VILNIUS TECH

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Faculty of Civil Engineering

Department of Construction Management and Real Estate

Dissertation

BIM, GIS AND WEB ENVIRONMENTS INTEGRATION FOR SOLVING MULTIFACETED PROBLEMS IN A CONSTRUCTION PROJECT

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Scientific supervisor
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Problem Formulation

Real-world data is an essential component in the construction project used at all stages of a project's life cycle.

Main issues in the integration of GIS and BIM environments:

- Environment-native methods and technics, standards
- Data interoperability
- Datatype allowance restrictions
- Analyses implementation
- Difference of geometric data
- Difference of attributive data

The research problem of the dissertation is to improve the decision-making process by supplementing BIM models with real-world data, which is achieved by integration of BIM, GIS and geospatial analysis within a Web environment to be able to address problems in the construction field.

Structure of dissertation

- Introduction
- 1.Literature analysis on the integration of BIM, GIS and Web environments
- 2. A conceptual model for the modelling of rational solutions in construction project
- 3. Application of the conceptual model for the modelling of rational solutions in construction project
- General Conclusions
- References
- List of Scientific Publications by the Author on the Topic of the Dissertation
- Summary in Lithuanian

The volume of the work is 163 pages, the text contains 50 numbered formulas, 37 figures and 24 tables. When writing the dissertation, 328 literary sources were used.

Relevance of the Thesis

The integration of BIM, GIS and Web environments became an important field of study in the scientific community, where the number of scientific articles has significantly increased in recent years.

Main topics in the integration process:
- The lack of methods and technics for processing BIM models inside the Web environment
- The standardization of the integration process
- The standardization of the data exchange
- Interoperability issues

Main focus of the integration:
- The implementation of the geospatial analyses
- The implementation of the geospatial databases
- The optimization of the processes in the construction project
- The optimization of the decision-making

There are no studies addressing problems in the construction field that rely on multi-criteria decision-making analysis using BIM models as a source of data, and real-world data presented by GIS or geospatial analysis inside the Web environment.

Research Object

The integration of BIM, GIS, and Web environments for decision-making in a construction project.

Aim of dissertation

To develop a conceptual model based on the integration of BIM, GIS, Web environments and multi-criteria decision-making methods to allow complex analyses for more efficient solutions in a construction project.

Objectives of the dissertation

1. To conduct the state-of-the-art analysis related to the integration of BIM, GIS, and Web environments.
2. To develop a principal solution for relationships between in-model objects in a BIM model representation in the Web environment.
3. To develop a method (QUVIAS) for visibility analysis that uses BIM, GIS, and Web environments to mathematically calculate visibility and represent it by quantitative parameters.
4. To develop methodological and technological solutions to automate the data collection process in multi-criteria decision-making analysis addressing property attractiveness and building location problems.
5. To develop a method for solving the problems of selecting and operating a crane based on the integration of BIM, GIS and Web environments.
6. To demonstrate the practical application of the proposed model and methods in case studies. Development of a Web-based spatial decision-support system for construction projects.

Research Methodology

Literature analysis:
A bibliometric analysis, analytical methods, regression and numerical methods, scientific theoretical and comparative analyses.

In-model objects' relation and QUVIAS methods:
Analytical methods, scientific theoretical methods, comparative and statistical methods, case study method.

Multi-criteria decision-making analysis:
Delphi method, a concordance approach, fuzzy TOPSIS, fuzzy COPRAS, and fuzzy EDAS methods, QUVIAS method, in-model object's relation method, geospatial analyses, case study method.

Crane selection and operation, data collection:
Geospatial analysis, QUVIAS method, buffers analysis, case study method.

Web-based SDSS: JavaScript, HTML, CSS (SCSS), WebGL, PhP, ThreeJS, Bootstrap, GLSL, OpenStreetMap API, ArcGIS API, SolarAtlas API, Overpass API, etc.

The BIM models: Autodesk Revit.

Defended Statements

1. The proposed conceptual model enables the complex analysis of rational solutions in a construction project by integrating BIM, GIS, Web environments and multi-criteria decision-making methods.
2. Objects presented in the BIM model within the Web environment can be manipulated and analysed based on the in-model relations.
3. The QUVIAS method makes it possible to mathematically calculate a view from a window and present it by a quantitative parameter through the integration of BIM, GIS, and Web environments.
4. The visibility analysis performed inside the Web environment can improve the crane selection and operation process.
5. The integration of BIM, GIS, and Web environments allows for solving the property attractiveness problem.
6. The solution for automating multi-criteria analysis using data provided by BIM and GIS inside the Web environment allows fast and accurate estimation of appropriate and rational building location.

Scientific Novelty of the dissertation

1. The original conceptual model was proposed for the complex analysis of rational solutions in a construction project with the integration of BIM, GIS, Web environments and multi-criteria analysis.
2. A novel method was developed to define a relations between objects presented by the BIM model inside the Web environment.
3. The new unique method (QUVIAS) for visibility analysis was created and validated by a case study. This method determines view quality in terms of quantitative parameters using mathematical calculations based on spherical coordinates and data from BIM and GIS environments within the Web environment.
4. A novel approach was proposed based on the QUVIAS method for solving the property attractiveness problem.
5. A new method was presented for automating multi-criteria decision-making analysis and validated in a case study on building location problems. The method uses data provided by BIM and GIS environments and performs geospatial analysis within the Web environment. A new method for crane selection and operation based on visibility analysis and buffer method was presented and validated in a case study.

Practical Value of the Research Findings

The presented research proves the usefulness of the BIM, GIS and Web environment integration by solving problems in the construction project and increasing the accuracy of decision-making process.

- The developed methodology for BIM model processing enables the inclusion of BIM models into a geospatial analysis inside the Web environment.
- The proposed QUVIAS method for visibility analysis introduces a mathematical computation of the view that increases the accuracy of view calculations and presents it as quantitative criteria.
- The proposed automated multi-criteria decision-making analysis significantly decreases time consumption and increases the accuracy of the decision-making process with up-to-date real-world data.
- Practical implementation of all the results into a web-based spatial decision-support system developed in this dissertation.

The results of this study are related to digitalization in construction and the introduction of innovations in the construction industry, which can, directly and indirectly, affect the economic sector. The developed spatial decision-support system with methods proposed in this dissertation can support the decisions of municipalities, real estate and project developers for efficient design of the built environment, thus leading to sustainable construction

Approval of the Research Findings (List of scientific publications)

Publication in peer-reviewed journals

1. Shkundalov, D., & Vilutienė, T. (2021). Bibliometric Analysis of Building Information Modeling, Geographic Information Systems and Web Environment Integration. Automation in Construction, 128, 103757. www.doi.org/10.1016/j.autcon.2021.103757
2. Shkundalov, D., & Vilutienė, T. (2022). Quantitative View Assessment (QUVIAS) method for window visibility analysis utilizing BIM, GIS and Web environments. International Journal of Strategic Property Management, 26(4), 287–304. www.doi.org/10.3846/ijspm.2022.17754

Conference publications in peer-revirewed conference proceedings

1. Shkundalov, D., & Vilutienė, T. (2023). Automotive MCDA for Alternative Building Locations by Employing BIM and GIS. The 18th Colloquium New Trends in Construction Management, 39–69, vb.vgtu.lt/object/elaba:160940601
2. Shkundalov, D., & Vilutienė, T. (2021). Selection of crane in Web environment based on visibility analysis. In Research in Building Engineering EXCO'21. Universitat Politècnica de València, 406–417, exco.webs.upv.es/wp-content/uploads/2021/12/CATALOGUE_INTERNATIONAL_ITINERANT_EXHIBITION_IN_BUILDING_ENGINEERING_EXCO-21.pdf
3. Shkundalov, D., & Vilutienė, T. (2020). Building management system in WebBIM environment. In 11th International Conference "Environmental Engineering", 1–5. www.doi.org/10.3846/enviro.2020.725
4. Shkundalov, D., & Vilutienė, T. (2019). A new approach for extending the possibilities of collaboration between BIM, GIS and Web environments to increase the efficiency of building space management. The 13th international conference "Modern building materials, structures and techniques", Vilnius, 670–674. www.doi.org/10.3846/mbmst.2019.057
5. Shkundalov, D., & Vilutienė, T. (2019). The analysis of Web technologies for BIM model processing. In The 17th Colloquium „Sustainable decisions in built environment, 1–4. www.doi.org/10.3846/colloquium.2019.009
6. Shkundalov, D. (2017). Development of visualization and manipulation methods for BIM and digital city models using Web graphic library. In 20th conference for junior researchers „Science – future of Lithuania, 1–6. jmk.msk.vgtu.lt/index.php/geodezija/2017/paper/view/146

Conceptual model

Research

Literature analysis

Software: VOSviewer
Bibliographic coupling: co-citation networks, co-authorship networks, co-occurrence map of keywords

Problem formulation

Main issues
Lack of standards and methods for processing BIM model presented inside the Web environment

Main focuses
Geospatial analysis implementation , specifically visibility analysis, based on integration of BIM, GIS and Web environments

Main observations
Lack of investigations into integration of MCDA with BIM, GIS and Web environments

Methodology

Objects' relations

- Development of the method for determination of objects' relation sequences presented inside the BIM model representation
- Recalculation of the in-model objects' coordinates

Geospatial analysis

Development of the visibility analysis method "quantitative view assessment" (QUVIAS) for mathematical calculation of the view and presenting it as a quantitative parameter

Automation of MCDA

Development of the method for automation of the data gathering in solving MCDA problems, specifically building location problem

Practical application and case study

Web-based Spatial Decision-Support System

Crane selection and operation
Implementation of objects' relations for processing objects inside the BIM model representation for crane selection and operation problems.

- Crane visibility coefficient
- Crane reachability coefficient

Premise attractiveness
Implementation of the quantitative view assessment method for assessment of the premise attractiveness and building location problems

- Window view coefficient
- Premise view coefficient
- Building view coefficient

Building view coefficient

Building location
Implementation of the automatic data gathering method for solving MCDA problems, specifically building location problem.

