ALGORITHM-BASED BIM MODEL ANALYSIS METHODOLOGY AT URBAN LEVEL

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ABSTRACT

In this paper, we described the use of Building Information Modeling methods for urban analysis. This purpose has been usually established by Geographic Information Systems however the development of Computer-Aided Design software made it possible to analyse large areas or parts of cities with the help of BIM models. This study focuses on the assessment of prefabricated large-panel buildings in the garden city of Pécs, in Hungary. The goal was to determine a building selection method according to the integrity of the area. We took into consideration infrastructural facilities, spatial position of shops, bus stations, and educational institutions compared to the locations of selected buildings. This approach supported the determination of potential inherent in renovations. The research consisted of three main stages: BIM model production methods and procedures, use of algorithm-based workflows during data import and spatial analysis, and quantification and evaluation of generated information. Due to the high complexity of Architectural, Engineering, and Construction projects and new digitalized methods, the use of algorithms and BIM models has been the fastest growing part of the industry in the past few years. This combination can support logical examinations and calculations between 3D and 2D information. The generated final results derived from locations made it possible to evaluate prospective renovations. The presented methodologies can be used in the case of other types of buildings and can support the decisions during the delivery of assets.

KEYWORDS _ *building information modelling, algorithms, urban analysis, location value, renovation*

INTRODUCTION

Hungarian prime minister has made a pronouncement in 2017 containing that 10 storey large-panel buildings' top floor could be demolished to solve overheating issues (HVG 2017). The news has brought the dilemma of these buildings into public awareness. In Hungary, there about 510.000 apartments that were built between 1961 and 1992 by manufactured technologies (Dési 1996).

The lifetime of the large-panel buildings is close to reach their estimated operating time (Dr. Birghoffer and Hikisch 1994; Orbán 1978). There are examples of refurbishments (Ghazi Wakili et al. 2018; Ligęza 2015; Osztroluczky and Csoknyai 2005) but those were just pilot projects and nobody has made an urban level analysis of these buildings yet. The presented methods take into account the location of buildings compared to infrastructure, educational institutions, grocery stores, and restaurants. The main thesis of this research is that the location of the buildings affects their renovation value so it makes sense to calculate.

Development of Information Technology (IT) and Building Information Modelling (BIM) made it possible to analyse spatial information of a city. A few articles present economy based location value calculations (Akogun 2013; Kolbe et al. n.d.) but our research uses non-statistical methodologies finding impact value. BIM models are usually used in building level which allows supporting operations during the lifecycle (Ham Namhyuk et al. 2018; Heaton et al. 2019; Lee et al. 2012) and the previous studies were focused on the Return on Investment (ROI) of using BIM technologies (Kim et al. 2017; Walasek and Barszcz 2017). The purpose of this paper is to give urban design and management support due to the values of the examined buildings.

Urban models are commonly prepared in Geographic Information Systems (GIS) due to a huge amount of stored data. These models contain information about the location and spatial position but not in the geometry rather than as attributes. In this study, we examined what advantages can be obtained using 3D BIM models. There are researches applying algorithms but those were focused on the efficiency of energy consumption and possibilities of better living area development (Natanian et al. 2019; Vartholomaios 2017).

Garden city of Pécs (Figure 1.) has been chosen for the study because we knew this area well and had a great amount of data available. Large-panel buildings of the garden city were modelled to develop methodologies. (The "large-panel building" nomination is used for this type of asset. German nomination is "Plattenbau" but some articles using "prefabricated buildings".)

_ Figure 1. Photo of the examined area of Pécs, Hungary

MATERIALS AND METHODS

The BIM model was produced in Autodesk Revit 2020 platform because it can manage huge areas, lots of model elements, and has an algorithm module. The manual modelling method was used for the buildings' geometry and location. Data can be found in Google maps or Open Street Map were inaccurate to adopt automated workflow for modelling. Information on these websites were handled to position the elements but with corrections. Extra data were added into model elements from a study of Pécs garden city (Sipos 2015) such as building type and year of built parameters. Table 1 presents an element type list which contains the elements that were built in the virtual space. The

number of elements is also shown in Table 1 to see how many geometries were utilized for the analysis. The examined area was about 6,8 km2 where all these model elements were placed.

