Householders' Maintenance System for Former Rental Houses in the Historic Urban Structure of Budapest

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Abstract

The urban structure of historic districts of Budapest, Hungary can be described with the semi-intensive installation of rental houses. The building stock that determines the cityscape was largely constructed between 1890 and 1944. The economic and social environment of this era influenced the life cycle of these buildings. The war damage and the compulsory socialization that followed the war (and therefore the centralized maintenance protocol) were major factors in the degradation of their condition.

Due to the transition to democracy in the ‘90s changes have happened in the property structure of apartment building stocks. Nowadays, the maintenance of former rental houses causes serious problem for owner communities (inhabitants). The overall cause of decay of global consistence is complex and only a (not negligible) segment of this originates from economic factors. The lack of technical knowledge and the ignorance of the methods of Facility Management also influenced the state of the buildings adversely. In practice the interventions have been ad hoc, based on avoiding life-threatening failures.

Based on the statements above it is clearly evident that the former rental houses, which represent a dominant proportion of the building stock of the inner districts of Budapest are ‘heavily handicapped’. Due to their age these low quality buildings made of weak building constructions are in critical state; the applied maintenance protocol is insufficient (value added repair processes were done in small rate only).

The preservation of historical urban structure, the total commercial value of concerned apartments and the global national economy status also justify the sustainment of rental buildings, despite the fact that the individual architectural value of these buildings is low.

In this paper we propose a decision support tool that considers its user’s competency in Facility Management and the attributes of the former rental houses discussed above. This method may support the unprofessional owners’ communities in managing the renovation process of the given building.

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The construction of the evaluation method is based on the fuzzy signature rule base, where the needed information and data is obtained from former surveys and analyses.

The application of the method is represented on an overall analysis of the total building construction of a rental house built in 1912. Beyond the analysis of the results of the case study we recommend further developments for expanding the efficacy and availability of the method.

Keywords: historic rental house, evaluation method, Facility Management, fuzzy signatures, decision support

1. Introduction

In the frame of an overall survey of changing living conditions in Budapest, the rehabilitated urban areas were examined focusing on social, economic and environmental sustainability. In the near past, two major urban rehabilitation projects were (almost) accomplished in the interior districts: one in the Mid-Francis' Town (district N° 9) and another in Joseph's Town (district N° 8). At present time, the building stock built before the WWII in eight blocks of Mid-Francis' Town are being studied.

Among the 88 houses located in this area, 41 apartment houses were built before 1944; 24 buildings were totally rehabilitated with the organization and financial support of the Local Government before the privatization of apartments. The rest (17 buildings / 320 apartments) were sold without important repairs – a previously accomplished visual diagnostic survey considered them as houses in good physical condition. As a matter of fact, these buildings also have several defects, and an overall comparison with the other historic buildings in the examined area visibly shows that these buildings and their owners are the losers of the urban rehabilitation.

The ownership communities of these houses are now in an uncertain situation: they have to manage their maintenance without any strategy and little financial background.

In the present article a proposal for a decision-support tool is outlined that is based on a collection of technical information of the involved buildings. The attributes of buildings can be arranged in a predefined structure, where all information on the buildings can be evaluated systematically. Without any detailed explanation it is obvious that the goal (decision-support tool) and the circumstances (classified data structure, involvement of experts) strongly recommend the application of an expert system. Issuing from the character of data on hand and the observation methods applied, the expert system may well be based on fuzzy set theory, especially on the approach of fuzzy signatures that is an effective tool for describing and characterizing objects with multiple and vague uncertain attributes.

2. The Examined Type of Apartment Houses

2.1 History of Rental Houses from the End of 19th Century in Hungary to the present time

The golden age of Budapest took place between 1870 and 1920. During these fifty years the urban structure of inner districts was developed; the closure of streets almost obtained their present state. The main characteristic architectural element that represents Budapest's golden age is the rental house-type apartment building. There are several different rental houses by the quality, the style, the owner, the inhabitants' social status, the location, etc. This together reflects well the mood of the nineteenth century-fashioned downtown of Budapest. Another urbanization progress happened after 1928 that ended in 1942; the social rental houses that were built in this period represent the so-called modern attitude to life.

The socialization of building stock extended to the rental houses of historic districts of Budapest; this procedure took ten years only after the Second World War. Since these houses symbolized the middle class of an ancient regime, the political leadership took more effort in developing new quarters then maintaining existing former rental houses. A state-owned company maintained the flat stock with low efficacy. The result: old and untouched rental houses were in bad condition at the end of socialist era.

