at local and global levels due to the rapid growth of their urban populations and economic development recently. A special volume of the Journal of Cleaner Production (Volume 58, 2013 November 1) reports on the results of several studies in cities across Asia designed to investigate the potential of climate co-benefit approaches [5].

Strong economic growth in China fuelled development of cities where increases in energy demand and transportation led to severe air pollution. These cities also contribute a significant share of the national greenhouse gas emissions [6]. Liu et al. [6] identify strong synergies between air quality and climate relevant measures that would allow improving the cost-efficiency of air pollution policies. Local policy makers needed help to identify viable and efficient solutions. Thus a city-scale emission model (GAINS-City) was developed based on the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model developed by the International Institute for Applied Systems Analysis (IIASA, Austria). This calls for a wider application of cleaner technologies such as integrated gasification combined cycle (IGCC) and carbon capture and storage (CCS) and more aggressive air quality measures by neighbouring provinces to control regional air pollution [6].

Many Asian countries are facing the challenge of reducing air pollution and CO_2 emissions simultaneously under the pressures of rapid industrialization and urbanization [7, 35]. Meanwhile they must continue maintaining their economic growth. Under such circumstances, cities are focusing more and more on successful implementation of co-benefit policies that are designed to reduce both air pollutants and CO_2 emissions [7]. A systematic review of co-benefit research and air pollution control policies in Japan provided Kanada et al. [7] the basis for investigating the local air pollution control policy in Kawasaki City, one of the industrial centres of Japan. They confirmed that it has contributed both to the sharp decline of atmospheric sulphur dioxide (SO_2) levels and to energy efficiency improvements in local industries.

The housing industry has been accused of causing environmental problems ranging from excessive energy consumption to pollution of the surrounding environment [8, 36]. Research on the impact of energy efficiency parameters in minimizing consumption to achieve sustainable housing development is already underway. Roufechaei et al. [8] investigate the potential link between energy efficiency parameters and the environmental, social and economic dimensions of sustainable housing development. Assessment of the energy-efficiency parameters in the design phase of housing projects revealed that there was a strong correlation between the three dimensions of sustainability in housing development practices. The study also provides some recommendations for both the government and construction companies to increase their participation in sustainable housing development progress in the country, particularly in energy-efficient design [8].

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 houses. There are 29 hazards in houses. These are arranged in four main groups reflecting basic health requirements. The four groups are sub-divided according to the nature of the hazards [9]:

- Physiological Requirements including hygrothermal conditions and pollutants (non-microbial)
- Psychological Requirements including space, security, light and noise
- Infection Prevention including hygiene, sanitation and the water supply
- Accident Prevention including falls, electric shock, burns and scalds and building-related collisions

The above-mentioned and other problems relate to a built environment's air pollution, the premise's microclimate, health and safety effects, climate change, real estate market value and other factors. However, the Housing Health and Safety Decision Support System with Augmented Reality (HUSSAR) can analyse the above factors in an integrated way.

The authors of this paper participated in two projects: "Learning Augmented Reality Global Environment" (LARGE), a Lifelong Learning Programme project, and the "Development of National Housing Health and Safety Certification Model" (DNHHSCM) project. One of LARGE's and DNHHSCM's goals (on the Lithuanian side) was to integrate augmented reality and decision support systems, i.e., to develop the Housing Health and Safety Decision Support System with Augmented Reality (HUSSAR).

One of the stated priorities of the Europe 2020 Strategy is that smart growth is driven by complex interactions between technical, social, economic and human factors. The "Learning Augmented Reality Global Environment" (LARGE) project superimposes graphics, audio, video, 3D objects and other enhancements from computers screens to real time environments thereby expanding user knowledge, skills and experience.

The main aim of the "Development of National Housing Health and Safety Certification Model" (DNHHSCM) project is to improve the quality of public healthcare services and to improve the management of the residential environmental health risk factor. The goal of this project was to develop tools for managing the residential, environmental health, risk factor.