Most suitable building location problem solved

BIM

Software: Autodesk Revit

- BIM model
- Revit Families
- IFC classes

GIS

- GIS databases
- 3D batched model
- 2D map
- Line-of-sight
- Coordinate systems

Web

- JavaScript
- WebGL
- HTML
- CSS (SCSS)
- Other

Analysis of the state-of-the-art related to BIM, GIS and Web integration

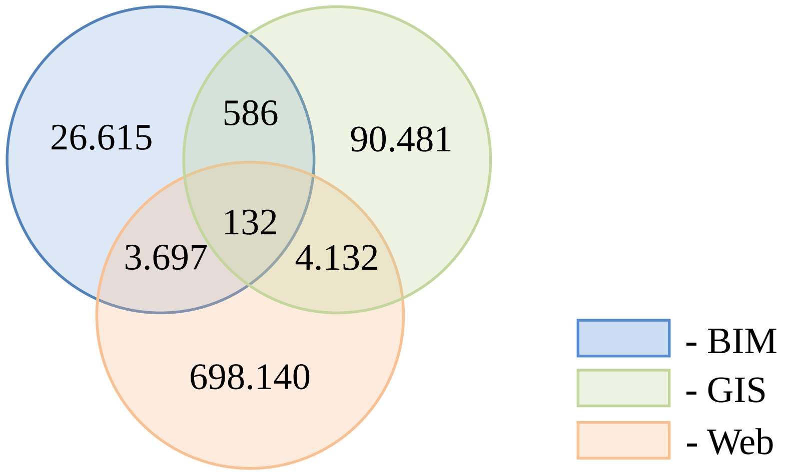


Fig. 1. Number of scientific articles in each related environment and their integrations (developed by the author)

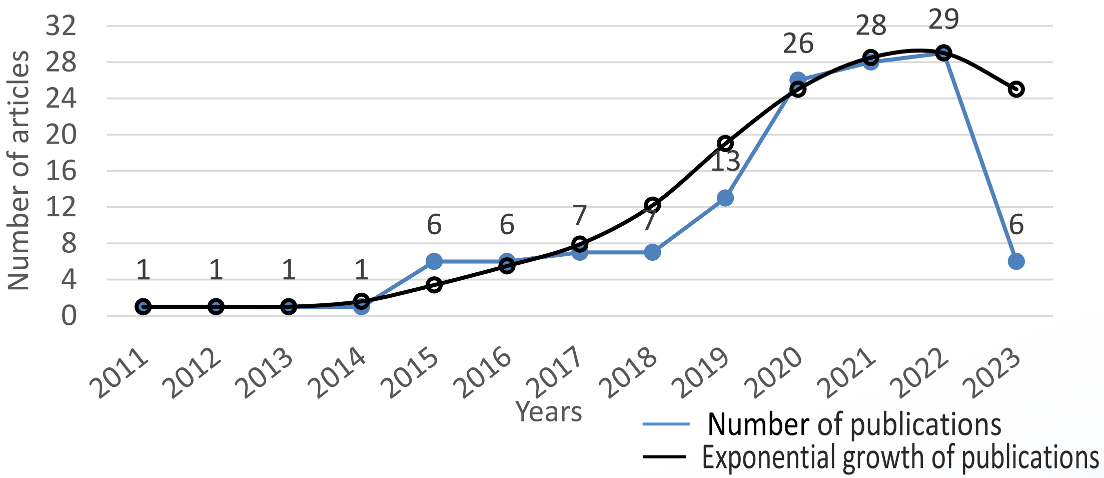


Fig. 2. Number of scientific articles related to BIM, GIS and Web integration (developed by the author)

Table 1. Research on state-of-the-art related to BIM, GIS and Web integration

- Main issues: lack of standards and methods for BIM model processing inside the Web environment
- Main focuses: GIS analyses, BIM model processing
- Main use cases: geospatial analysis, visibility analysis
- Lack of researches in BIM, GIS and Web integrations for solving MCDA problems

Principal solution for in-model objects' relations of the BIM model representation in a Web environment

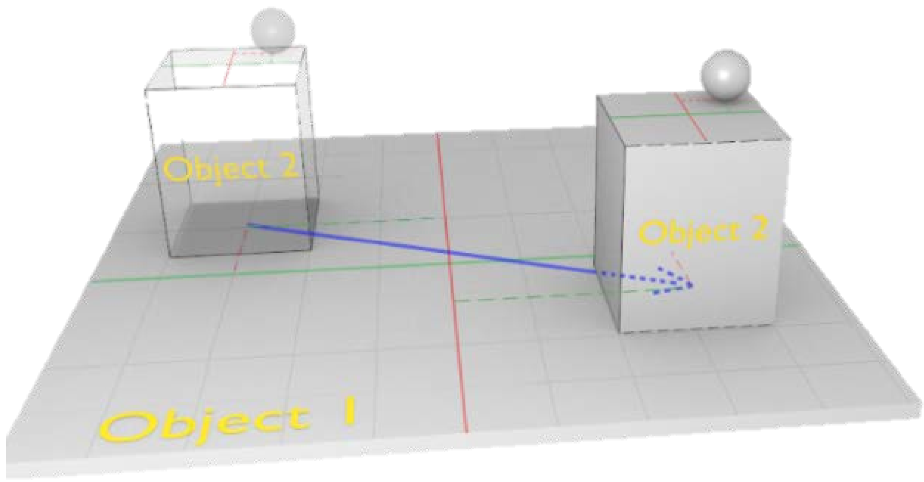


Fig. 3. The sequence of the object's relations in BIM model presented within the Web environment (developed by the author)

Table 2. Tasks related to coordinate calculation

- Determination of the in-model relations.
- Calculation of the correlated coordinates for the objects.
- Creation of the relations of the objects.
- Recalculation of the objects coordinates in the WebGL environment coordinate system.
- The rebuilding of the BIM model based on new coordinates.

$$x_n^C y_n^C = \begin{bmatrix} (x_n - x_{n-1}) \\ \left(y_n - \frac{h_n}{2} - y_{n-1} + \frac{h_{n-1}}{2} \right) \end{bmatrix}$$

Formula 1. Object's coordinates correlated to the host object

$$y_n^S x_n^S = \sum_{i=2}^{n} \begin{bmatrix} x_i^C \\ y_i^C \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{h_n}{2} \end{bmatrix}$$

Formula 2. calculation of the scene coordinates of the objects based on the sequence of hosts objects

Coordinate specification for BIM, GIS and Web environments integration

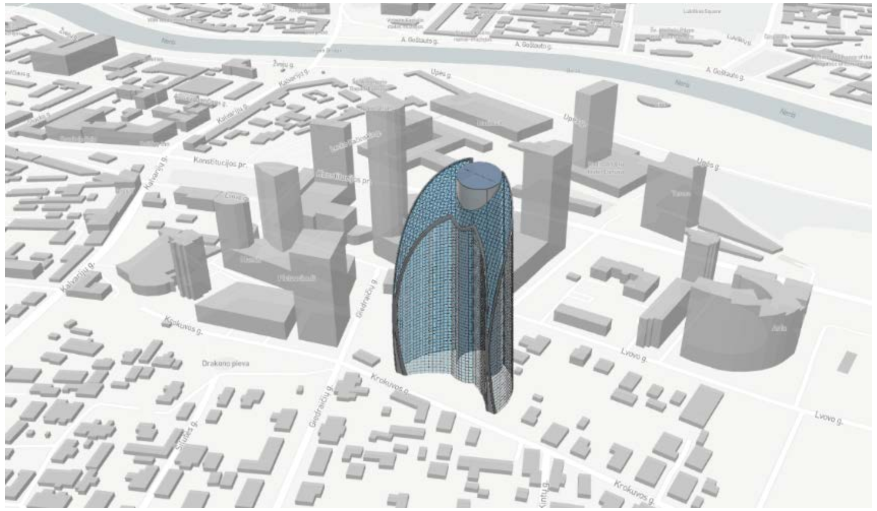


Fig. 4. BIM model representation in GIS environment based on Web technology (developed by the author)

Table 3. Tasks related to coordinate conversion

- Specifying or detecting the model coordinates
- Converting the coordinates into web supportable coordinate system

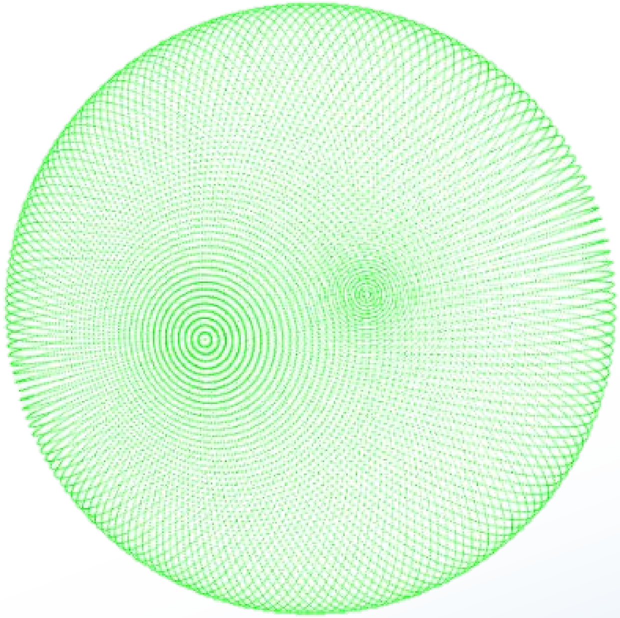
$$\begin{cases} \lambda = \dfrac{X * 180}{\pi * R} \\ \phi = \dfrac{180 * \left(2 * \arctan\left(e^{\frac{Y}{R}}\right) - \frac{\pi}{2}\right)}{\pi} \end{cases}$$

Formula 3. Conversion of the WGS84 into Web Mercator

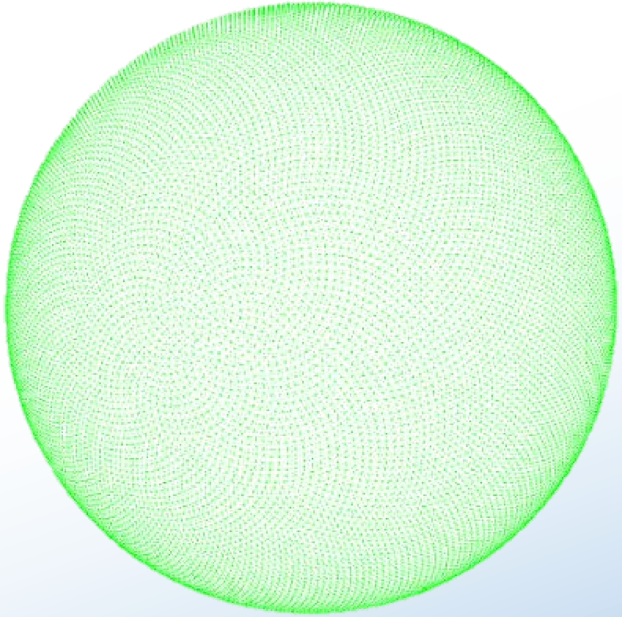
Quantitative View Assessment (QUVIAS) method method for visibility analysis in integrated BIM, GIS and Web environments

