A Precise Computer Model for Real Estate Assessment

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Abstract. Real Estate Assessment –or Appraisal– is mainly employed in government for taxation purposes. There are a number of methodologies to assess the value of a property so as to calculate taxes or just its value. Normally, several attributes belonging to the property are used for this purpose, and one of the most simple method employed it is the additive method. Among the attributes used, it can be found the plot area, the area of the buildings, the improvements on the property, the intended use (e.g. production, habitation, etc.), geographical location, etc. This assessment can be used as a percentage, index, proportion, etc. to levy the taxes. There are different kinds of property tax, e.g. ad valorem, special tax, etc. We propose here the use of a general method that can be used with any of these. This method –the Logic Score of Preference (LSP) method– provides a way to aggregate different attributes of a property into a single value using a Continuous Logic. The resulting index can then be used to calculate the final value of the tax. The method is flexible and it allows a wide range of possibilities as well as a fine gradation of the value of different properties; it also allows to contemplate the varied conditions and attributes of properties to make a more precise assessment.

Keywords: Real Estate. Real Estate Assessment. Property taxation. Continuous Logic. Logic Score of Preferences. LSP Method.

1 Introduction

When assessing the value of a property for different purposes –e.g.. taxation, valuation for selling or buying, etc.– several attributes of the property are considered. The actual value of these attributes must be aggregated to obtain a final value. Different criteria can be used to achieve this aggregation. The most common is a simple addition of the different values that are attributed to each category; sometimes the different values assigned to each property's attribute are weighted to reflect the relative importance that each attribute is considered to have.

One method that is often used is the market value of the property. In this method, the resulting value supposedly reflects the true value of the property, considering all the different aspects or improvements of the property –i.e. services, location, buildings, neighbourhood, etc. However, the 'market value' is just that: the estimated price that somebody would pay for it. This may sometimes match with the real value; however, this price is subject to market forces. Appraisal then could be the price that a property may reach in a particular market or it may depend on the different characteristics that the property has, i.e. services, area, buildings, etc.

Bearing the above in mind, we present in this work a model that aggregates a number of characteristics or items of a property for taxation and general evaluation purposes. These items are those normally employed to produce an assessment of a property; however, there is no universal prescription for the selection of them or their aggregation. Therefore, there exists the need to propose a unified model to obtain a single value out the evaluation of the considered property's characteristics.

Using these data obtained from the assessment of different property's characteristics, we aggregate them in coherent groupings to get new indicators that can in turn be aggregated again. The aggregation process ends getting a single global indicator or index for the property under evaluation. The aggregation of different characteristics to obtain a single value helps in the global evaluation of a given property. This single value can be used as an index for taxation or other valuation purposes.

To achieve this process we use operators from a Continuous Logic, specifically the Logic employed by the LSP method [5],[6],[7],[8],[9],[10] that proposes the aggregation of preferences by using a set of logic functions called Generalized Conjunction Disjunction (GCD) operators.

The rest of the article is organized as follows. In Section 2, we give an overview of both some recommendations for property assessment and the LSP method. In Section 3, we describe our proposal and illustrate it with some examples. A discussion on the approach, conclusions and future directions for research are given in Section 4.

2 Property Assessment Recommendations and the LSP Method

There are several standards or recommendations for assessment and appraisals. Most of them are guidelines for the assessment of property values and not necessarily for taxation purposes but for other objectives such as financial, mortgages, etc. However, they can be used as well for taxation purposes. To develop our model for the evaluation of properties we have taken into consideration different standards and recommendations at the same time that we have used the Continuous Logic operators of the Logic Score of Preference (LSP) method to aggregate the characteristics proposed in the above-mentioned recommendations and obtain a single indicator. Subsections 2.1 and 2.2 give an overview of both.