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

2. Housing health and safety decision support model and system with augmented reality

A National Housing Health and Safety Certification Model was developed on the basis of worldwide healthy housing models [10-19]. It may be described as follows: a life cycle of housing health and safety, the parties involved in its design and realization as well as the micro-, meso- and macro-environments particularly impacting it thereby making an integral whole. A complex analysis of the formulated research object was made with the help of multiple criteria project analysis methods developed by authors [20, 21].

An analysis of existing systems including expert [22, 23], decision support [24, 25, 37, 38], intelligent [26-30] and knowledge [31, 32] served as the basis for developing the Housing Health and Safety Rating System Model. Moreover these served to develop a means for determining the most efficient versions of the Housing Health and Safety Decision Support System with Augmented Reality (HUSSAR) consisting of a database, database management system, model-base, model-base management system and user interface.

The presentation of information needed for decision making in the HUSSAR system may be in quantitative forms as well as in conceptual forms (digital [numerical], textual, graphic [diagrams, graphs, drawings, etc], photographic, sound [audial], visual [video] and augmented reality. The HUSSAR system has a relational database structure, when the information is stored in the form of tables. These tables contain quantitative and conceptual information. Each table is given a name and saved in the computer's external memory as a separate file. Logically linked parts of the table constitute a relational model. The following tables comprise the HUSSAR system database:

- Initial data tables containing general facts about the house under consideration
- Tables assessing a house and its composite parts containing quantitative and conceptual information thereof
- Physiological Requirements data tables, including hygrothermal conditions and non-microbial pollutants
- Psychological Requirements data tables, including space, security, light and noise
- Infection Prevention data tables, including hygiene, sanitation and water supply
- Accident Prevention data tables, including falls, electric shock, burns and scalds and building related collisions.

The efficiency of a house is often analysed by accounting for different quantitative and qualitative factors. Therefore a HUSSAR model-base needs to include models enabling a decision maker to perform a comprehensive analysis of the available variants and make a proper choice. The following models of model-base are earmarked for performing this function:

- Locations of Interest Search Model (see Fig. 1)
- Pollution Assessment and Recommender Model (see Fig. 2)

- Search and Multiple Criteria Analysis Model
- Housing Health and Safety Analysis Model (see Fig. 3)
- Advisory Model (see Fig. 4, Fig. 5)
- Augmented Reality Model
- Healthy Homes/Living Spaces Certification Model

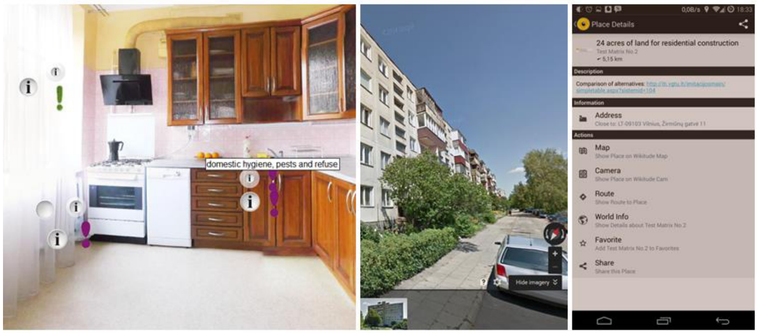


Fig. 1. House interior by using augmented reality and house location by using Google Maps and Google Earth programes.