Table 4. Existing methods for window visibility analysis (developed by the author)

Method name	Distance	Clear view	Landscape area	Shape accuracy
QUVIAS	+	+	+	+
View dome	-	+	+	+
QLA360	-	+	+	-
Viewshed	-	-	+	+
Line-of-sight	+	-	-	Not applicable



a)



b)

Fig. 5. The difference between the mathematical shapes of the view:
a - plane shape flattened on the sphere; b - spherical shape (developed by the author)

Quantitative View Assessment (QUVIAS) method method for visibility analysis in integrated BIM, GIS and Web environments

Table 5. Comparative analysis of step angles from one window (developed by the author)

Angle step	Required duration	Result (distance based)	Result (Boolean variables)	Total iterations
180º	0 sec	0.00006	0	4
90º	0 sec	0.33337	33.33333	9
45º	0 sec	0.40031	40.00000	25
22º 30' 30.00''	0 sec	0.44513	44.44444	81
11º 15' 15.00''	0 sec	0.45094	44.98270	289
5º 37' 37.50''	0 sec	0.43101	42.97521	1089
2º 48' 48.75''	01 sec	0.42659	42.48521	4225
1º 24' 24.38''	05 sec	0.42543	42.34121	16641
0º 42' 42.19''	19 sec	0.42285	42.05514	66049
0º 33' 33.75''	33.38 sec	0.42161	41.92015	103041
0º 21' 21.09''	01:13 min	0.42159	41.90425	263169
0º 10' 10.55''	04:44 min	0.42163	41.88878	1050625
0º 05' 05.27''	18:28 min	0.42150	41.86401	4198401
0º 02' 02.64''	1:13:14 h	0.42157	41.86986	16785409
0º 01' 01.32''	4:51:06 h	0.42158	41.87237	67125249
0º 01'	12:16:56 h	0.42156	41.87108	116661601

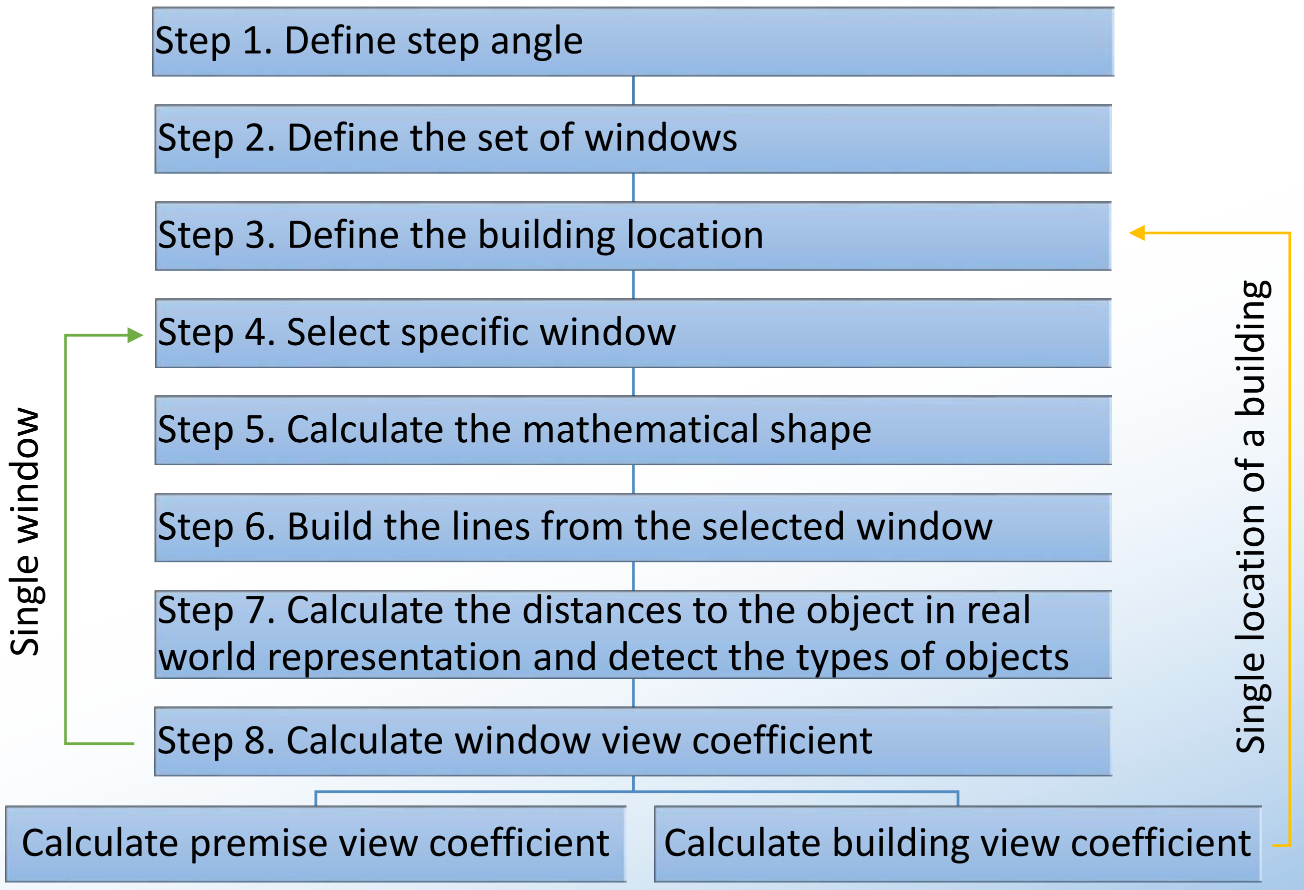


Fig. 6. Methodological scheme of the QUVIAS method for window visibility analysis (developed by the author)

Crane selection and operation methods based on the integration of BIM, GIS and Web environments

Table 6. Crane selection and operation tasks (developed the by author)

Group of tasks	Articles
Detection of the most suitable number of cranes, crane types and required specifications	(Abdelmegid, Shawki, & Abdel-Khalek, 2015) (Al Hattab, Zankoul, & Hamzeh, 2017) (Al Hattab, Zankoul, Barakat, & Hamzeh, 2017) (Han, Bouferguene, Al-Hussein, & Hermann, 2017) (Hermann, Hendi, Olearczyk, & Al-Hussein, 2010)
Optimization of crane and storage locations	(Pan, Guo, & Li, 2017) (Tam & Tong, 2003) (Moussavi Nadoushani, Hammad, & Akbarnezhad, 2016) (Hermann, Hendi, Olearczyk, & Al-Hussein, 2010) (Younes & Marzouk, 2018) (Lewis & Bejczy, 1973) (Wang X. , Zhang, Wu, & Gao, 2011) (Safouhi, Mouattamid, Hermann, & Hendi, 2011) (Astour & Franz, 2014) (Wang J. , et al., 2015) (Alkriz & Mangin, 2005) (Irizarry & Karan, 2012)
Coordination of multiple cranes	(Al Hattab, Zankoul, & Hamzeh, 2017) (Al Hattab, Zankoul, Barakat, & Hamzeh, 2017) (Alkriz & Mangin, 2005) (Irizarry & Karan, 2012) (Al Hattab, Zankoul, & Hamzeh, 2014) (Ali, Babu, & Varghese, 2005) (Zhang, Harris, Olomolaiye, & Holt, 1999)
Lifting or erection path planning	(Hornaday & Haas, 1993) (Lozano-Perez & Wesley, 1979) (Goldobina, Demenkov, & Trushko, 2019) (Zhou, Guo, Ma, Zhang, & Skitmore, 2021) (Souravik, Yiyu, Lihui, & Jianmin, 2020)
Visualization and simulation of the crane operations	(Zavichi, Madani, Xanthopoulos, & Oloufa, 2014) (Han, Bouferguene, Al-Hussein, & Hermann, 2017) (Hermann, Hendi, Olearczyk, & Al-Hussein, 2010) (Younes & Marzouk, 2018) (Wang X. , Zhang, Wu, & Gao, 2011) (Astour & Franz, 2014) (Irizarry & Karan, 2012) (Al Hattab, Zankoul, & Hamzeh, 2014) (Goldobina, Demenkov, & Trushko, 2019) (Han, Hasan, Bouferguène, Al-Hussein, & Kosa, 2015)