2.1 Property Assessment Recommendations

Several countries and assessment organizations –especially in those countries generally called developed, where the market is relatively stable– mainly employ as a valuation technique the fair market value of the property on a specific date. The “fair market value” is generally defined as the price a willing and informed purchaser would pay to an unrelated willing and informed seller, where neither party is under compulsion to buy or sell. Generally, the market value of the property has a date limit, e.g. one year, if a certain period is exceeded then other methods are used, e.g. cost, price of a comparable recently bought property, etc.

This method is used particularly when assessing for taxation purposes, where an assessment ratio or a tax ratio or both are applied to the market value. For example, in the United States, forty states define as standard the price paid for the property and describe the type of transaction that produces an appropriate price, while eleven define other methods of assessment, and define their standard as the value these methods produce [11].

Several organizations have standards or guides so an appraiser has guidance on how to produce a fair appraisal. Such guides are for example [12], [13], [2], [3], [4]. Some of these give a detailed list of characteristics to be taken into consideration when doing a property evaluation.

2.2 The Logic Score of Preference Method

The LSP (Logic Score of Preference) method [5],[6],[7],[8],[9],[10] is a method for the creation and use in the evaluation, optimization, index building, comparison, and selection of all kinds of complex systems and not necessarily those based on computers.

This method allows building models composed of aggregation structures, that are based in the combined used of different GCD (Generalized Conjunction Disjunction) operators of a Continuous Logic provided by the method itself. An overview of the LSP method showing its different components and process is depicted in Figure 1.

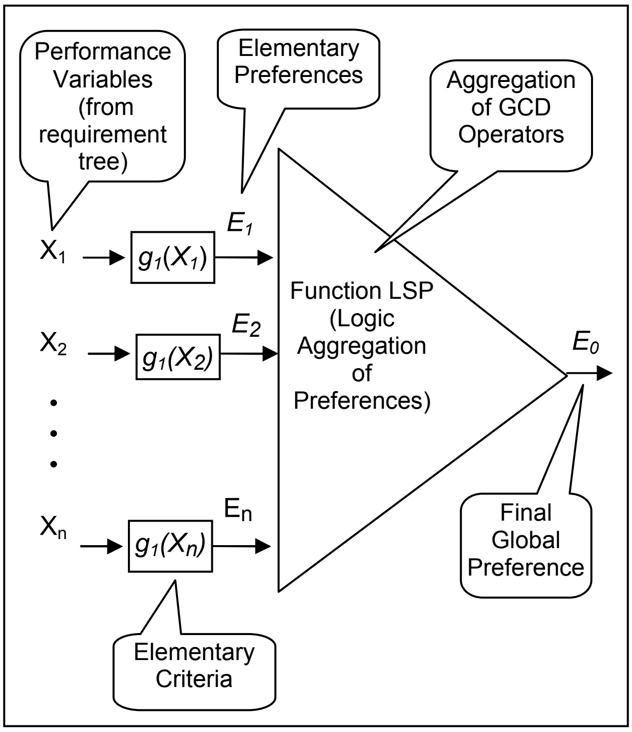

Figure 1. An overview of the LSP method evaluation process.

The method proposes:

(a) The creation of a model of the user's requirements that is called the *Preference Tree*. On this tree, the *Performance Variables* –that are the main attributes of the system– and their corresponding values are determined. Here the user's requirements are elicited so as to be incorporated into the Preference Tree.

(b) The definition of functions called *Elementary Criteria*. An Elementary Criterion transforms values from the domain of values a Performance Variable can take into values in the

[0,100] interval. These values represent the percentage of compliance of the corresponding requirement and are referred as *Elementary Preferences*.

(c) The creation of an *Aggregation Structure*. The inputs to this structure are the Elementary Preferences obtained from the application of the defined Elementary Criteria to the Performance Variables. This model is built by aggregating, in as many levels as is deemed necessary, the Elementary Preferences and the intermediate resulting preferences by means of Continuous Logic functions called Generalized Conjunction Disjunction (GCD) operators [10]. The aggregation in intermediate levels gives partial results corresponding to groups of requirements. The complete final model of the Aggregation Structure, also called the LSP criterion function, returns a unique value that is an indicator of the degree of compliance with respect to all the requirements of the system.