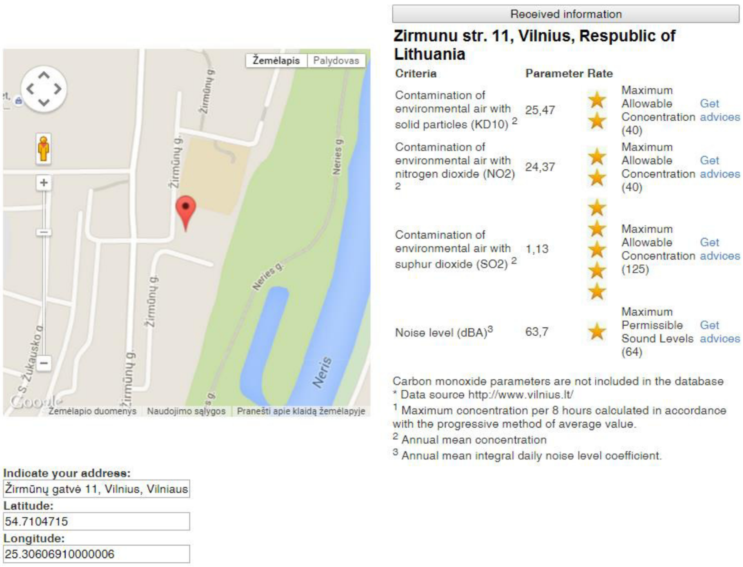
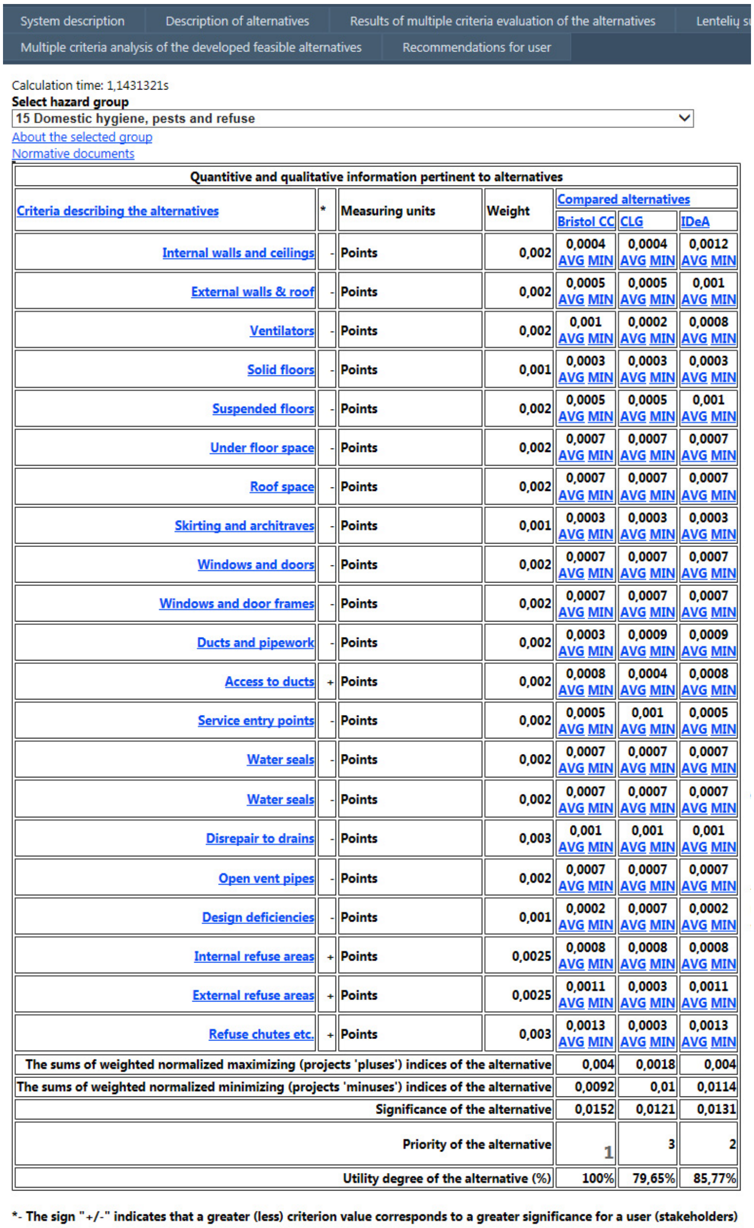


Fig. 2. Environmental quality of a house under assessment (NO_2, KD_{10}, SO_2 concentrations and environmental noise level).