After the transition to democracy (1989) the obligatory maintenance task in the housing sector was the task on the new political leadership Since there was not any economically powerful customer, the state sold the apartments to their tenant for an artificial low price (regulated by the housing laws, 1991; 1994). In ten years the ownership system has changed totally: before the privatization the state owned more than 50% of total apartment stock, in 2001 only 8,6% of apartments were in the hand of the state.

2.2 Actual Status of Former Rental Houses in Historic Urban Structure

After analysing the available nationwide statistic survey it is ascertainable that a significant number of existing apartment houses were built before the WWII (see ***Error! Reference source not found.***). This percentage becomes higher when the analysis focuses on the historic districts of towns. In the examined area 57,5% of apartments is located in buildings more than seventy years old.

Table 1: The distribution of flat stock by building period by Aczél G and Gutai B (2006)

	district N°9	Mid-Francis Town	Rehabilitated Area	Nationwide
before 1919	15 351	6 862	1 238	484 677
1919-1944	5 285	1 120	394	442 403
1945-1959	630	205	2	424 950
1960-1969	7 764	246	2	550 944
1970-1979	1 242	62	0	861 271
1980-1989	1 206	699	10	685 518
1990-2001	1 575	1 359	1 190	273 279
Total	33 053	10 553	2 836	3 723 042
before 1944	**20 636**	**7 982**	**1 632**	**927 080**
	62,43%	*75,64%*	*57,55%*	*24,90%*

The Act of Freehold Flats (2003) regulates the law regarding discussed apartment houses. Among other instructions it also determines the organization structure of the living community and the owners' responsibility in maintenance procedure. The annual meeting of house tenants makes decision about the maintenance processes; the process is managed by the community's freely elected joint representative.

Twenty years after a transition to the market-based sector in the housing market the financial consolidation of rental houses has not yet finished. The experienced migration process resulted in the appearance of new inhabitants in the historic districts of Budapest and the available capital of the owners' community is still insufficient for supporting total renovation procedures.

Beside the unfavourable financial situation and the interdependence of the owners, the lack of knowledge and experience in building maintenance on the part of joint representatives also hinders the technical consolidation of former rental houses. However, Local Governments give limited financial aid for houses improving their condition; this support may be effective with well-organized reconstruction plans.

In major cases the society of owners is able to repair only the most dangerous damage that originates from obsolescence process. The required interventions override every previously determined schedule; therefore the inhabitants may feel that the physical condition of their house remains unchanged year after year.

3. Attributes of the Examined Rental House

In the examination area a representative building was chosen from the seventeen rental houses involved. In this five-storey building (built in 1912, the copy of original blueprint is presented in ***Error! Reference source not found.***) there are 52 apartments at several sizes and lived in by residents with different social status. Considering the shape, the materials and the decorations applied, this building can be classified as an historic rental house. The ownership community (52 owners) has a small bank savings that grows slowly year by year and is reserved for renovation and repairs.

Figure 1: Site plan, section and elevation of the examined building (1912, source Budapest Archives)

After a joint representative election an overall visual diagnostic survey was done by an independent professional team in 2012. The survey report describes the observations of professionals - statics, constructional, mechanical and electric - divisions. The statements of this report represent an average former rental house of the historic areas of Budapest with typical failures. The report summarizes the problems that have to be solved, without proposing any action plan or giving a priority list of interventions.

With the information obtained by diagnostic surveys the owners' community aimed to develop a maintenance action plan. Although a well-constructed Facility Management application can help scheduling the repair tasks, the available FM software is overpriced for such building size.

The building failures and their repairs can be ordered in several ways. The main aspects for the comparison are the dangerousness and the repair costs; but there are other important factors that have to be taken into consideration (the interrelation of building failures, possible Local Government financial supports, comfort and aesthetic demands of inhabitants, etc.). Many of these aspects cannot be measured or there is no data that can be evaluated. In addition, the number of total collected factors that cannot be handled with a simple decision-support tool is twelve.

Without any detailed description of the experienced failures, the report emphasizes more than twenty significant building failures that have to be repaired. The evaluation of the failures by all factors with a traditional method would take long and would be inefficient.