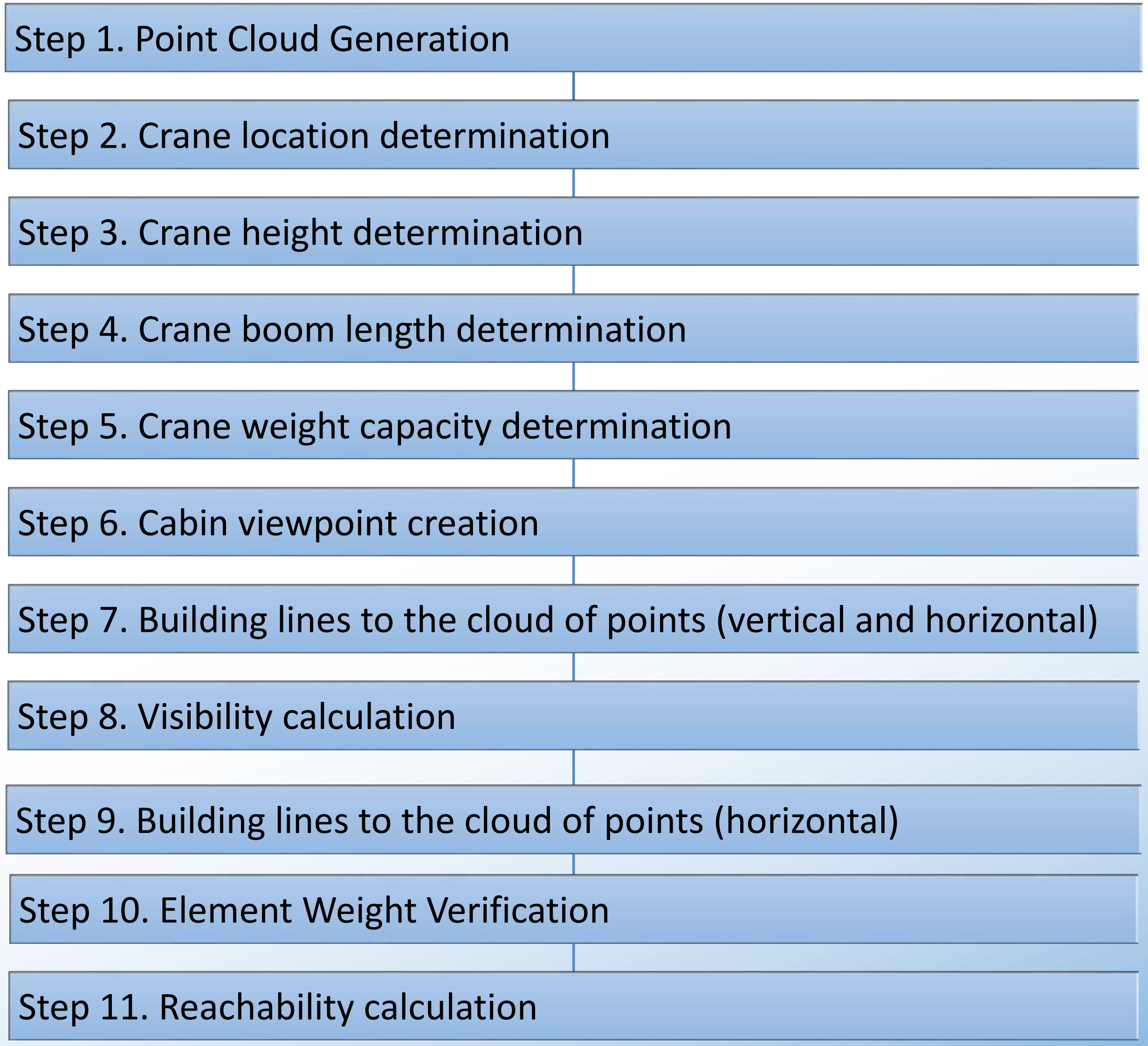


Fig. 7. Scheme of crane selection and operation method (developed by the author)

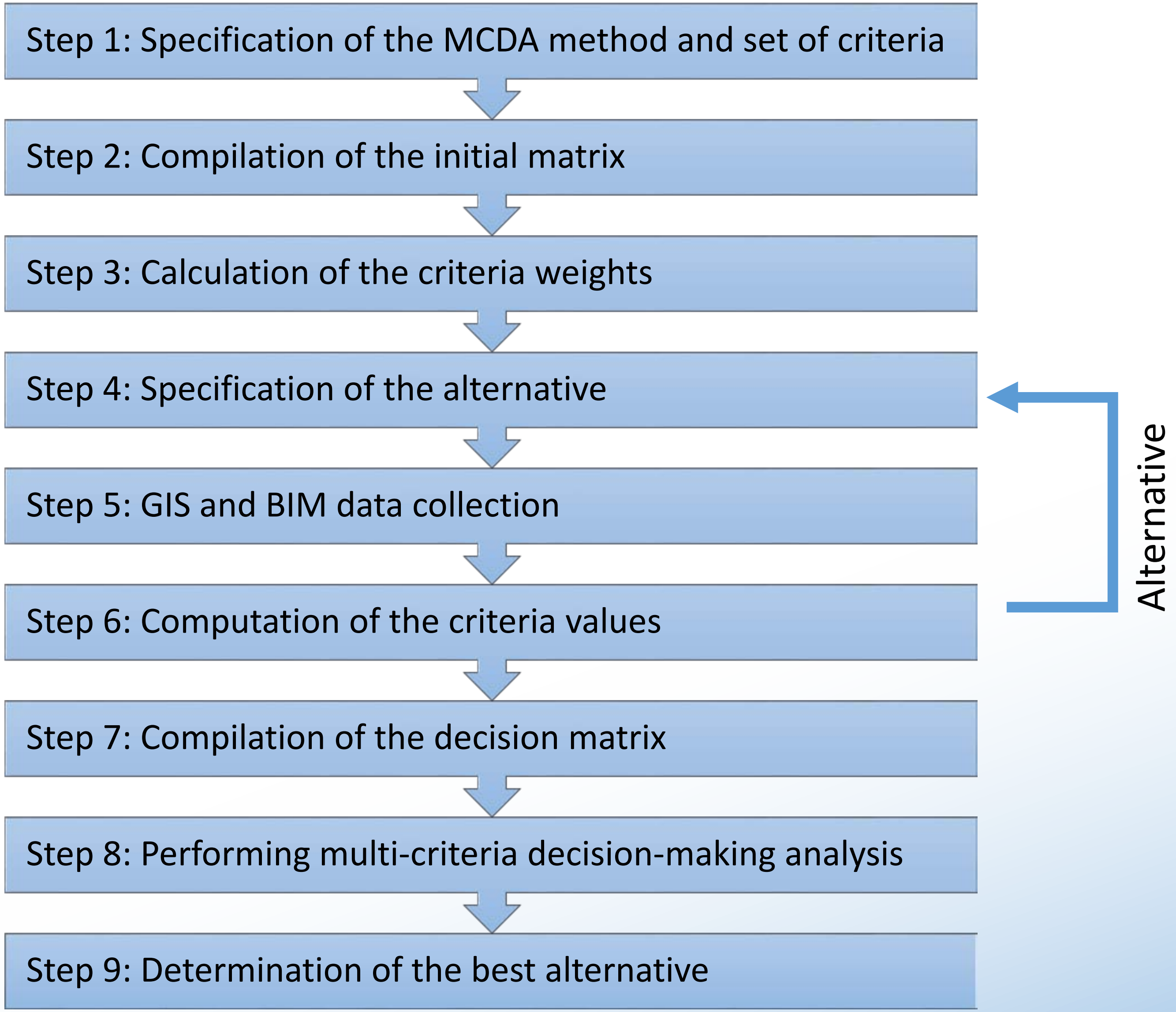


Fig. 8. Methodology for automatic multi-criteria decision-making analysis (developed by the author)

Table 7. Common criteria presented in the relevant scientific articles (developed by author)

Criteria	Sources
Selling price	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (McCluskey, Deddis, Mannis, McBurney, & Borst, 1997) (Chou, Hsu, & Chen, 2008) (Achillas, Vlachokostas, Moussiopoulos, & Banias, 2010)
Prestige of locality	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Jegelaviciute, 2017) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007) (Achillas, Vlachokostas, Moussiopoulos, & Banias, 2010)
Accessibility	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Jegelaviciute, 2017) (Wyatt, 1997) (Chou, Hsu, & Chen, 2008)
Environmental aesthetics	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Interior	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Public transport	(Maliene, 2011) (Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Chou, Hsu, & Chen, 2008) (Achillas, Vlachokostas, Moussiopoulos, & Banias, 2010)
Year of construction	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Jegelaviciute, 2017) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Distance from city center	(Maliene, 2011) (Din, Hoesli, & Bender, 2001)
The need for renovation	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Jegelaviciute, 2017) (Din, Hoesli, & Bender, 2001) (McCluskey, Deddis, Mannis, McBurney, & Borst, 1997) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Window View	(Maliene, 2011) (Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Din, Hoesli, & Bender, 2001)
Social environment and crimes	(Maliene, 2011) (Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Din, Hoesli, & Bender, 2001) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007) (Chou, Hsu, & Chen, 2008) (Chou, Hsu, & Chen, 2008)
Engineering solutions and communications	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Jegelaviciute, 2017) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Parking and garages	(Maliene, 2011) (Jegelaviciute, 2017) (Wyatt, 1997) (McCluskey, Deddis, Mannis, McBurney, & Borst, 1997) (Chou, Hsu, & Chen, 2008)
Exterior	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Heating method	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (McCluskey, Deddis, Mannis, McBurney, & Borst, 1997)
Residential space and area of land plot	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (McCluskey, Deddis, Mannis, McBurney, & Borst, 1997)
Floor	(Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Wyatt, 1997)
Equipping of a territory	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Assessment of market conditions	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021)
Type of area	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Din, Hoesli, & Bender, 2001) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Balcony	(Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021)
Number of floors	(Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Wyatt, 1997)
Construction design	(Maliene, 2011) (Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Layout of premises	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Number of Auxiliary buildings	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021)
Public welfare and culture	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Din, Hoesli, & Bender, 2001) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007) (Chou, Hsu, & Chen, 2008) (Achillas, Vlachokostas, Moussiopoulos, & Banias, 2010)
Trees and vegetation	(Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Assessment of air conditioning	(Maliene, 2011) (Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021) (Natividade-Jesus, Coutinho-Rodrigues, & Antunes, 2007)
Basement	(Jegelaviciute, 2017) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021)
Distance from public transport stops	(Maliene, 2011) (Din, Hoesli, & Bender, 2001) (Chou, Hsu, & Chen, 2008) (Achillas, Vlachokostas, Moussiopoulos, & Banias, 2010)
Number of telephone lines	(Kaklauskas A. , Zavadskas, Banaitis, & Datkauskas, 2007) (Maliene, 2011)
Location with respect to parts of the world	(Maliene, 2011) (Zavadskas E. , Kaklauskas, Bausys, Naumcik, & Ubarte, 2021)

Delphi method

Based on Paniotto (Vveinhardt & Petrauskaite, 2013) equation the required number of experts was calculated and is equal to **17**

Table 8. Experts who participated in Delphi analysis (developed by the author)

Experts	Position, organisation	Experience (years)
Expert 1	PhD, Vilnius Gediminas Technical University	6
Expert 2	Head of building structures department, OAO “Giprojivmash”	35
Expert 3	Civil engineer	21
Expert 4	PhD, Katholieke Universiteit Leuven	7
Expert 5	Construction project manager, consultant	22
Expert 6	Professor, Vilnius Gediminas Technical University	20
Expert 7	Project manager	21
Expert 8	Researcher, Vilnius Gediminas Technical University	20
Expert 9	Assoc. prof., Vilnius Gediminas Technical University	20
Expert 10	Assoc. prof., Vilnius Gediminas Technical University	19
Expert 11	Urban planning, Kyiv National University of Construction and Architecture	7
Expert 12	Assoc. prof., Vilnius Gediminas Technical University	20
Expert 13	Professor, Vilnius Gediminas Technical University	20
Expert 14	Professor, Kyiv National University of Construction and Architecture	21
Expert 15	Owner, real estate agency	27
Expert 16	Real estate agent	16
Expert 17	PhD, Kyiv National University of Construction and Architecture	6