Quantitive and qualitative information pertinent to alternatives						
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives		
				Bristol CC	CLG	IDeA
Internal walls and ceilings	-	Points	0,002	0,0004 AVG MIN	0,0004 AVG MIN	0,0012 AVG MIN
External walls & roof	-	Points	0,002	0,0005 AVG MIN	0,0005 AVG MIN	0,001 AVG MIN
Ventilators	-	Points	0,002	0,001 AVG MIN	0,0002 AVG MIN	0,0008 AVG MIN
Solid floors	-	Points	0,001	0,0003 AVG MIN	0,0003 AVG MIN	0,0003 AVG MIN
Suspended floors	-	Points	0,002	0,0005 AVG MIN	0,0005 AVG MIN	0,001 AVG MIN
Under floor space	-	Points	0,002	0,0007 AVG MIN	0,0007 AVG MIN	0,0007 AVG MIN
Roof space	-	Points	0,002	0,0007 AVG MIN	0,0007 AVG MIN	0,0007 AVG MIN
Skirting and architraves	-	Points	0,001	0,0003 AVG MIN	0,0003 AVG MIN	0,0003 AVG MIN
Windows and doors	-	Points	0,002	0,0007 AVG MIN	0,0007 AVG MIN	0,0007 AVG MIN
Windows and door frames	-	Points	0,002	0,0007 AVG MIN	0,0007 AVG MIN	0,0007 AVG MIN
Ducts and pipework	-	Points	0,002	0,0003 AVG MIN	0,0009 AVG MIN	0,0009 AVG MIN
Access to ducts	+	Points	0,002	0,0008 AVG MIN	0,0004 AVG MIN	0,0008 AVG MIN
Service entry points	-	Points	0,002	0,0005 AVG MIN	0,001 AVG MIN	0,0005 AVG MIN
Water seals	-	Points	0,002	0,0007 AVG MIN	0,0007 AVG MIN	0,0007 AVG MIN
Water seals	-	Points	0,002	0,0007 AVG MIN	0,0007 AVG MIN	0,0007 AVG MIN
Disrepair to drains	-	Points	0,003	0,001 AVG MIN	0,001 AVG MIN	0,001 AVG MIN
Open vent pipes	-	Points	0,002	0,0007 AVG MIN	0,0007 AVG MIN	0,0007 AVG MIN
Design deficiencies	-	Points	0,001	0,0002 AVG MIN	0,0007 AVG MIN	0,0002 AVG MIN
Internal refuse areas	+	Points	0,0025	0,0008 AVG MIN	0,0008 AVG MIN	0,0008 AVG MIN
External refuse areas	+	Points	0,0025	0,0011 AVG MIN	0,0003 AVG MIN	0,0011 AVG MIN
Refuse chutes etc.	+	Points	0,003	0,0013 AVG MIN	0,0003 AVG MIN	0,0013 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0,004	0,0018	0,004
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0,0092	0,01	0,0114
Significance of the alternative				0,0152	0,0121	0,0131
Priority of the alternative				1	3	2
Utility degree of the alternative (%)				100%	79,65%	85,77%

*- The sign "+/-" indicates that a greater (less) criterion value corresponds to a greater significance for a user (stakeholders)

Fig. 3. Multiple criteria assessment of domestic hygiene, pests and refuse.

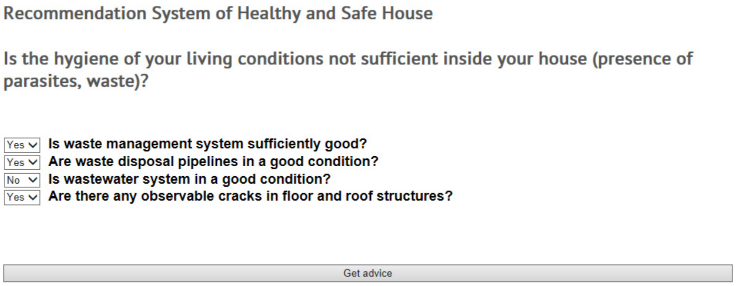


Fig. 4. Advisory Model questions about domestic hygiene, pests and refuse.