4. The Fuzzy Signature-based Expert System

4.1 Application of Fuzzy Signatures

In the case of the planned decision support tool the generalization of fuzzy sets first introduced by Zadeh's proposal (1965) has to be mentioned; Zadeh's early student, Goguen (1967) proposed the concept of L-fuzzy sets. Vector-valued fuzzy sets are introduced by Kóczy (1980). Vector valued fuzzy sets assign to each element of X a set of quantitative features rather than a single degree – this way providing additional information about the specific element.

Fuzzy signatures (Kóczy et al, 1999) are generalized vector valued fuzzy sets, where each vector component is possibly another nested vector. This generalization can be continued recursively to any finite depth, thus forming a signature with depth *m*.

The structure of fuzzy signatures can be represented both in vector form and also as a tree graph (

Figure 2 represents both the vector form and the tree graph of the proposed structure).

Fuzzy signatures can be considered as special, multidimensional constructions that are applicable for storing structured fuzzy data. In this structure the dimensions are interrelated in that a sub-group of variables determines a character on a higher level. Therefore, complex and interdependent data components can be described and evaluated in a compact way.

In many applications, the observation of experts can be described in different ways, even the structure of observation can be different; nevertheless decisions have to be taken based on these data. With the assistance of signatures these alterations in structures can be handled. The main advantage of the application of fuzzy signatures is that they can handle situations with uneven data structures and information.

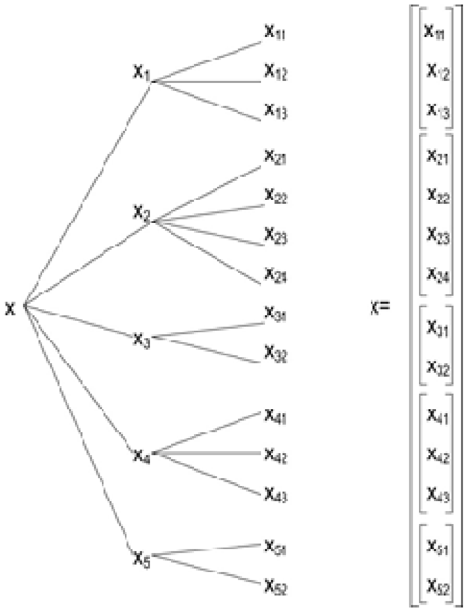

Figure 2: Tree structure and vector form of fuzzy signature

Furthermore, the model created for the given task can be arranged hierarchically (Wong et al, 2003); this feature is very similar to the way of thinking of human experts. This fact underlines the argument that fuzzy signatures are deployable in the area of decision making.

The advantage of fuzzy signatures is that they organize the available data components into hierarchical structures. This hierarchy determines the basic structure of fuzzy signature-based observations. It may occur that some elements are missing at several observations. Therefore, it is necessary to have a kind of structure modifying operator for comparing signatures with quite different structures. It is advisable to apply aggregation operators for reducing sub-trees to their parent node. In the case of a multileveled hierarchy, a recursive process leads to the aggregated value of the parent node being generated.

In our case, the most important question was definition of the aggregation operators. The structure of the fuzzy signature supports the use of different aggregation operators for each node.

5. Proposal: Application of Fuzzy Signature-based System in Building Maintenance Protocol

As described in *Section 3*, it is difficult to rank the necessary interventions if every aspect is kept in mind. This fact ends to decisions in the maintenance process, being based on professionally incomplete information.

In the following a formal system will be proposed that may support the decisions of owner communities in the maintenance procedure. The proposed tool offers an effective solution for applying the experts' knowledge in responsible decision making. This system is based on fuzzy signatures described in *Section 4*.

The application of fuzzy set theory was proposed in bridge maintenance systems recently (Szaradics, 2007). As Agárdy implies (2008), soft computing techniques may help differentiating sets of objects of built environment by several aspects. As a decision support tool the fuzzy expert system was also proposed for determining the ranking of intervention in case of building failures (Molnárka, 2010).

The circumstances determining of intervention ranking discussed above are quite different from the core problem being considered here. The methods of the assessments that were implied in the mentioned papers are applicable for examining the physical condition of the buildings and their elements without considering the financial, energetics and other non-professional context in their place. The aim of the present paper is to obtain a comprehensive and comparable data set for each needed maintenance action; therefore it was not possible to narrow the aspects to the physical and measurable conditions without losing important information.