Therefore, if we want to aggregate n elementary preferences $E_1,...,E_n$ in a single preference E, the resulting preference E –interpreted as the degree of satisfaction of the n requirements– must be expressed as a function having the following properties:

1. The relative importance of each elementary preference E_i (i = 1...n) can be expressed by a weight W_i,
2. $min(E_1,...,E_n) \leq E \leq max(E_1,..., E_n)$.

These properties can be achieved using a family of functions (the weighted power means):

$$E(r) = (W_1 E_1^r + W_2 E_2^r + ... + W_n E_n^r)^{1/r} \text{, where}$$

$$0 < W_i < 100,\ 0 \leq E_i \leq 100,\ i = 1, \dots, n,\ W_1 + ... + W_n = 1,\ -\infty \leq r \leq +\infty$$

The choice of r determines the location of $E(r)$ between the minimum value $E_{min}=min(E_1,...,E_n)$ and the maximum value $E_{max}=max(E_1,...,E_n)$, giving place to a Continuous Logic Preference (CPL). For $r = -\infty$ the weighted power mean reduces to the pure conjunction (the minimum function) and for $r = +\infty$ to the pure disjunction (the maximum function). The range between pure conjunction and pure disjunction is usually covered by a sequence of equidistantly located CPL operators (also referred as GCD operators) named: C, C++, C+, C+–, CA, C–+, C–, C– –, A, D– –, D–, D–+, DA, D+–, D+, D++, D.

Once the Aggregation Structure has been calibrated, using the different GCD operators and the corresponding weights, then every property under analysis can be evaluated and a single indicator for each can be obtained.

In our case, we obtain –from all the characteristics assigned to a property– a single aggregated value between 0 and 100. This value can be used as an index to calculate the value of a property serving as well as a means of comparison between different properties. We show how the index can be used in Section 3.

3 The Aggregated Index for Property Assessment

Using the LSP method allows to express different aspects of the assessment that other purely additive techniques do not permit. LSP allows the creation of models that are more close to the users' needs, whether those users are assessment agents, states or any other stakeholder interested in obtaining a property valuation.

Property evaluation is a task undertaken by different stakeholders, being them private or state or local governments, etc. These stakeholders may want to evaluate a property for different reasons, e.g. a bank as a warranty for a loan, or a mortgage or a state government for taxation purposes, or a real estate agent for buying or selling a property.

In most cases the property assessment models, when they exist as a computational system, are based on its market value or on the simple weighted addition of different characteristics of the property. On the contrary, the LSP method permits the creation of complex functions and its application, not only for the evaluation and comparisons of different systems but also for the creation of indexes that can be applied to a variety of purposes and easily adapted to the needs of the users, as we do in this work.

In this section, we show how to obtain –using the LSP method– an index that is the result of aggregating different characteristics of a property under evaluation and how that index can be used for taxation purposes. The aggregated index is a unique value in the interval [0..100] and it can be used to determine the final value of the property or the tax that the property owner should pay.

To build our assessment model, in the first place it was necessary to identify clearly the main parameters or property characteristics to be taken into consideration for the valuation. As we explained in Section 2, the LSP method starts by building a Requirement Tree –a structure that holds all the user's requirements. In this particular case, we started building our Requirement Tree for a urban property, which is partially shown in Table 1, by identifying the main characteristics and sub characteristics obtained from different recommendations and standards. In a stepwise fashion, we decomposed the first level characteristics into sub characteristics. This decomposition process went on until the characteristics could not be further decomposed. These atomic characteristics –the leaves of the resulting requirement tree– are referred as *performance variables*.