Table 9. Final set of criteria for building location problem selected by experts through Delphi study

Criteria	Sub-criteria	Units	Type (Max/Min)
Window View	View landscape	Number	Max
	Type of view	Number	Max
Trees and vegetation	Trees and vegetation	Number	Max
	Forests and green areas	Distance	Min
Type of area	Distance to industrial facilities	Distance	Min
Parking and garage	Distance to parking and garage	Distance	Min
Location with respect to parts of the world	Solar insolation	Number	Max
Distance from the city center	Distance from city center	Distance	Min
Public transport stops	Public transport stops	Number	Min
Public culture	Sustenance	Number	Max
	Education	Number	Max
	Financial	Number	Max
	Entertainment, art and culture	Number	Max
	Worship	Distance	Min
	Sport activities	Number	Max
Public welfare and service	Hospital and medical clinic	Distance	Min
	Fire station	Distance	Min
	Police station	Distance	Min
	Post office	Distance	Min
Public transport	Number of public transport routes	Number	Max

Delphi method

Table 10. Weights of the criteria defined by the experts (developed by the author)

Criteria	Experts												
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	…	E15	E16	E17
View landscape	10	10	10	10	9	7	7	7	9	9	…	10	7	10
Trees and vegetation	9	8	9	9	7	9	9	8	9	9	…	9	9	9
Distance to industrial facilities	7	10	8	8	8	8	9	9	10	8	…	8	9	8
Type of view	10	9	10	9	7	6	7	6	10	9	…	9	7	9
Forests and green areas	6	6	9	9	9	9	9	9	10	8	…	9	9	6
Parking and garage	6	8	7	8	10	6	9	6	10	8	…	8	9	10
Simplified Solar insolation	9	10	7	8	9	7	9	7	9	7	…	8	9	6
Police station	6	8	8	6	10	9	9	9	10	6	…	6	9	7
Distance from city center	8	5	7	8	8	7	8	6	10	10	…	8	8	8
Distance to public transport stops	9	5	6	8	8	8	8	8	10	8	…	8	8	7
Public transport	7	3	6	7	10	8	9	3	10	8	…	7	9	9
Sustenance	6	4	9	8	7	7	9	7	10	6	…	8	9	5
Education	7	3	5	5	8	8	9	10	10	7	…	5	9	6
Healthcare	8	8	6	5	9	9	9	3	10	6	…	5	8	5
Entertainment	2	6	6	7	8	9	8	7	10	6	…	7	8	7
Sport activities	2	7	6	7	3	9	10	8	10	7	…	7	9	6
Fire station	4	4	9	7	9	7	9	2	8	6	…	7	8	7
Worship	3	8	4	5	8	6	7	8	8	7	…	5	7	6
Financial	4	1	5	4	5	8	8	8	7	6	…	4	7	6
Post office	5	4	2	1	3	6	6	3	5	5	…	2	6	4

Concordance coefficient (Podvezko, 2005) was calculated based on Pearson (Pearson, 2009) formula, $\chi 2$ = **131.7**
According to Chi-Square Probabilities (Plackett, 1983) for degree of freedom 19, $\chi 2$ = **30.144** .

Table 11. Functions of criteria data gathering (developed by the author)

Criteria	Sources of data
View landscape	The relevant coefficients was calculated by visibility analysis using QUVIAS method implemented in the developed web-based SDSS. This criterion represents the view that can be seen from the windows of the building in certain location.
Type of view	The value was calculated as difference between normalised negatively and positively influence of the objects that can be seen in the view determined by QUVIAS method based on the data gathered from GIS databases OpenStreetMap and ESRI. Where, according to the multiple researches (Souravik, Yiyu, Lihui, & Jianmin, 2020) (Benson, Hansen, Schwartz, & Smersh, 1998) (Irizarry & Karan, Optimizing location of tower cranes on construction sites through GIS and BIM integration, 2012) (Paterson & Boyle, 2002) (Medendorp & Semwal, 2019) (Yuan, Wu, Wei, & Wang, 2018) (Zhou, Guo, Ma, Zhang, & Skitmore, 2021) (Shkundalov & Vilutiene, Building management system in WebBIM environment, 2020) (Baranzini & Schaerer, 2011), oceans, green areas, rivers and lakes are considered as an objects with positive influence, and other objects presents a negative influence, such as roads, buildings, parking, etc. Objects that are not defined in the GIS database was excluded from the calculation.
Solar insolation	The values was calculated according to the (Bird & Hulstrom, 1980) (Kamali, Moradi, & Khalili, 2006) (Honsberg & Bowden, 2019) and based on the direct normal irradiation and diffuse horizontal irradiation gathered from the Global Solar Atlas (Global Solar Atlas, 2022) and European Commission (European Commission: Photovoltaic Geographical Information System, 2022) databases in certain location.
Trees and vegetation	The data was gathered from OpenStreetMap and ESRI databases. The requests for OpenStreetMap includes three types of objects, specifically “node”, “way” and “relation”. The used parameters for the requests are as follows: amenity, leisure, boundary, tourism, natural, landuse, landcover, route, route_master, aerialway, railway_routes, train_routes, highway, public_transport, communication, telecom. The categories used in requests for ESRI database correlates with the date that is required, therefore the similar categories are applied.
Forests and green areas	
Distance to industrial facilities	
Distance to parking and garage	
Distance from city center	
Public transport stops	
Sustenance	
Education	
Financial	
Entertainment, art and culture	
Worship	
Sport activities	
Hospital and medical clinic	
Fire station	
Police station	
Post office	
Number of public transport routes	

Developed web-based spatial decision-support system

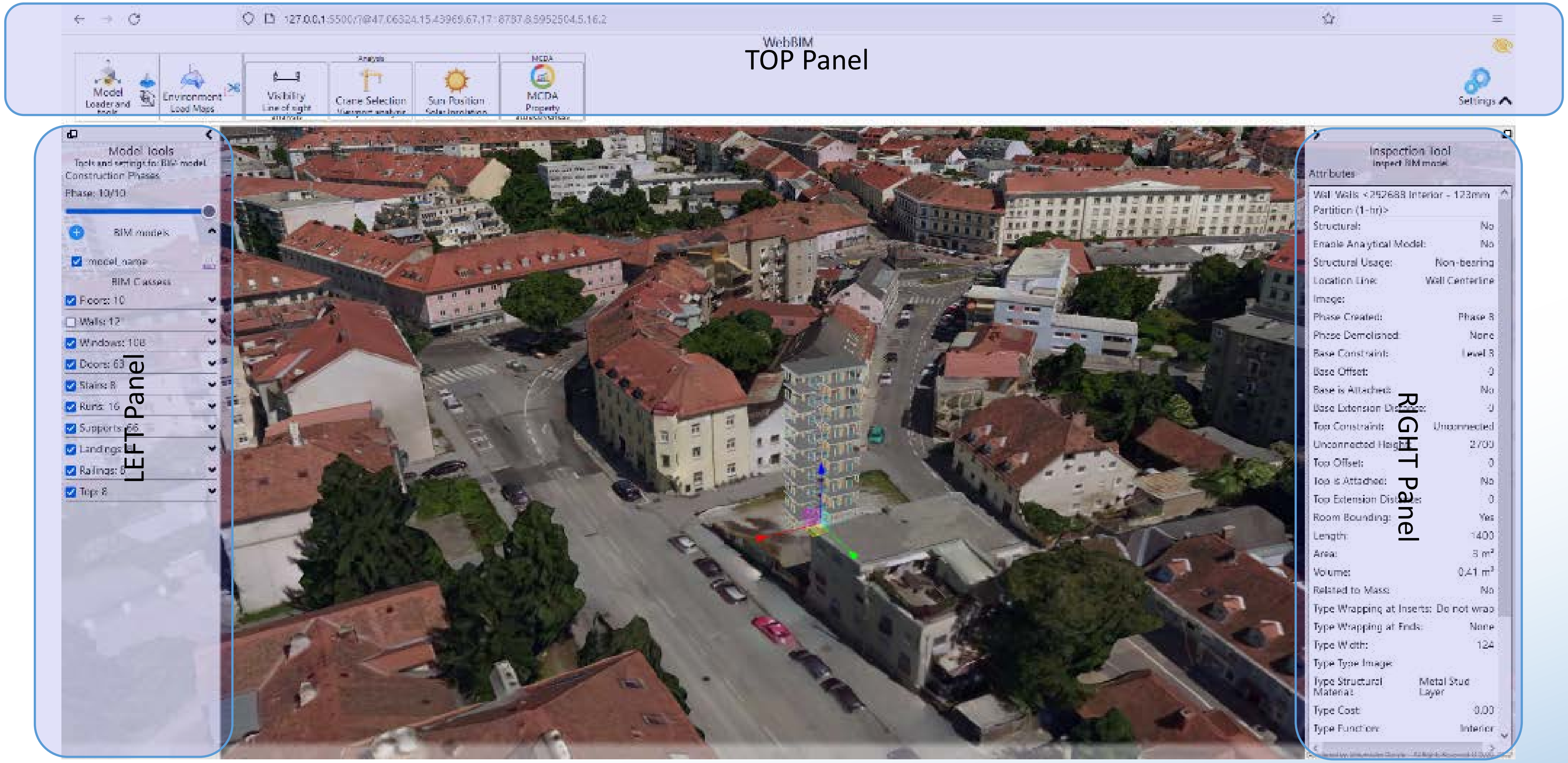


Fig. 9. Web-based spatial decision-support system (developed by the author)