This intent has resulted in a large scale set of examination aspects that is difficult to handle without any classification abilities. This also explains why the adaptation of hierarchical system of fuzzy signature makes the support tool effective.

5.1 The model

As the first step, the basic structure of the fuzzy signature is developed from the available data and the experts' knowledge; then the adequate fuzzy sets of data elements must be determined. The next step is the identification of fuzzy signature based rules applying the experts' knowledge and the available input-output pairs. When the rule base is ready, the fuzzy signature based observation can be directly evaluated, thus generating a suggested decision.

Let us overview the concrete structure of the fuzzy signature suitable for representing the set of attributes and their respective relations used in the maintenance order evaluation approach.

In the context of this study the accessible information on a building failure may be arranged in three main groups, which constitute the first level of the fuzzy signature structure (nodes x_1; x_2 and x_3).

For aggregating sub-trees within the fuzzy signatures the WRAO operator (Weighted Relevance Aggregation Operator, introduced by Mendis et al. (2006) was applied. With the application of weighted aggregations more expert knowledge can be involved in the examination. Via this operator the owners' community may also articulate its intention in the decision making without decreasing the weight of technical and financial factors. The initiated relevance weight determines the relevancy of a child node on a higher level. For determining the relevance weights by observation Mendis et al. (2006) propose a method that is applied in the current evaluation; in addition, questionnaires of experts of several professional fields (architects, urban sociologists, diagnostics) were taken into account.

For describing different components of the structure linguistic variables may be applied. The next step is to define these linguistic variables and their membership functions.

The global evaluation and range determination of maintenance process is a complex task. As mentioned above a large number of factors have to be considered when a failure and its repair are evaluated. The goal of the discussed study was to obtain a comprehensive character of each intervention. Therefore, the parent nodes in the fuzzy signature structure are the three basic factors of the decision making in the given situation: importance of intervention; financial aspects and subjective components.

In the following, the parent and child nodes are described in groups: their relevance weights are denoted with *w*. For the proper application of fuzzy set signatures it has to be confirmed that at the leaves, membership functions shall be applied over the [0,1] interval: for this reason the basic sets of the determined attributes have to be normalized to [0,1]. The closer the value of observation is to 1 the better is the quality in each respect.

At the nodes and at the leaves of the fuzzy signature structure partitions of triangular or trapezoidal sets are applied forming Ruspini partitions. Accordingly to this, the aggregate of function parameter of sets is 1 for every elements of basic set.

The results of the building diagnostic report are represented with the *Importance of Intervention* (x_1; $w_1=0.8$) input variable in the parent node; its leaves describe the different attributes of the subjected failure (dangerousness, interdependence, etc). The assessments are evaluated and encoded with the assistance of a knowledge base of building diagnostic expert system.

The financial calculations that are only estimated data in the present state are based on available statistic data base of building industry. These calculations are supplemented with additional information of the possibility of Local Government Support and the analysis of financial perspective of the owners' community. In addition, the possible value improvement of the subjected building was also examined with a separated variable. *The Financial Aspects* (x_2; $w_2=0.6$) input variable as a parent node synthetizes these data. However while some information consist of numerical values, several data can be described with linguistic variables only.

After presenting the results of the diagnostic survey an opinion poll was taken in the owners' community about their preferences. In this survey the owners had to rank the experienced failures subjectively. With this survey the most bothering failures were compared to each other from the users' point of view. The *Subjective Factors* (x_3; w_3=0.3) input variable gives an extra aspect that cannot be evaluated with classic methods.

It is clearly visible that the data structure is mainly vague; therefore the application of fuzzy logic is reasonable. *Table 2* represents the input variables in hierarchy with remarks about data sources.

Table 2: Classified and weighted input variables and data source

First level (parent nodes)	**Leaves (child nodes)**	**Data source**
Importance of Intervention x_1; w_1=0.8	danger x_{11}; w_{11}=0.8 interdependence with other failure x_{12}; w_{12}=0.7 protection of other construction x_{13}; w_{13}=0.5 energetic performance x_{14}; w_{14}=0.3 accessibility x_{15}; w_{15}=0.2 hygienic, aesthetic aspect x_{16}; w_{16}=0.1	diagnostic report database built on former building diagnostic analyses technical literature
Financial aspects x_2; w_2=0.6	estimated cost x_{21}; w_{21}=0.9 Local Government support x_{22}; w_{22}=0.7 schedulable expenses x_{23}; w_{23}=0.4 value improvement effects x_{24}; w_{24}=0.3	quotation of contractors Local Government regulations estimations based on experiences
Subjective factors x_3; w_3=0.3	non-professional priority x_{31}; w_{31}=0.8 visibility x_{32}; w_{32}=0.5	data mining from a questionnaire

The *Figure 3* represents the child nodes of the *Financial Aspects* variable. This figure summarizes the aggregation procedures and other consecutive steps of calculation.