Table 1. Partial Requirement Tree (Urban)

1. Urban
1.1. Market Value
1.1.1. Sales comparison
1.1.2. Cost
1.1.3. Future income
1.1.4. Location
1.1.4.1. Neighbourhood
1.1.4.2. Location in the neighbourhood
1.1.4.3. Proximity to schools
1.1.4.4. Proximity to hospitals
1.1.4.5. Proximity to shops
1.2. Plot area
1.3. Services
1.3.1. Water
1.3.2. Drains
1.3.3. Electricity
1.3.4. Gas
1.3.5. Internet
1.3.6. Cable television
1.3.7. Garbage collection frequency
1.4. Use
1.4.1. Habitation
1.4.2. Commerce
1.4.3. Industry
1.5. Building
1.5.1. Total built area
1.5.2. Construction type
1.5.2.1. Roof
1.5.2.2. Walls
1.5.2.3. Floors
1.5.3. Building type
1.5.3.1. House
1.5.3.2. Apartment building
1.5.3.3. Warehouse
1.5.3.4. Factory
1.5.3.5. Commerce
1.5.3.6. Office
1.5.3.7. Office building

Let us note that each of the characteristics of a property (i.e. market value, plot area, services, use, building, etc.) gives a different point of view on the valuation of the property, returning different results in the valuation space according with the evaluation model. Using the requirement tree means the user should assign, for each property, the values for the performance variables, e.g. 1.5.1. 'Total built area'; 1.5.2.1. 'Roof'; 1.5.2.2. 'Walls'; 1.5.2.3. 'Floors'. Performance variables correspond to observed values from the property under valuation, while the other items in the tree correspond to groups of sub items. In this example, the last three performance variables have been grouped under the item 1.5.2. 'Construction type', and both 1.5.1. 'Total built area' and 1.5.2. 'Construction type' have been grouped under 1.5. 'Building'. This example illustrates one possible set of items and grouping; different items, groupings and levels in the tree could be chosen configuring different models under the user discretion.

In Table 2 we show another example of a requirement tree. This is a partial requirement tree built by considering the characteristics given by TEGoVA [12] for residential properties under the Criteria Class 3, 'Property'; the percentages given are equivalent to the weights used in LSP models. TEGoVA rates each item in each class using the values in the interval [1, 10].

Table 2. "3. Criteria Class 'Property' – Residential"

	Weighting	
Sub-criteria	**Sub-criterion**	**Criteria class**
3.1 Architecture / type of construction	20%	Criteria class 3 20%
3.2 Fitout	10%	
3.3 Structural condition	15%	
3.4 Plot situation	25%	
3.5 Ecological sustainability	10%	
3.6 Profitability of the building concept	20%	
RESULT FOR THE PROPERTY RATING	100%	

Once we finished our requirement tree, we defined clearly each *elementary criterion* to be used during the assessment process. As we explained in Section 2, the data obtained from the instantiation of the performance variables must be mapped to values in the interval [0,100] called *elementary preferences*, and then aggregated by the GCD operators to obtain the final global preference E_0, as we have shown in Figure 1.

Therefore, as many elementary criteria as performance variables the requirement tree must be defined to get the corresponding elementary preferences. The resulting value of an elementary criterion – an elementary preference– represents the degree of compliance of the corresponding property requisite.

To illustrate the point let us suppose that a single value has been obtained from the evaluation of each leave in the tree. In general, these values can be of different data types: real, integer, nominal or categorical (e.g. bad, poor, fair, good, excellent), etc. So, for example, if we consider the requisite 'total built area' of the property (performance variable 1.5.1. in the requirement tree of Table 1), the area value must be transformed, using the corresponding elementary criterion, into a value in the interval [0,100]. The relation between the area and the interval is established by the choice made by the model builders of the elementary criterion. Therefore, the user has several choices regarding this item. For example, these elementary criteria allow establishing, if it is so desired, minimum or maximum values for a performance variable like the elementary criterion ec_a –shown in equation (1)– that produces a value for the elementary preference that is directly proportional to the area (A) and it assigns the value 100 to those properties that exceed a certain area A_{max}. The elementary criterion ec_b –shown in equation (2)– returns a value that is related to several stretches of areas, also reserving 100 for those areas exceeding a certain value A_{max}. In both equations appears a constant A_{min} that reflects the fact that there is a minimum of built area, and in this case, the criterion assigns 0 to all those properties that do not exceed this minimum. This example illustrates the flexibility of the method, allowing the user to define the elementary criterion according to his needs.

