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Assessment Method for Individual Value of a Location

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Abstract

Selection of a location for residential purpose has a long-term impact on the individual's life. The decision-making process can be supported by location assessment applications. The individual value of a location is a subjective value depending on several non-mobility and mobility related attributes. Missing services are accessible by transportation therefore mobility attributes are to be considered. We have elaborated quantitative assessment method to determine the individual value of a location; with consideration to personal preferences. The attributes of the territory, where the assessed location is located, and the attributes of routes by different transportation modes to frequent destinations are considered by the value of location. The value expresses how attractive the territory for living purpose is and how attractive the mobility from the location for the individual is. The method is based on a simplified city model containing the relevant entities and their attributes. The elaborated method is to be embedded in applications for residential location selection. The method can be applied to compare the value of a location before and after a development.

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Keywords: decision support; life quality; mobility quality; personalization; residential location selection; value of location

1. Introduction

Selection of the most appropriate location for a certain activity type is only possible if several aspects are considered at the same time. Residential location selection for individuals has long-term impact therefore comprehensive analysis of the attributes of the selected location is necessary. The value of a location is different for everyone. The individual value of a location expresses the quality of a location for an individual considering his/her preferences. Transport-

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aware urban planning (Gaál and Horváth, 2017) and transport-aware residential selection are important; however, existing residential selection applications usually do not consider the individual's mobility habits.

The motivation of the research was to develop a quantitative multi-criteria location assessment method which supports the individual's residential location selection. A location is assessed in a complex way considering several mobility related and non-mobility related attributes. The novelty of the method is that travel opportunities (routes) of individual's frequent travel destinations are considered besides the non-mobility related attributes of the territory where the location is located.

During the method, the user assesses the objective attributes determining a qualifier number, weight numbers and frequencies. Qualifier number expresses the individual's subjective value of an attribute. Aggregated attributes are considered which express the common impacts of similar or related attributes. Route resistance value is calculated which is a weighted sum value of aggregated attributes of a route and it expresses the personalized attractiveness of a travel opportunity. Travel resistance value is considered which is a sum value of each route resistance. It expresses the mobility attractiveness of a destination. The result is the individual value of a location which is described by the attributes of the territory, where the location is located, and the attributes of the routes to frequent travel destinations. It is weighted sum value of quality items:

- life quality: expresses the living attractiveness of a territory, where the assessed location is located, considering non-mobility related aggregated attributes,
- mobility quality: expresses the mobility attractiveness of a location considering the resistance values of routes to frequent destinations.

The subjectivity of life quality and mobility quality is considered in the developed method by qualifier numbers and weight numbers. Mobility quality determines the transport accessibility of a location. The transport accessibility is a complex indicator of a location which describes the impact of mobility related attributes on travel in a combined way (e.g. available modes, frequency, average travel time, route characteristics, infrastructure quality) (Handy, 2005). The value of a location expresses how attractive the territory for living purpose is and how attractive the mobility from the location for the individual is. Application opportunities of the method:

- supporting individual's decision-making for residential location selection,
- comparison before-after situation; examine the alteration of the individual value of a location after some mobility related (e.g. introduction new public transportation line) or non-mobility related (e.g. introduction new CCTV system for improving the safety) investment.

The remainder of the paper is structured as follows. In Section 2, state of the art about residential location selection, land-use and transportation impacts are summarized. The city model mapping the considered entities and their attributes are introduced in Section 3. The elaborated method is described in Section 4. The paper is completed by the concluding remarks, including further research directions.

2. State of the art

The value of a location can be calculated with consideration to either general or individual preferences. Identification of importance regarding personal setting criteria was discussed in several papers (Duleba et al. 2012; Sivilevičius and Maskeliūnaitė, 2010). AHP (Analytic Hierarchy Process) methodology based on the pairwise criteria comparison is often used to determine the significances of an attribute. Balbontin et al. (2015) combined best-worst scaling data with stated choice data to model the choice of residential location. The method can be also used to determine the user's expectation towards attributes.