Case study 1. Modelling optimal crane operation

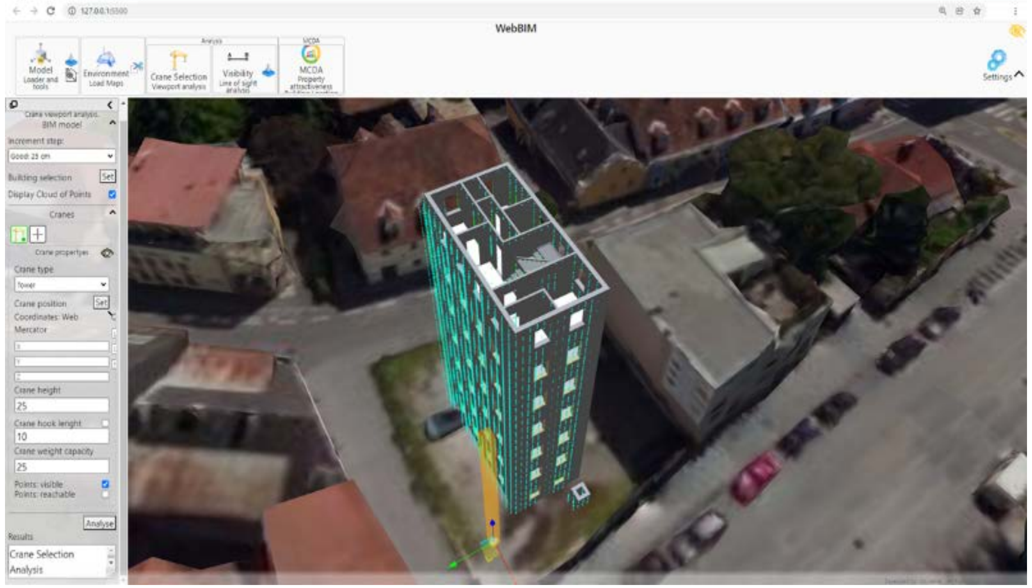


Fig. 10. Crane visibility rate (developed by the author)

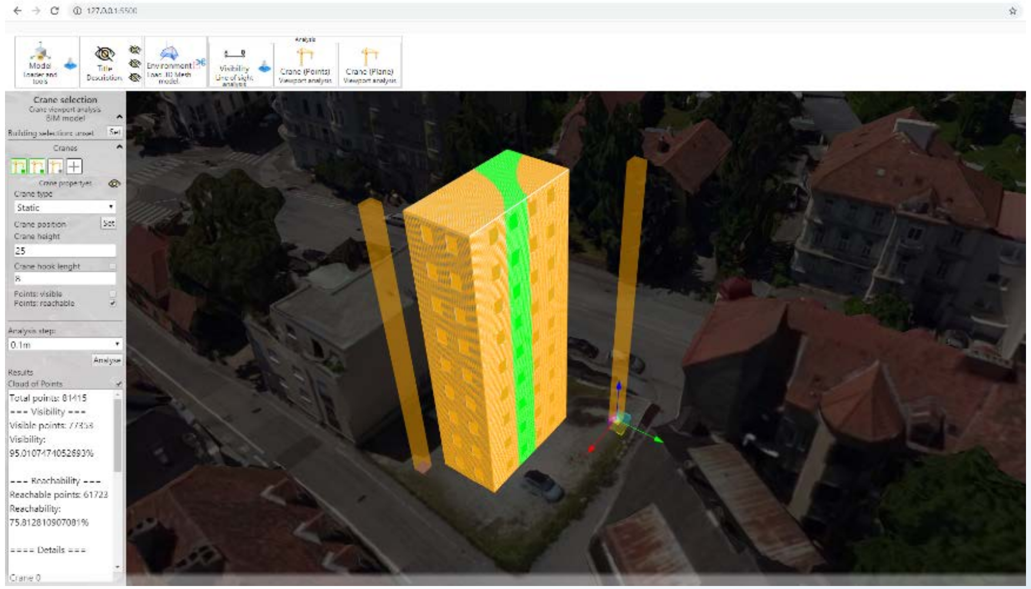


Fig. 11. Crane reachability rate (developed by the author)

Table 12. Results of the crane selection and operation analysis: visibility

Visibility : 95% (77353 points).

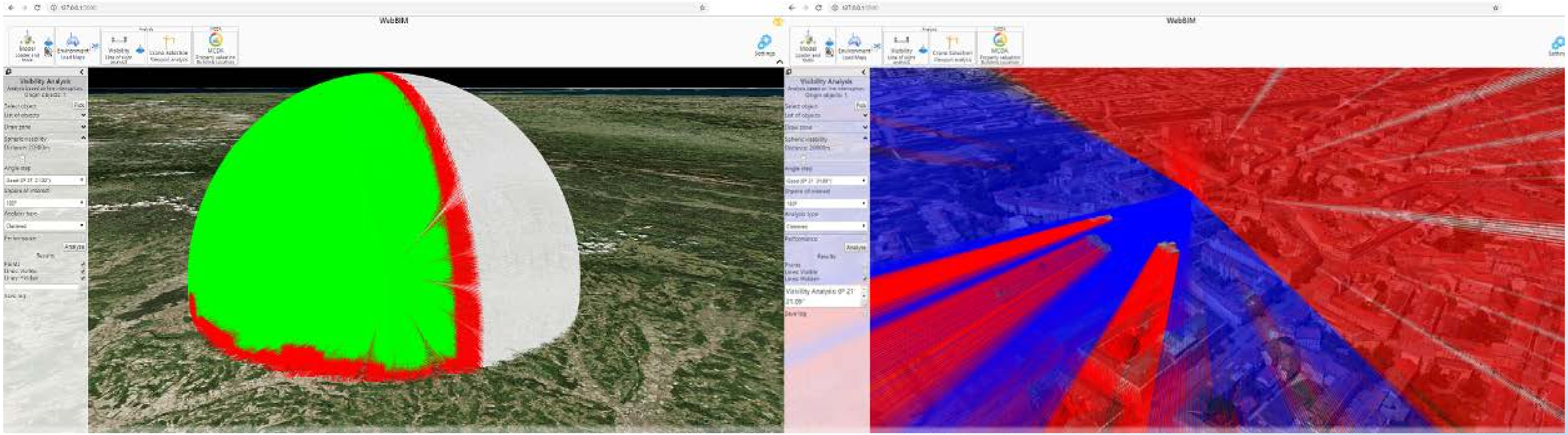
First crane: 51.9% (42287 points)
Second crane: 49.7% (40463,57 points)

Table 13. Results of the crane selection and operation analysis: reachability

Reachability of the first crane – 27% (21976 points)
Reachability of the second - 48,8% (39747 points)

Single crane task:
Second crane location is 21,8% more effective compared to the first location
Multiple cranes task:
Not suitable locations (24,3% not reachable)

Case study 2. Utilization of visibility and geospatial analysis for the assessment of property attractiveness and building location problems: ***view analysis***



a) b)

Fig. 12. Visualization of the QUVIAS method: a - view sphere presented by lines; b - part of the view sphere (developed by the author)

Case study 2. Utilization of visibility and geospatial analysis for the assessment of property attractiveness and building location problems: ***window view coefficient***

a)

b)

Fig. 13. Practical research of proposed window visibility analysis: a - the view from the second floor; b - the view from the ninth floor (developed by the author)

Benefits of applying the window view coefficient:

- No on-site measurements;
- Removes subjective judgments;
- Reduces time consumption.

Table 14. Results of the visibility analysis utilizing QUVIAS method: Window view coefficients

Second floor:		**Ninth floor:**
Window view coefficient : 0.24730;	Difference: 63,4%	Window view coefficient: 0.40399;
Types of the objects:	Difference:	Type of objects:
0.11266 (or 45.6%) roads;	29.5%	0.06509 (or 16.1%) roads;
0.03710 (or 15%) buildings;	13.8%	0.11671 (or 28.8%) buildings;
	0.4%	0.00180 (or 0.4%) green areas;
0.01030 (or 4.2%) undefined.	1.9%	0.02469 (or 6.1%) unknown.

Case study 2. Utilization of visibility and geospatial analysis for the assessment of property attractiveness and building location problems: ***premise view coefficient***

Fig. 14. Windows view coefficients for all floors (developed by the author)

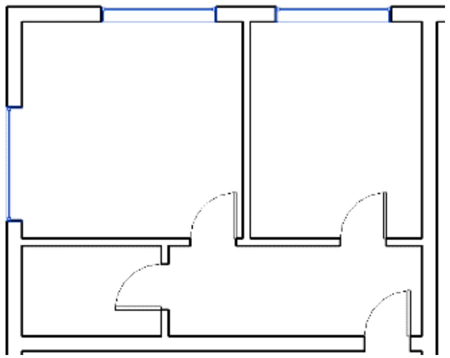


Fig. 15. Required windows for the calculation of the premises view coefficient (developed by the author)

Table 15. Results of the visibility analysis utilizing QUVIAS method

Second floor:		**Ninth floor:**
Premises view coefficient :	Difference:	Premises view coefficient:
0.19816;	113,0%	0.42199;
Types of the objects:	Difference:	Type of objects:
0.067772 (or 34.2%) roads;	24.4%	0.041355 (or 9.8%) roads;
0.046767 (or 23.6%) buildings;	8.3%	0.134613 (or 31.9%) buildings;
0.036264 (or 18.3%) parking;	17.2%	0.004642 (or 1.1%) parking;
0.000396 (or 0.2%) green area;	0.7%	0.003798 (or 0.9%) green area;
0.003567 (or 1.8%) undefined.	5.8%	0.032071 (or 7.6%) unknown.

Case study 2. Utilization of visibility and geospatial analysis for the assessment of property attractiveness and building location problems: ***building view coefficient***

a)

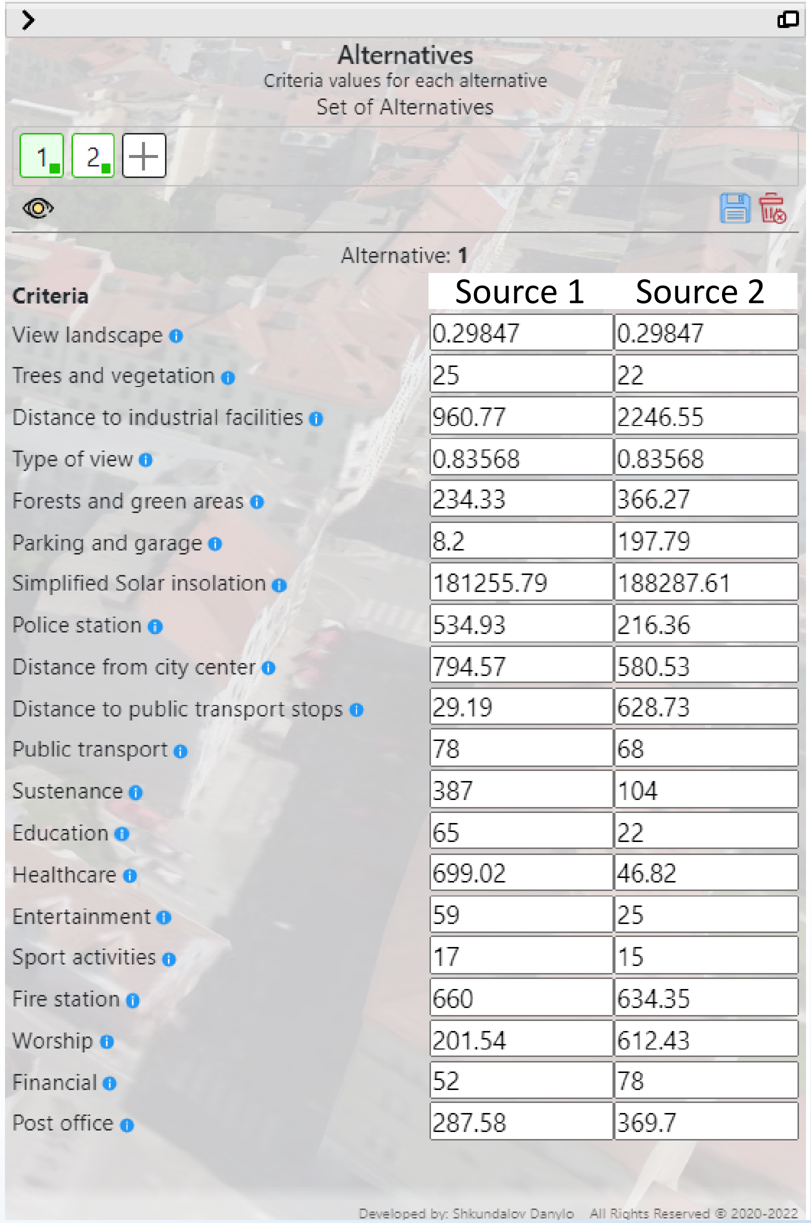
b)