_ Table 1: List of type and number of elements

| Large-panel buildings	Shops	Schools	Bus stops	Green areas	Playgrounds	Shopping malls	Restaurants
840	28	7	64	31	59	2	17

The main focus was on location analysis with the help of algorithms. There are studies about algorithm-based model examinations (Caetano and Leitão 2019; Feist et al. n.d.; Márk Máder et al. 2018) and solutions are connecting GIS and BIM models (Diakite and Zlatanova 2020; Wang et al. 2019; Zhang et al. 2020). However, algorithm-based BIM model analysis fields are not covered yet by the Architectural, Engineering, and Construction (AEC) industry.

Dynamo add-on was selected to carry out the analysis which enables application of logical connections for data examination. Due to the comparison of thousands element and accurate data requirement algorithms were necessary to be applied. Model elements were collated by the XYZ coordination of the center points which were calculated by the algorithms. In the case of larger areas such as green areas, all edges of virtual elements were examined in the calculation to find the closest points. Figure 2. presents the algorithm that was developed for the analysis. Different parts of the algorithm were used for different purposes as the colours highlight in Figure 2.
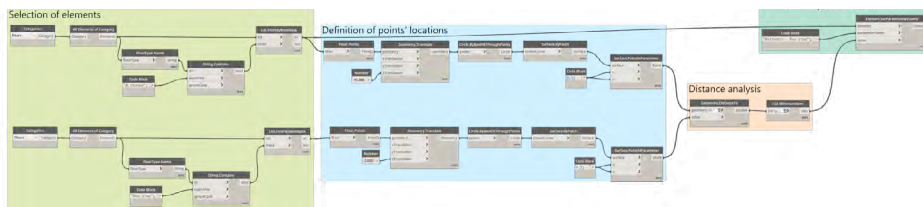
_ Figure 2. Screenshot of the developed algorithm from Autodesk Dynamo in the case of bus stops and 4 storey large-panel buildings analysis

"Selection of elements" group contained nodes for finding large-panel buildings (in this case "4 storey") and "bus stop" elements. As it is shown in Figure 2. the point location definition was difficult because of the floor type elements. These elements geometry could have more than four points and circles were used to define them center points. Distance calculations were made by coordinates. There were two parts of the algorithm (one part for the large-panel buildings and one for the bus stops) which were compared to each other in the "Distance analysis" group. The results were sorted by the buildings and only the minimum values of the list were added to specific parameters of model elements. This process was adopted for all criteria except for green areas.
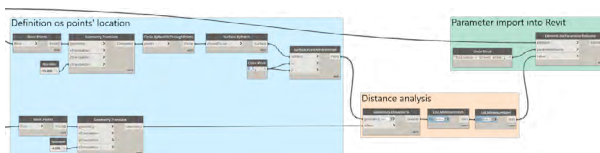
_ Figure 3. Screenshot of the developed algorithm from Autodesk Dynamo in the case of green areas and 4 storey large-panel buildings analysis

As it is shown in Figure 3. the algorithm was modified to compare the locations of every point of elements to find the smallest distance between them.

A quantitative survey was also developed to define the relation and importance of criteria that were used in the research. It was filled by 320 respondents on an online form. It contained questions about apartment purchase preferences. Table 2 represents the questions and answer possibilities of the survey.

_ Table 2: Quantitative survey questions and answer possibilities

Questions	Possibilities of answers
What is your age?	*Number*
Where do you live?	*"I live in Pécs", "I don't live in Pécs"*
When have you bought last an asset?	*Number*
What was the purpose of the purchase?	*"For investment", "For private purposes", "I didn't buy yet"*
How important is it for you? – The distance of shops from the chosen asset:	*Linear scale from 1 to 10*
How important is it for you? – The distance of education institutions from the chosen asset:	*Linear scale from 1 to 10*
How important is it for you? – The distance of bus stops from the chosen asset:	*Linear scale from 1 to 10*
How important is it for you? – The distance of green areas from the chosen asset:	*Linear scale from 1 to 10*
How important is it for you? – The distance of playgrounds from the chosen asset:	*Linear scale from 1 to 10*
How important is it for you? – The distance of shopping malls from the chosen asset:	*Linear scale from 1 to 10*
How important is it for you? – The distance of restaurants from the chosen asset:	*Linear scale from 1 to 10*
If you have any other additional preference please describe it:	*Text*

This survey was developed to find weightings for the relevant factors in the calculation of the location values. Evaluation of the survey was made to calculate average numbers for the importance of distances from the selected asset. Analytical Hierarchy Process (AHP) (Saaty 1987, 1988, 1990) was applied to compare the importance of criteria. During the process, a comparison matrix was established where the differentiation was made by the survey results. There was a study where AHP was used for GIS data comparison (Al-shabeeb 2016) but not for building location analysis.