The integrated land-use/transportation models intend to represent all opportunities of travel and household location, maximize utilities and find an equilibrium in which no person or household could improve their satisfaction any further (Moeckel, 2017). Every household, person, and dwelling is treated as an individual object in the case of SILO (Simple Integrated Land Use Orchestrator) model. The household location choice is modeled in a microscopic way which means that every individual need and expectation of a household is simulated (Wegener, 2014). All decisions that are spatial in nature (e.g. household relocation) are modeled with logit models. An agent-based joint model of residential location choice and real estate price was proposed by Zhuge et al. (2016). The utility function incorporates only two variables: house price and accessibility. Bagloee et al. (2016) proposed a logit-based model to predict relative land value changes with respect to changes in transportation facilities and accessibility. The relative price of a land is predicted with respect to transportation accessibility, neighborhood amenities, and availability of land. They found that any change in the transportation infrastructure would affect the travel time and, hence, the utility from choosing a location and the corresponding property value.

A dynamic model for the regulation of the urban environment was elaborated by Tánczos and Török (2009). They defined different short, medium, and long-term decisions and dynamic input variables. Choice of residence location is a long-term decision which is influenced by medium-term inputs such as transport network attributes, land price and population attributes (e.g. density). Data were analyzed to find the tendency of changing residential locations and changing employment locations by Merlin (2017). He found that residential locations were generally shifting toward low-accessibility locations, degrading regional accessibility.

The interaction between level of mobility and residential location decision was examined in several papers. Humpreys and Ahern (2017) found that while transport is an important factor in choosing where to live, it is not the primary factor for all residents and its role is dependent on the characteristics of the respondent involved (e.g. age, number of children). Susilo et al. (2012) found that for public transport use the main determinants are car availability, distance to public transport stops, and household size. Changes in car use and public transport use were significantly determined by changes in household structure (Scheiner and Holz-Rau, 2012).

The literature review showed that existing location assessment methods focuses on general mobility and non-mobility related preferences, not considering the travel opportunities to frequent destinations. In this way, the methods support the residential location selection only superficially; wide range of personalization of mobility and non-mobility related attributes are necessary in order to improve the efficiency of the selection and enhance the user's satisfaction.

3. City Model

We developed a city model which maps the relevant entities. The model is the base of the assessment method.

3.1. Entities

The considered entities are illustrated in Fig 1.

- location (m): is a point which is being assessed.
- service point (j): is a point where a type of service is located (e.g. supermarket, park, bike-sharing station). The existence and attractiveness of the service point are being considered during the assessment.
- territory (i): close catchment area of the assessed location. The shape is a regular hexagon. The location is in the middle of the hexagon. The hexagon is regular so edges are the same distance from the middle. Several service points can be located in a territory. The distance between the parallel edges depends on the user corresponding the acceptable walking distance.
- surrounding (o): wider catchment area of the assessed location. It contains the nearby territories (hexagons). The attributes of the nearby territories (e.g. located service points) have the influence on the value of the assessed location. Functional (e.g. residential area) or administrative (e.g. district) areas are typical surrounding.
- destination (n): is a point where the user has the intention to travel frequently.
- route (n,k,t): travel opportunity to n. destination using k. transportation mode. Only the route with the smallest travel resistance according to each k. mode is considered. The resistance depends on the user's expectations (e.g. shortest route in time). The best travel opportunity to the same n. destination may vary in time corresponding with the general traffic situation, road condition and the alteration of public transport network. Accordingly, route entity depends on t time intervals (e.g. rush-hours, daytime, at night, daytime of weekends).

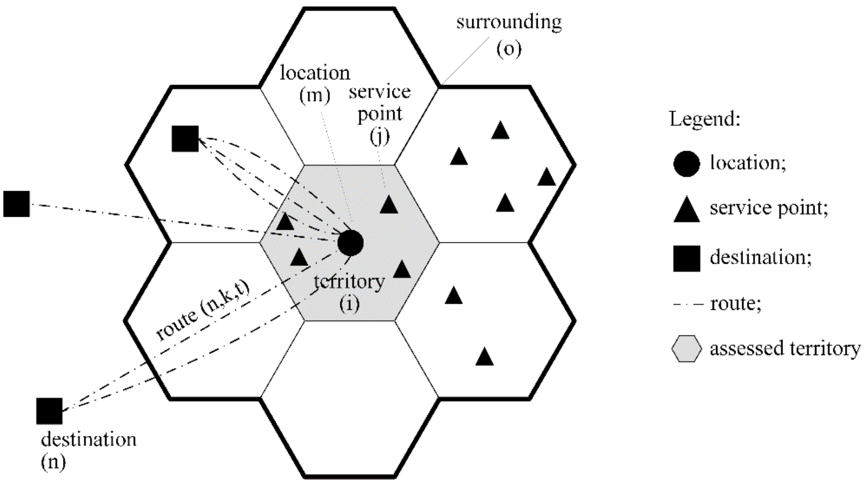

Fig. 1. City model - entities.