Fig. 16. Web-based SDSS - alternative locations of the building: a) first alternative; b) second alternative (developed by the author)

Table 16. Results of the visibility analysis utilizing QUVIAS method: Building view coefficients

First location:		**Second location:**
Building view coefficient : 0.29847;	Difference: 6,9%	Building view coefficient: 0.31904;
Types of the objects:	Difference:	Type of objects:
0.06865 (or 23%) roads;	15.2%	0.02489 (or 7.8%) roads;
0.08283 (or 27.8%) buildings;	6.1%	0.06939 (or 21.75%) buildings;
0.01448 (or 4.85%) parking lots;	4.85%	
0.00164 (or 0.55%) green area;	17.35%	0.05711 (or 17.9%) green areas;
0.01851 (or 6.2%) undefined	1%	0.01659 (or 5.2%) undefined

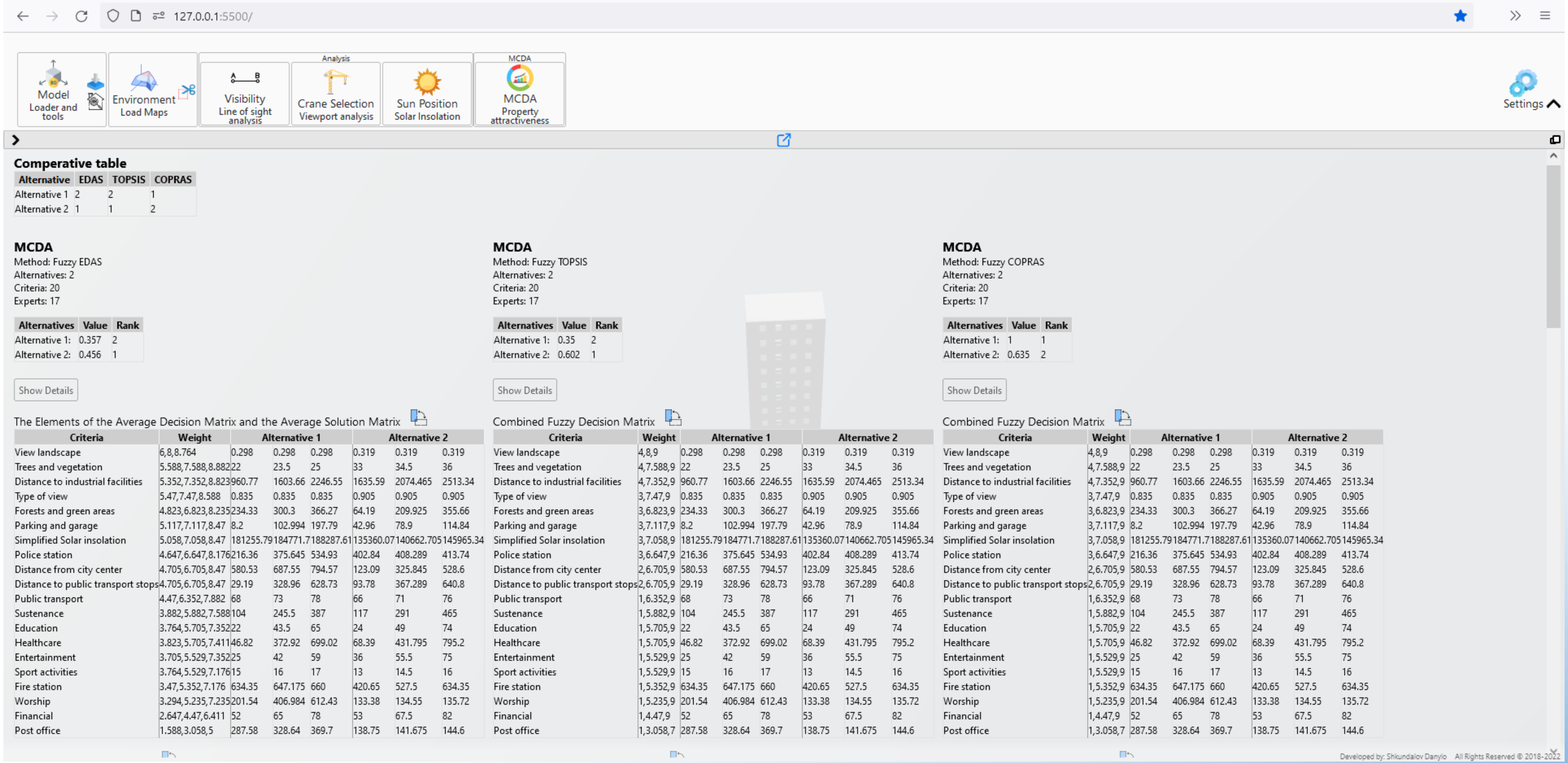
Case study 3. Solving the building location problem by applying multi-criteria decision-making analysis



Criteria	Source 1	Source 2
View landscape	0.29847	0.29847
Trees and vegetation	25	22
Distance to industrial facilities	960.77	2246.55
Type of view	0.83568	0.83568
Forests and green areas	234.33	366.27
Parking and garage	8.2	197.79
Simplified Solar insolation	181255.79	188287.61
Police station	534.93	216.36
Distance from city center	794.57	580.53
Distance to public transport stops	29.19	628.73
Public transport	78	68
Sustenance	387	104
Education	65	22
Healthcare	699.02	46.82
Entertainment	59	25
Sport activities	17	15
Fire station	660	634.35
Worship	201.54	612.43
Financial	52	78
Post office	287.58	369.7

Fig. 17. Comparison of data gathered from different GIS databases for the first alternative (developed by the author)

Case study 3. Solving the building location problem by applying multi-criteria decision-making analysis



Comperative table

Alternative	EDAS	TOPSIS	COPRAS
Alternative 1	2	2	1
Alternative 2	1	1	2

MCDA

Method: Fuzzy EDAS
Alternatives: 2
Criteria: 20
Experts: 17

Alternatives	Value	Rank
Alternative 1:	0.357	2
Alternative 2:	0.456	1

The Elements of the Average Decision Matrix and the Average Solution Matrix

Criteria	Weight	Alternative 1			Alternative 2		
View landscape	6,8,8.764	0.298	0.298	0.298	0.319	0.319	0.319
Trees and vegetation	5.588,7.588,8.882	22	23.5	25	33	34.5	36
Distance to industrial facilities	5.352,7.352,8.823	960.77	1603.66	2246.55	1635.59	2074.465	2513.34
Type of view	5.47,7.47,8.588	0.835	0.835	0.835	0.905	0.905	0.905
Forests and green areas	4.823,6.823,8.235	234.33	300.3	366.27	64.19	209.925	355.66
Parking and garage	5.117,7.117,8.47	8.2	102.994	197.79	42.96	78.9	114.84
Simplified Solar insolation	5.058,7.058,8.47	181255.79	184771.7	188287.61	135360.07	140662.705	145965.34
Police station	4.647,6.647,8.176	216.36	375.645	534.93	402.84	408.289	413.74
Distance from city center	4.705,6.705,8.47	580.53	687.55	794.57	123.09	325.845	528.6
Distance to public transport stops	4.705,6.705,8.47	29.19	328.96	628.73	93.78	367.289	640.8
Public transport	4.47,6.352,7.882	68	73	78	66	71	76
Sustenance	3.882,5.882,7.588	104	245.5	387	117	291	465
Education	3.764,5.705,7.352	22	43.5	65	24	49	74
Healthcare	3.823,5.705,7.411	46.82	372.92	699.02	68.39	431.795	795.2
Entertainment	3.705,5.529,7.352	25	42	59	36	55.5	75
Sport activities	3.764,5.529,7.176	15	16	17	13	14.5	16
Fire station	3.47,5.352,7.176	634.35	647.175	660	420.65	527.5	634.35
Worship	3.294,5.235,7.235	201.54	406.984	612.43	133.38	134.55	135.72
Financial	2.647,4.47,6.411	52	65	78	53	67.5	82
Post office	1.588,3.058,5	287.58	328.64	369.7	138.75	141.675	144.6