RESULTS

As a result, the BIM model analysis was made by the examined processes in previous sections. Distance parameters were calculated for all large-panel buildings ("4 storey" and "10 storey") compared to every factor (Bus stop, Green area, Grocery store, Playground, Restaurant, School, Shopping mall). As figure 4. presents there were parameters made for distances in Revit and algorithms filled in the specific parameters according to the calculated results.
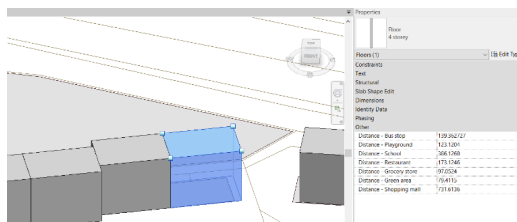
_ Figure 4. Screenshot of the parameters that were created in model elements in Autodesk Revit 2020

After completing the calculation of distances, the questionnaire results were examined to define the weighting of the factors. AHP was used to establish it by pairwise comparison matrixes. As AHP requires criteria weights were calculated by a normalization method as it is shown in Table 4. In the case of the AHP application, a review is needed to control calculations. Review steps: 1st determine the Weight sums vector (Ws): Ws=C*W; 2nd find the Consistency vector (C): C=Ws*1/W; 3rd determine the average (λ); 4th calculate the Consistency Index: CI=(λ-n)/(n-1), where "n" is the number of criteria; 5th determine the Random Index (RI) – in the case of seven criteria the value is 1,32; 8th determine the Consistency ratio (CR): CR=CI/RI (Saaty 1987). In this case, the calculated CR value was 0,0946 which is less than 0,1 and it means the consistency of the calculation was correct.

_ Table 4: Normalized Criteria Comparison Matrix [C]

Factors	Shop	School	Bus stop	Green area	Playground	Shopping mall	Restaurant	Criteria weights
Shop	0,103	0,103	0,176	0,034	0,159	0,171	0,176	**0,131802568**
School	0,103	0,103	0,176	0,034	0,159	0,171	0,176	**0,131802568**
Bus stop	0,205	0,205	0,352	0,688	0,212	0,214	0,206	**0,297565169**
Green area	0,513	0,513	0,088	0,172	0,372	0,3	0,235	**0,31323602**
Playground	0,034	0,034	0,088	0,025	0,053	0,086	0,088	**0,05827826**
Shopping mall	0,026	0,026	0,07	0,025	0,027	0,043	0,088	**0,043408578**
Restaurant	0,017	0,017	0,05	0,022	0,018	0,014	0,029	**0,023906839**

The use of criteria weights is presented in table 5. in the section of appendixes. There were ten buildings randomly selected which distance parameter values were generated by the algorithms. The list was made as a schedule in Revit but the following calculations were established in Microsoft Excel. In the "calculated v." raw the used distances reciprocal values were calculated because of higher distance means worst location. Inverse parameters were multiplied by the related criteria weight. (E.g. Anikó street 2. – Bus stop: (1 / 203.4705)*0,2976=0,0015). The normalized values were computed according to "Calculated v." data. In the results column, the normalized values were assumed and translated to percentage which resulted in relative location values for the selected assets. As an example due to this method, the building at Aidinger János street 8. had the highest rate (16,44%) and that means its location was the best of all selected large-panel buildings compared by criteria.

DISCUSSION AND CONCLUSION

The results are well organized and stored in Revit model elements. Those could be more accurate if the land characteristic can be taken into account but in Pécs Garden city the area was nearly horizontal and modelling process would not worth it. According to the questionnaire and algorithm-based calculation results, the parameter comparison is well supported. But the requirements can be more specific by costumers, therefore criteria weights and used factors can be changed in the case of other circumstances. In general, the factors used in this research are relevant and as the survey presents there were no more criteria suggestion to use by the respondents.