$$ec_a(A) = \begin{cases} A > A_{max} \rightarrow 100 \\ A_{min} < A \leq A_{max} \rightarrow (A \cdot 100) / A_{max} \\ A \leq A_{min} \rightarrow 0 \end{cases} \qquad (1)$$

$$ec_b(A) = \begin{cases} A > A_{max} \rightarrow 100 \\ A_{min} < A \leq A_{max} \rightarrow t(A) \\ A \leq A_{min} \rightarrow 0 \end{cases} \qquad (2)$$

t –given in equation (2)– is a function that given an area A returns a value in the interval [1.. 99] extracted from a table of predefined stretches of area.

Clearly, in this example, ec_a and ec_b are exclusive, they cannot be both in the same model.

Once identified the performance variables that will take part into the property valuation and the elementary criteria have been defined, then the integration proceeds so as to obtain an index between 0 and 100 that will be used to calculate the value of the property for market or taxation purposes. Let us suppose that, according to the user's needs, item 1.5.1. 'Total area built' has a high significance. This can be represented, for example, by giving to this item, when constructing the aggregation structure, a higher weight than the other items in the same grouping.

Therefore, by using the GCD operators we have combined the elementary preferences to construct an evaluation model or LSP Aggregation Structure. This model corresponds with the user's needs –in this case the needs to obtain an index for the properties under assessment.

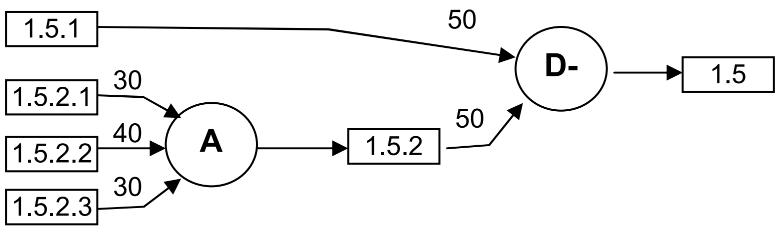

Figure 2. A simple aggregation structure for item 1.5.

In Figure 2, we show an Aggregation Structure where the elementary preference obtained from the application of the elementary criterion $ec_b(A)$ corresponding to the item 1.5.1. 'Total built area' has been aggregated with the item 1.5.2. 'Construction type', which corresponds to the aggregation of the items 1.5.2.1. 'Roof', 1.5.2.2. 'Walls', and 1.5.2.3. 'Floors' using the GCD operator **A**. Both item 1.5.1. 'Total built area' and 1.5.2. 'Construction type' have been grouped under 1.5. 'Construction' also using the GCD operator **D-**.

A is a function that returns the weighted arithmetic media of all the values that are input to it. Let us note that apart from being able to choose the GCD function, each of the inputs has an associated weight that plays a part in the final value. In this case, item 1.5.2.2 has a weight greater than other item's in its grouping therefore its value will have a bigger impact in the total value of the **A** function. This is so since item 1.5.2.2 has been considered to be more important than the other two.

Operator **D-** –grouping items 1.5.1 and 1.5.2– is a weak quasi-disjunctive operator that allows any of the items it aggregates to be missing. In this case, any of the items grouped under item

1.5 might be missing, i.e. might be zero. This situation will drop the result but it will not penalize it as much as an arithmetic media **A** would do it.