For dwellings in purpose built blocks with not more than four storeys, refuse provision can be either by use of chutes, or by waste storage containers with free ventilation. For dwellings in purpose built blocks with more than four storeys, communal chutes are recommended (unless solid fuel appliances are installed). The chutes should discharge into large containers within a store. Any such store should be designed, constructed and maintained to reduce, so far as is possible, invasion by pests. It should also be sited, designed, constructed and maintained so as not to allow air from the store to enter any living space.

Source:The Office of the Deputy Prime Minister 2006. Housing health and safety rating system: operating guidance, Office of the Deputy Prime Minister: London, 185 p.

For houses, bungalows and houses converted to self-contained flats, there should be a clearly defined area for refuse containers. This is best in the open air, and away from windows and ventilators, and, if possible, in shade or in a shelter.

Source:The Office of the Deputy Prime Minister 2006. Housing health and safety rating system: operating guidance, Office of the Deputy Prime Minister: London, 185 p.

There should be suitable and sufficient provision for the storage of refuse awaiting collection or disposal outside the dwelling. There should also be suitable and sufficient provision for the storage of household refuse within the dwelling. The storage provisions should be readily accessible to the occupants, but sited so as not to create a danger to children. The refuse facilities should not cause problems of hygiene, nor attract and allow access to pests.

Source:The Office of the Deputy Prime Minister 2006. Housing health and safety rating system: operating guidance, Office of the Deputy Prime Minister: London, 185 p.

The design and construction should reduce, so far as is possible, any means of access by pests from the outside into the dwelling. All openings into drains should be sealed with an effective water seal; this includes openings such as into the wc basin and drainage inlets for waste and surface water. To prevent mice entering there should be no holes or gaps in excess of 6.25mm. Service entry points should be effectively sealed as should any points in walls penetrated by waste, drain or other pipes or cables. There should not be any holes through roof coverings, eaves and verges which might allow access into the roof space of rats, mice, squirrels or birds. Any necessary holes for ventilation should be covered with grilles.

Source:The Office of the Deputy Prime Minister 2006. Housing health and safety rating system: operating guidance, Office of the Deputy Prime Minister: London, 185 p.

Any spaces within the dwelling such as service ducting, roof spaces and under floor spaces and service ducting, should be capable of being effectively sealed off from the living area. There should be means of access to these spaces for treatment in case of any infestation. Generally, dwellings should be designed and constructed so as to reduce, so far as is possible, gaps or voids that may be inaccessible to the dwelling occupants, and which may provide harbourage for pests. Particular attention should be given to the siting of such fittings as hot water tanks and boilers.

Source:The Office of the Deputy Prime Minister 2006. Housing health and safety rating system: operating guidance, Office of the Deputy Prime Minister: London, 185 p.

Fig. 5. Recommendations to the user for domestic hygiene, pests and refuse – an example.

3. Conclusions

Generating conditions for a healthy lifestyle and bettering the quality of life in enclosed facilities take on special meaning because these can increase the work productivity of the residents, improve their quality of life, lower the rates of illnesses and save on expenses designated for medical treatment. Developed HUSSAR can analyse the above factors in an integrated way. HUSSAR system enables the decision maker to get a variety of conceptual and quantitative information from the database and the model-base, thereby allowing him/her to analyze the above factors and arrive at an efficient resolution. The System uses the digital maps to detect automatically the data on CO_2, NO_2, KD_{10}, $KD_{2.5}$, O3 and SO_2 indicators and environmental noise, the Advisory Model provides personalized recommendations for upgrading living conditions taken from the answers to the questions generated by the system and the Augmented Reality Model offers real-time additional information about a piece of property. In the future, the authors of this paper intend to integrate HUSSAR with the Web-based Refurbishment [33], Construction [34], Facilities Management and Pollution Analysis Decision Support Systems.

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