As a conclusion, BIM models were adaptable to establish location analysis in urban level. Automatic calculations and imports of values were supported by algorithms that reduced the time it takes to do. According to the study results the location values can be calculated and it provided relevant information for a comprehensive refurbishment project. The applied and developed methodologies can be used for analysis of other types of buildings or in the case of more specific criteria, too. This development can be profitable for real estate or property managers to have relevant information on the locations not only derived from the prices.

This study was the first step of a more comprehensive analysis. This research is going to be continued to determine data for refurbishment value in the case of Hungarian large-panel buildings according to the locations, conditions and renovation possibilities.

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APPENDIXES

_ Table 5. Calculation and final results of the comparison of ten randomly selected buildings

Street name	House number	Bus stop	Green area	Grocery store	Shopping mall	Playground	Restaurant	School	RESULTS
Criteria weights		*0,2976*	*0,3132*	*0,1318*	*0,0434*	*0,0583*	*0,0239*	*0,1318*	
Anikó 2.		203,4705	216,0000	89,0000	760,0000	124,0000	185,0000	74,0000	
Calculated v.		0,0015	0,0015	0,0015	0,0001	0,0005	0,0001	0,0018	
Normalized v.		0,0694	0,0454	0,1718	0,1156	0,0536	0,0955	0,2631	**11,64%**
Dóra 8.		126,7471	154,0000	159,0000	642,0000	54,0000	197,0000	177,0000	
Calculated v.		0,0023	0,0020	0,0008	0,0001	0,0011	0,0001	0,0007	
Normalized v.		0,1114	0,0637	0,0961	0,1368	0,1232	0,0897	0,1100	**10,44%**
Enyezd 24.		108,5934	100,0000	90,0000	1061,0000	128,0000	140,0000	350,0000	
Calculated v.		0,0027	0,0031	0,0015	0,0000	0,0005	0,0002	0,0004	
Normalized v.		0,1301	0,0981	0,1699	0,0828	0,0520	0,1263	0,0556	**10,21%**
Aidinger János 8.		130,6471	26,0000	102,0000	922,0000	24,0000	210,0000	332,0000	
Calculated v.		0,0023	0,0120	0,0013	0,0000	0,0024	0,0001	0,0004	
Normalized v.		0,1081	0,3774	0,1499	0,0953	0,2772	0,0842	0,0586	**16,44%**
Enyezd 13.		138,9428	131,0000	246,0000	1106,0000	25,0000	300,0000	438,0000	
Calculated v.		0,0021	0,0024	0,0005	0,0000	0,0023	0,0001	0,0003	
Normalized v.		0,1017	0,0749	0,0621	0,0794	0,2661	0,0589	0,0444	**9,82%**
Aidinger János 39.		170,5001	53,0000	158,0000	579,0000	143,0000	147,0000	411,0000	
Calculated v.		0,0017	0,0059	0,0008	0,0001	0,0004	0,0002	0,0003	
Normalized v.		0,0828	0,1851	0,0968	0,1517	0,0465	0,1202	0,0474	**10,44%**
Csikor Kálmán 31.		259,2919	679,0000	567,0000	907,0000	198,0000	252,0000	1216,0000	
Calculated v.		0,0011	0,0005	0,0002	0,0000	0,0003	0,0001	0,0001	
Normalized v.		0,0545	0,0145	0,0270	0,0969	0,0336	0,0701	0,0160	**4,46%**
Berek 7.		178,4722	173,0000	97,0000	867,0000	124,0000	62,0000	56,0000	

Calculated v.	0,0017	0,0018	0,0014	0,0001	0,0005	0,0004	0,0024	
Normalized v.	0,0791	0,0567	0,1576	0,1013	0,0536	0,2851	0,3477	**15,45%**
Csipke 3.	95,4689	229,0000	1087,0000	1403,0000	136,0000	937,0000	882,0000	
Calculated v.	0,0031	0,0014	0,0001	0,0000	0,0004	0,0000	0,0001	
Normalized v.	0,1480	0,0429	0,0141	0,0626	0,0489	0,0189	0,0221	**5,10%**
Boros István 1.	122,9586	238,0000	279,0000	1134,0000	147,0000	346,0000	555,0000	
Calculated v.	0,0024	0,0013	0,0005	0,0000	0,0004	0,0001	0,0002	
Normalized v.	0,1149	0,0412	0,0548	0,0775	0,0453	0,0511	0,0351	**6,00%**