3.2. Attributes

The attributes of i. territory are summarized in Table 1 ($x^{i}_{a,b}$ where a is index of attribute, b is index of type of a. attribute). The attributes of route to n. destination with k. mode are summarized in Table 2 ($y^{n,k}_{c,d}(t)$) where c is index of attribute, d is index of type of c. attribute). Each attribute has different types; the second lower index describes the index of the type (e.g. pollution distraction has f type, for instance PM_{10} concentration, noise).

During the selection of the attributes, we considered the results of scientific literature and our own experiences. Physical, social, infrastructure, environmental, economic and legal factors can be considered (Droj and Droj, 2015). Csete and Buzási (2016) highlighted several other indicators which facilitate the creation of livable urban spaces (e.g. enhance public transport service level)

The level of different type of pollution influences life quality (e.g. healthy environment) which has been identified as a key element of land-use policies (Glaeser and Kahn, 2010). Safe environment (less crime) is preferred during residential selection and in the case of walking as well (Aditjandra et al., 2016). Built-up environment influences both life quality and mobility quality. In general, denser territories have better mobility services as a consequence of located facilities and more opportunities (Vale et al., 2016). Residential density is the main determinant of mode choice; the denser an area is, the less the car use is (Milakis, 2011).

Travelers usually select their route based on the shortest time or distance which has the smallest price (Ortúzar, Willumsen 2011). The frequency of public transportation mode can be a time attribute as well as it highly influences the service level (Susilo et al., 2012). Walking comfort is a key of mobility; travelers take into account a lot of factors (e.g. personal impressions) to choose the appropriate walking route (Yuen et al., 2013). Different walking distances are to be distinguished according to the modes as the willingness to walk is different (Daniels and Mulley, 2013). Travel comfort is important especially by public transportation (e.g. number of changing) and cycling (e.g. cycle friendly connections, bike storage) (Susilo et al., 2012).

Table 1. Attributes of a territory $x^{i}_{a,b}$.

sign	name	description
$x^{i}_{1,e}$	service point attraction	attraction value of e. type of service point (e.g. supermarket, hospital, green areas)
$x^{i}_{2,f}$	pollution distraction	distraction value of annual average volume of f. type of pollution (e.g. PM_{10} concentration, noise)
$x^{i}_{3,g}$	criminal distraction	distraction value of g. type of criminal (e.g. car braking, burglary)
$x^{i}_{4,g}$	criminal proportion	number of g. type of criminal, $x^{i}_{4,g} \in \mathbb{N}^{+}$
$x^{i}_{5,h}$	build-up type attraction	attraction value of h. build-up type (e.g. building estate, industry)
$x^{i}_{6,h}$	build-up type proportion	proportion of h. build-up type [%]

Table 2. Attributes of route $y_{c,d}^{n,k}(t)$.

$y_{c,d}^{n,k}(t)$	name	description
$y_{1,u}^{n,k}(t)$	time	attraction value of u. time type (e.g. travel time, frequency)
$y_{2,v}^{n,k}(t)$	cost	attraction value of v. cost type (e.g. price of travel)
$y_{3,w}^{n,k}(t)$	walking comfort	attraction value of w. walking comfort type (e.g. walking distance, use of stair)
$y_{4,z}^{n,k}(t)$	travel comfort	attraction value of z. travel comfort type (e.g. use of cycle friendly road, use of low-flor vehicle,)

The attributes are altering after any mobility related or a non-mobility related measure. The altering public transport network and traffic situation in a day or in a week have an effect on mobility attractiveness of a destination, therefore attributes of a route are t time interval dependent. The source of the data, in the case of territorial unit, can be, a so-called, exterior geoinformatics databases or applications, and in the case of routes, is exterior route planner application which plans the routes as detailed as possible considering all combinations and preferences (e.g. number of changes in the case of public transportation)

The user sets qualifier numbers for each attribute. The attributes of the considered territories and routes are assessed according to the qualifier number. Each attribute takes either a null value (the field of the record is empty) or a discrete qualifier number (1-5). The attributes take null value:

- if e. type of service point entity is not available in the territory,
- if the attribute is not typical or irrelevant in the territory (e.g. industry as a build-up type is not typical in the territory, or cycle friendly road use as a travel comfort attribute is irrelevant in the case of PT or car route)

Higher qualifier number indicates higher attractivity of an attribute. For instance, in the case of territory, if the user prefers green areas in a territory and the assessed territory contains a j park service point, the value of e. type ('green areas') service point attraction attribute is 5 ($x_{1,e}^{i} = 5$), where e type of service point attraction is 'green areas'). In the case of route, if the user sets the preferred travel time (qualifier number) by public transportation mode to n. destination in t time interval in the following way: < 20 minutes: 5, 20-30 minutes: 4, etc. and the travel time is 25 minutes, the travel time attribute takes 4 value ($y_{1,u}^{n,k}(t) = 4$, where u is travel time attribute, k is public transportation mode).

4. Assessment method

The main steps are summarized in Fig. 2. The steps and signs are described in detail in the following subsections. The subsections are divided whether the steps of determination of life quality [4.1.], mobility quality [4.2.] or value of location [4.3.] are described. The method contains:

- initialization steps: the user sets the territory, location, qualifier numbers, weight factors and frequencies values,
- determination steps: an exterior application determines the attributes or, in the case of the calculation of mobility quality, the assessed routes as well and
- calculation steps.

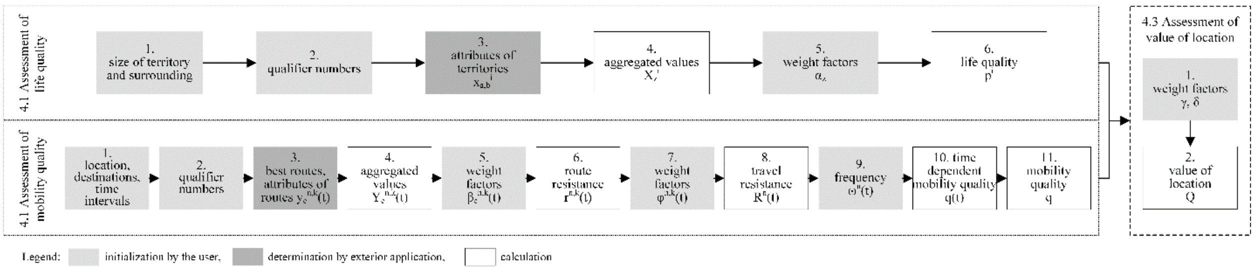

Fig. 2. Description of the method.

4.1. *Assessment of life quality*

The calculation steps of life quality are the following:

1. step: user sets the size of the assessed territory and the surrounding.
2. step: user determines the qualifier numbers of the attributes.
3. step: determination of attributes of the territories ($x^{i}_{a,b}$) using exterior databases or applications.
4. step: calculation of aggregated values (X^{i}_{z} where z is index of aggregated value) (Table 3, (4.1)-(4.4)). The qualifier numbers of the similar or related attributes are summarized and normalized. During the normalization, the summarized value of the territory is divided by the summarized maximum value of the territory of the surrounding. In this way, the aggregated values are influenced by the surrounding and the aggregated values are comparable.

Table 3. Aggregated values X^{i}_{z} .

u	description	equation		u	description	equation	
1	aggregated attraction value of available service points	$X^{i}_{1} = \frac{\sum_{e} x^{i}_{1,e}}{\max_{o} \sum_{e} x^{i}_{1,e}} \cdot 5$	(4.1)	3	aggregated distraction value of criminal type and proportion	$X^{i}_{3} = \frac{\sum_{g} x^{i}_{3,g} \cdot x^{i}_{4,g}}{\max_{o} \sum_{g} x^{i}_{3,g} \cdot x^{i}_{4,g}} \cdot 5$	(4.3)
2	aggregated distraction value of pollution	$X^{i}_{2} = \frac{\sum_{f} x^{i}_{2,f}}{\max_{o} \sum_{f} x^{i}_{2,f}} \cdot 5$	(4.2)	4	aggregated attraction value of build-up type and proportion	$X^{i}_{4} = \frac{\sum_{h} x^{i}_{4,h} \cdot x^{i}_{5,h}}{\max_{o} \sum_{h} x^{i}_{4,h} \cdot x^{i}_{5,h}} \cdot 5$	(4.4)

5. step: user expresses the subjective importance of the aggregated values setting weight factors (α_z). The weight factor may be negative, thus the aggregated attribute reduces the living quality (e.g. X^{i}_{2}, X^{i}_{3}). The sum of the weight factors in absolute value is 1.
6. step: calculation of life quality (p^{i}) (4.5)

$$p^{i} = \sum_{z} \alpha_{z} \cdot X^{i}_{z} \tag{4.5}$$

4.2. Assessment mobility quality

The logical structure of calculated values during the assessment of mobility quality is illustrated in Fig. 3. The used data and data sources are described as well. The steps are described as follows.