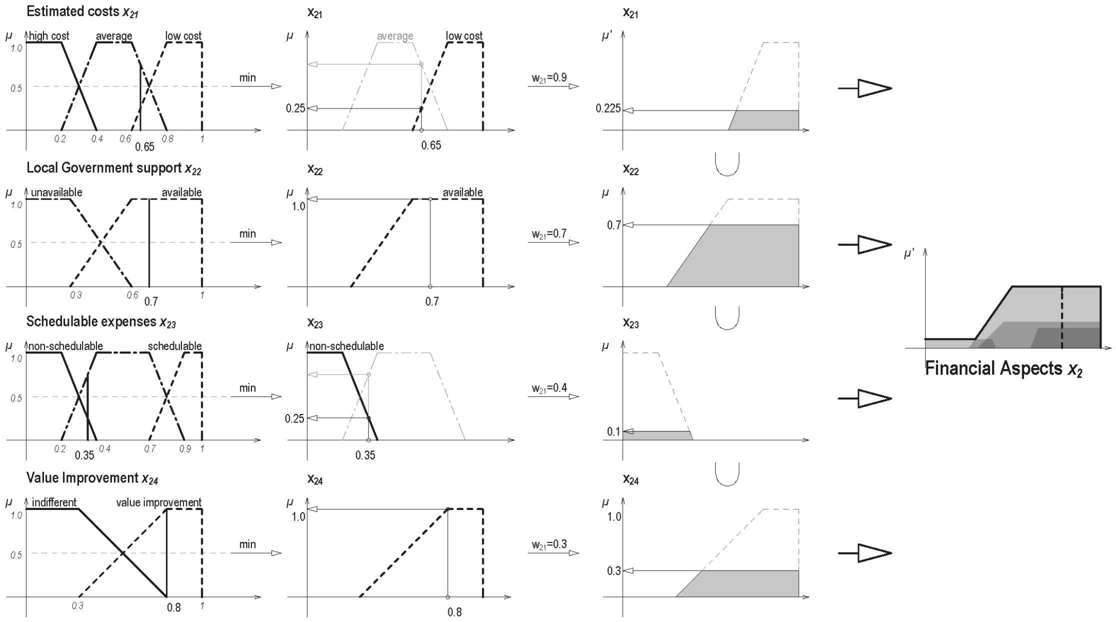

Figure 3: The membership functions of 'financial aspects' (x_2)

5.2 The Rule Base

At the first level the number of available input variables is three. Their partitions (6;4;2 partitions) result in the total number of rules in the rule base being 48. At the level of child nodes a different (much higher) number of rules can be identified from the partitions of input variables. The detailed description of these input variables and their partitions can be found above. The hierarchical structure of the signatures necessitates dealing with a rule base of very high complexity.

5.3 Inference Method

Basing on Mamdani-type inference (introduced by Mamdani and Assilian, 1975), Tamás (2007) introduced the generalized method that operates on signature based rule bases. In this method the alteration is only in the first step, where the degree of matching between observation and the rule antecedents is determined.

In the discussed procedure this method is applied, where the minimum conjunction is taken as the aggregation operator for reducing the signature structure.

6. Results

The examined buildings were evaluated with the method discussed above. The partial results are collected in the *Table 3*. The experienced failures are denoted by keywords, the detailed diagnostic report gives further explanations.