MCDA

Method: Fuzzy TOPSIS
Alternatives: 2
Criteria: 20
Experts: 17

Alternatives	Value	Rank
Alternative 1:	0.35	2
Alternative 2:	0.602	1

Combined Fuzzy Decision Matrix

Criteria	Weight	Alternative 1			Alternative 2		
View landscape	4,8,9	0.298	0.298	0.298	0.319	0.319	0.319
Trees and vegetation	4,7.588,9	22	23.5	25	33	34.5	36
Distance to industrial facilities	4,7.352,9	960.77	1603.66	2246.55	1635.59	2074.465	2513.34
Type of view	3,7.47,9	0.835	0.835	0.835	0.905	0.905	0.905
Forests and green areas	3,6.823,9	234.33	300.3	366.27	64.19	209.925	355.66
Parking and garage	3,7.117,9	8.2	102.994	197.79	42.96	78.9	114.84
Simplified Solar insolation	3,7.058,9	181255.79	184771.7	188287.61	135360.07	140662.705	145965.34
Police station	3,6.647,9	216.36	375.645	534.93	402.84	408.289	413.74
Distance from city center	2,6.705,9	580.53	687.55	794.57	123.09	325.845	528.6
Distance to public transport stops	2,6.705,9	29.19	328.96	628.73	93.78	367.289	640.8
Public transport	1,6.352,9	68	73	78	66	71	76
Sustenance	1,5.882,9	104	245.5	387	117	291	465
Education	1,5.705,9	22	43.5	65	24	49	74
Healthcare	1,5.705,9	46.82	372.92	699.02	68.39	431.795	795.2
Entertainment	1,5.529,9	25	42	59	36	55.5	75
Sport activities	1,5.529,9	15	16	17	13	14.5	16
Fire station	1,5.352,9	634.35	647.175	660	420.65	527.5	634.35
Worship	1,5.235,9	201.54	406.984	612.43	133.38	134.55	135.72
Financial	1,4.47,9	52	65	78	53	67.5	82
Post office	1,3.058,7	287.58	328.64	369.7	138.75	141.675	144.6

MCDA

Method: Fuzzy COPRAS
Alternatives: 2
Criteria: 20
Experts: 17

Alternatives	Value	Rank
Alternative 1:	1	1
Alternative 2:	0.635	2

Combined Fuzzy Decision Matrix

Criteria	Weight	Alternative 1			Alternative 2		
View landscape	4,8,9	0.298	0.298	0.298	0.319	0.319	0.319
Trees and vegetation	4,7.588,9	22	23.5	25	33	34.5	36
Distance to industrial facilities	4,7.352,9	960.77	1603.66	2246.55	1635.59	2074.465	2513.34
Type of view	3,7.47,9	0.835	0.835	0.835	0.905	0.905	0.905
Forests and green areas	3,6.823,9	234.33	300.3	366.27	64.19	209.925	355.66
Parking and garage	3,7.117,9	8.2	102.994	197.79	42.96	78.9	114.84
Simplified Solar insolation	3,7.058,9	181255.79	184771.7	188287.61	135360.07	140662.705	145965.34
Police station	3,6.647,9	216.36	375.645	534.93	402.84	408.289	413.74
Distance from city center	2,6.705,9	580.53	687.55	794.57	123.09	325.845	528.6
Distance to public transport stops	2,6.705,9	29.19	328.96	628.73	93.78	367.289	640.8
Public transport	1,6.352,9	68	73	78	66	71	76
Sustenance	1,5.882,9	104	245.5	387	117	291	465
Education	1,5.705,9	22	43.5	65	24	49	74
Healthcare	1,5.705,9	46.82	372.92	699.02	68.39	431.795	795.2
Entertainment	1,5.529,9	25	42	59	36	55.5	75
Sport activities	1,5.529,9	15	16	17	13	14.5	16
Fire station	1,5.352,9	634.35	647.175	660	420.65	527.5	634.35
Worship	1,5.235,9	201.54	406.984	612.43	133.38	134.55	135.72
Financial	1,4.47,9	52	65	78	53	67.5	82
Post office	1,3.058,7	287.58	328.64	369.7	138.75	141.675	144.6

Fig. 18. Multi-criteria decision-making analysis in web-based SDSS (developed by the author)

Case study 3. Solving the building location problem by applying multi-criteria decision-making analysis

a) b)

Fig. 19. Web-based SDSS - alternative locations of the building: a) first alternative; b) second alternative (developed by the author)

Table 17. Comparison of the ranks determined by different multi-criteria decision-making methods (developed by the author)

Alternatives	**Fuzzy TOPSIS**[*1]	**Fuzzy COPRAS**[*2]	**Fuzzy EDAS**[*3]
Alternative 1	2	1	2
Alternative 2	1	2	1

[*1] - The Technique for Order Preference by Similarity to Ideal Solution;
[*2] - The COmplex PRoportional ASsessment;
[*3] - The Evaluation based on Distance from Average Solution;

Conclusions (I)

1. Deep research on the state-of-the-art related to BIM, GIS, and Web environments integration was conducted. According to the analysis results, the integration process of BIM, GIS, and Web environments faces many obstacles, where the most pressing issues are related to the implementation of the standards and methods for processing the data. Mainly, this issue is linked to the processing of the BIM model since no unified standard can be found that would present a method for data storing and managing that would be sufficient for all three environments.
2. The proposed method for determining the sequence of the objects' relation allowed recompiling the BIM model representation and processing it in a more BIM-native manner, where the recalculated coordinates were utilised in the geospatial analysis. The proposed method was used multiple times in other analyses presented in the dissertation. The proposed method has shown its value and usefulness according to the results of the development.
3. The proposed methodology for crane selection and operations has shown high accuracy of the calculation allowing analysis of single cranes as well as their groups. According to the analysis results, the proposed method allowed for differentiating the alternatives of the crane locations considering the visibility and reachability of the cranes.

Conclusions (II)

4. The proposed Quantitative View Assessment (QUVIAS) method for visibility analysis, which allows calculating the view mathematically, has shown high accuracy of the calculations and provided the following conclusions:
    a) The comparison of the existing and proposed methods for visibility analysis revealed a sufficient difference in accuracy and proved the value of the QUVIAS method.
    b) The window view coefficient allowed for determining the precise difference between the views of the windows, which proves the accuracy of the proposed method for quantitative view assessment.
    c) The proposed premise view coefficient revealed a significant difference in clearance of the views related to the two premises. The premise view coefficient has shown its potential to be used in the assessment of the premise attractiveness.
    d) The building view coefficient revealed a sufficient difference between the two views, which are related to alternative locations of the building. The analysis has shown that the proposed building view coefficient is suitable to be used for solving a building location problem by providing a quantitative representation of the view in the calculation.
5. The proposed conceptual model and methodology for multi-criteria decision-making analysis were applied to the case study for automation of solving a building location problem. The whole process of data gathering and MCDA problem solving was performed inside the developed Web-based SDSS. Achieved results proved the usefulness of BIM, GIS, and Web integration for solving problems in the construction field as well as proved the use of results obtained by the QUVIAS method.
6. The Web-based spatial decision-support system was developed, including all proposed methods and approaches and was approbated in the case study. The main obstacle in development was found in a lack of sources and GIS databases for gathering the data for multi-criteria decision-making analysis. This issue is related to the dissociation of the databases presented by institutions. The databases are inaccessible most of the time, which leads to the lack of data for performing multi-criteria analysis.

Thank you

Additional: Results of the analysis of the state-of-the-art related to BIM, GIS and Web integration

Table 1. Countries *

Country	Articles
China	44
USA	18
Australia	14
England	10
Italy	10
India	8
Germany	6
South Korea	6
Canada	5
Malaysia	5
Saudi Arabia	5
Spain	5
Belgium	3
France	3
Indonesia	3
Netherlands	3
Turkey	3
Lithuania	2
⋮	⋮

Table 2. Institutions *

Institution	Articles
Curtin University (Australia)	6
Rluk Research Libraries (UK)	4
Shenzhen University (China)	4
Tianjin University (China)	4
Chinese Academy of Sciences (China)	3
Ghent University (Belgium)	3
National Institute of Technology (India)	3
Qingdao University (China)	3
Shenzhen Institute of Advanced Technology (China)	3
Southeast University China (China)	3
State University System of Florida (US)	3
Tongji University (China)	3
University College London (UK)	3
University of London (UK)	3
Vilnius Gediminas Technical University (Lithuania)	2
⋮	⋮

Table 3. Authors *

Author	Articles
Wang Xiangyu	5
Lv Zhihan	5
Zhu Junxiang	4
Zhang Sherong	3
Li Xiaoming	3
Vilutienė Tatjana	2
Shkundalov Danylo	2
⋮	⋮

Table 4. Scientific journals *

Name of the journal	Articles
International Journal of Geo Information	16
Automation in Construction	11
Sustainability	7
Buildings	6
Information Technology in Construction	4
Remote Sensing	4
Applied Sciences Basel	3
⋮	⋮

* – Number of articles more than 2

Additional: Potential uses of BIM, GIS and Web integration

Table 1. Construction project lifecycle phases and virtually integrated Design, Construction and Operation*

Planning and Design Phase
Programming, conceptualization and cost planning
Architectural, structural and systems design
Analysis, documentation, coordination and specification
Construction Phase
Construction planning and construction detailing
Manufacturing and construction
Commissioning, handover
Operations Phase
Occupancy and operations
Asset management and facility maintenance
Decommissioning and major re-programming

Table 2. BIM uses achievable on the current state of the BIM, GIS and Web integration

BIM uses
Visualization
Urban Planning
Conceptualization
Space Programming
Selection and Specification
Site Analysis
Solar Analysis
Accessibility Analysis
Safety Analysis
Security Analysis
Relocation Management
Building Inspection
Real-time Utilization
BIM/GIS Overlapping
BIM/Web Overlapping
VR/AR
Decision-making
Property attractiveness
Crane selection and operation

* - According to (Ustinovičius, Rasiulis, Nazarko, Vilutienė & Reizgevicius, 2015), “BIM Framework” and “BIMe Initiative”

Additional: Assessment of the property attractiveness

Table 1. Commonly used criteria presented in scientific articles related to property attractiveness *

Criterion	Criterion
Selling price	Floor
Prestige of locality	Equipment of a territory
Accessibility	Assessment of market conditions
Environmental aesthetics	Type of area
Interior	Balcony
Public transport	Number of floors
Year of construction	Construction design
Distance from the city centre	Layout of premises
The need for renovation	Number of Auxiliary buildings
Window View	Public welfare and culture
Social environment and crimes	Trees and vegetation
Engineering solutions and communications	Assessment of air conditioning
Parking and garages	Basement
Exterior	Distance from public transport stops
Heating method	Number of telephone lines
Residential space and area of a land plot	Location with respect to parts of the world

- - According to:

Zavadskas, Kaklauskas, Bausys, Naumcik & Ubarte, 2021;
Jegelavičiūtė, 2017;
Maliene, 2011;
Achillas, Vlachokostas, Moussiopoulos & Banias, 2010;
Chou, Hsu & Chen, 2008;
Kaklauskas, Zavadskas, Banaitis & Datkauskas, 2007;
Natividade-Jesus, Coutinho-Rodrigues & Antunes, 2007;
Din, Hoesli & Bender, 2001;
Wyatt, 1997;
McCluskey, Deddis, Mannis, McBurney & Borst, 1997;