Figure 3 shows a different situation for the same items. In this case, we have modelled the fact that item 1.5.1 could be zero but any of the items 1.5.2.*i* may not, i.e. some items are mandatory while other can be missing. This is a typical situation when not all the characteristics are essentials (mandatory); some of them could be desirable and others optional, i.e. they can be present or not. This can be achieved using a special aggregation structure, namely *Partial Absorption*. Figure 3 shows a partial absorption where the attribute 1.5.1, 'Total built area' has been considered optional, i.e. it describes a characteristic that is strongly wanted but is not absolutely essential to satisfy the sub tree requirements and whose contribution to the final result is not so significant. At the same time, attribute 1.5.2 'Construction type' has been considered mandatory (essential), i.e. it is an attribute that the system under evaluation must satisfy and whose absence should be penalized so that the whole sub tree is zero.

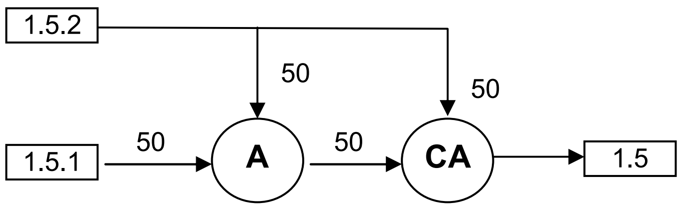

Figure 3. Partial Absorption.

The aggregation structure creation is not a linear process given that it implies the calibration of the model to reflect the user's needs. Once the model has been calibrated, the valuation process can proceed. Of course, the model can be adapted any time the requirements change.

Table 3 shows a value matrix that –in conjunction with the resulting index obtained from the valuation process by using the LSP model already constructed– we can use to calculate a value for property tax purposes. The matrix contemplates the use of a maximum and a minimum value both for rural and urban properties, denoted Vr_{mx}, Vr_{min}, Vu_{mx}, Vu_{min}, respectively. For example, if for a rural property, the index obtained is 100 then the corresponding assessment will be Vr_{mx}; if the index is below a certain minimum *min*, the assessment will be Vr_{min}, and if it has an index between *min* and 100 then it will have an assessment proportional to the interval [Vr_{min}, Vr_{mx}]. Therefore, the taxation entity (state or municipal authority) is who will have to instantiate these values according to its needs.

Table 3. Matrix for tax use

Assessment

	Maximum	Minimum
Rural	Vr_{mx}	Vr_{min}
Urban	Vu_{mx}	Vu_{min}

As an alternative to the assessment matrix, the taxation entity could assign a certain monetary value to a unit or fraction of the index; so the assessment can be in direct relation with the ‘price’ of the index of the property being evaluated.

The same matrix can be used not only for taxation purposes but also by an evaluator who can also assign a monetary value to the indexes in order to obtain an assessment of a property by evaluating a number of characteristics from the property.

As we can see, the proposed method allows the creation of a more complete and flexible model where the different points of view can be combined in different ways according to the user needs and getting a final unique index resulting from a model that is understandable, easily calibrated by the user according to her needs.

4 Discussion and Future Work

Being able to aggregate different characteristics of a property in one single value is extremely useful for assessment since it gives the analyst the possibility of comparing quickly and simply two or more properties based not only in one indicator –the market value as it is usually done– but on a number of features. We have seen in this work how an index obtained from the aggregation of several characteristics in a LSP model can be used for taxation purposes.

We have also seen how this method allows an aggregation of the desired property’s characteristics to be as complete as the user wants and how it also permits the creation of partial aggregations, namely only one or more items of the property or properties chosen and not necessarily all the characteristics of the property. We have also seen that having the complete aggregation model does not limit the capability of having partial results since the LSP model permits the collection of these partial results through partial aggregation structures that are part of the entire model.

Experimenting with different aggregation models is an easy task since, at the very least, it only involves changing functions or weights, especially if a software tool is used to construct and calibrate the model [1].

As part of future work we consider to propose the approach presented here to a tax administration as a way to test in a real situation how the construction and application of a model behaves.

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