Table 3: Evaluation of construction failures (section, rounded-off values)

			inter-floor slab control	side corridor sealing	court slope ratio	moisture in firewall	basement ventilation	footings	cracked stairs	cat-walk elements	shifted chimney-tops	roof structure	tiling & accessories	firewall edges tinning	finishing & insulation	side corridor drip edge
Importance of Intervention	danger	x_{11}	0.92	0.62	0.49	0.7	0.65	0.34	0.45	0.42	0.95	0.78	0.15	0.1	0.1	0.45
	interdependence	x_{12}	0.65	0.35	0.22	0.68	0.77	0.85	0.05	0.05	0.05	0.76	0.89	0.75	0.18	0.85
	protection role	x_{13}	0.76	0.86	0.66	0.25	0.62	0.88	0.05	0.65	0.15	0.95	0.99	0.96	0.86	0.95
	energetic performance	x_{14}	0.11	0.05	0.05	0.86	0.77	0.78	0.02	0.02	0.05	0.66	0.15	0.15	0.99	0.05
	accessibility	x_{15}	0.21	0.95	0.95	0.16	0.98	0.22	0.9	0.67	0.35	0.55	0.28	0.68	0.86	0.95
	hygienic& aesthetic aspects	x_{16}	0.16	0.8	0.65	0.9	0.84	0.77	0.63	0.3	0.95	0.2	0.19	0.05	0.95	0.78
		x_1	*0.82*	*0.55*	*0.51*	*0.69*	*0.68*	*0.62*	*0.54*	*0.46*	*0.8*	*0.65*	*0.5*	*0.5*	*0.5*	*0.52*
Financial Aspects	estimated cost	x_{21}	0.84	0.38	0.27	0.54	0.1	0.86	0.27	0.14	0.64	0.78	0.65	0.24	0.89	0.26
	Local Government support	x_{22}	0.1	0.09	0.64	0.36	0.06	0.4	0.35	0.38	0.82	0.59	0.46	0.37	0.85	0.38
	schedulable expenses	x_{23}	0.93	0.93	0.96	0.15	0.08	0.23	0.11	0.26	0.16	0.25	0.8	0.85	0.85	0.73
	value improvement effects	x_{24}	0.74	0.64	0.55	0.72	0.19	0.77	0.63	0.58	0.72	0.78	0.68	0.54	0.9	0.66
		x_2	*0.77*	*0.53*	*0.43*	*0.41*	*0.15*	*0.55*	*0.37*	*0.37*	*0.52*	*0.57*	*0.52*	*0.42*	*0.71*	*0.42*
Subjective Factors	owners' priority	x_{31}	0.16	0.28	0.15	0.1	0.28	0.34	0.21	0.38	0.77	0.57	0.48	0.16	0.76	0.28
	visibility	x_{32}	0.26	0.31	0.44	0.09	0.23	0.42	0.74	0.69	0.94	0.74	0.78	0.87	0.87	0.76
		x_3	*0.13*	*0.13*	*0.12*	*0.12*	*0.13*	*0.13*	*0.19*	*0.13*	*0.64*	*0.19*	*0.25*	*0.37*	*0.59*	*0.23*
	weighted result		***0.38***	***0.27***	***0.23***	***0.28***	***0.22***	***0.29***	***0.24***	***0.21***	***0.38***	***0.31***	***0.26***	***0.25***	***0.33***	***0.24***

As a result, the current study discloses the range of listed repairs (the defuzzification step is omissible in this case).

Whilst the discussed project was in process, the owners' community had the damaged chimney repaired, since an extra support was available from the Local Government. Our assessment also justifies this intervention; therefore it may prove the community's view correct.

In a further evaluation of the study was provided to the owners' community and their joint representative. After a short discussion at the annual meeting of the community, the list was accepted and a schedule of overall maintenance procedure was ordered based on this analysis.

The results of analysis underline the importance of the façade insulation procedure. However this statement surprised the community, the priority of this intervention is justifiable: the court and street façade insulation and finishing can be executed independently from other failures, and gives saving options in heating expenses – the extra savings may help in organizing faster and better maintenance procedure.

7. Conclusions and Future Work

In summary it can be stated that that the results of calculations correlate to the former assumptions. The utilization of linguistic variables supported the evaluation of non-measurable (e.g. 'aesthetic') and uncertain (e.g. 'value improvement') values. The application of weighted relevance aggregators in the reducing phase also maintained the professional aspects of the evaluation. The unique hierarchical construction of fuzzy signature structure enhanced the adequacy of the overall evaluation.

The complexity of the building (different structural and sub-structural components, spatial object with complicated relation to the users and the surroundings, etc.) required more complex analyses. That is why it is necessary to increase the number of attributes and to create more precise linguistic variables. To avoid the confusion in the system, in the process of the enlarging structure, it is advisable to create further sub-trees (sub-sub-trees).

The developed decision support tool may take the intermittently determined aspects of the owners' community. Therefore the application of controllable relevance weight on the parent nodes has to be examined.

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