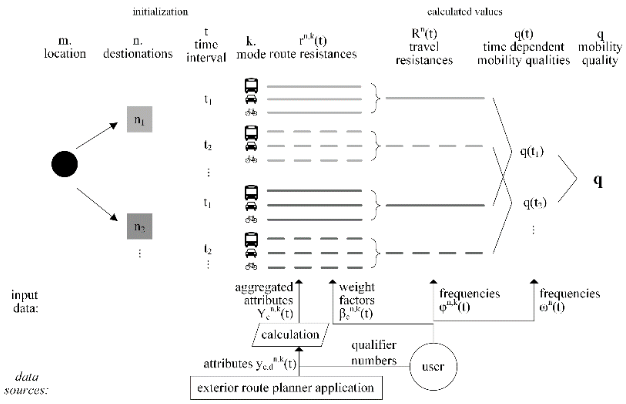

Fig. 3. Logical structure of assessment of mobility quality.

1. step: user sets the location, the frequent destinations (n=1..N) and the considered t time intervals.
2. step: user sets the qualifier numbers of the attributes in the considered t time interval.
3. step: determination of the best routes in each k. mode in each t time interval according to user preferences (by exterior route planner). In this way, the attributes of the routes are determined as well.

4. step: calculation of aggregated values for each k. mode, each n. destination and each t time interval $(Y_c^{n,k}(t))$. The calculation method is similar. Attributes of the same d. type are averaged (4.6).

$$Y_c^{n,k}(t) = \frac{1}{D}\sum_{d=1}^{D} y_{c,d}^{n,k}(t) \tag{4.6}$$

5. step: user expresses the subjective importance of aggregated attributes setting weight factors $(\beta_c^{n,k}(t))$ (sum is 1). The weight factors also alter according to t time interval as different attributes can be preferred.

6. step: calculation of route resistance $(r^{n,k}(t))$ (4.7). The resistance is calculated in each route according to k. transportation mode in t time interval considering the aggregated attributes. The importance of the aggregated attributes in each destination is expressed by weight factors.

$$r^{n,k}(t) = \sum_{c,k} \beta_c^{n,k}(t) \cdot Y_c^{n,k}(t) \tag{4.7}$$

7. step: user expresses how often he/she uses the k. transportation mode to reach n. destination setting frequency values $(\varphi^{n,k}(t))$ (sum is 1). The frequency alters in t time interval as different modes can be preferred in time.

8. step: calculation of travel resistance $(R^n(t))$ (4.8). It expresses how satisfactory to travel between the location and n. destination. The frequency of k. mode use and the route resistance of k. mode are summarized according to t.

$$R^n(t) = \sum_{k} \varphi^{n,k}(t) \cdot r^{n,k}(t) \tag{4.8}$$

9. step: user expresses how often he/she travels to n. destination in t time interval setting frequency values $(\omega^n(t))$ (sum is 1). The frequency alters in t time interval as the travel intentions are different in time.

10. step: calculation of t time-dependent mobility quality (q(t)) (4.9). If mobility quality is high, the location has good transportation connections to the assessed destinations for the user in t time interval.

$$q(t) = \sum_{n} \omega^n(t) \cdot R^n(t) \tag{4.9}$$

11. step: calculation of mobility quality (q) (4.10). It expresses the overall attractiveness of mobility connections of the location averaging the t time-dependent mobility qualities.

$$q = \overline{q(t)} \tag{4.10}$$

4.3 Assessment of value of location

1. step: user expresses whether life quality or mobility quality is more important setting weight factors (γ is weight factor of life quality, δ is weight factor of mobility quality (sum of $\gamma + \delta$ is 1).

2. step: calculation of the individual value of the location (4.11).

$$Q = \gamma \cdot w^i + \delta \cdot q \tag{4.11}$$

Conclusions

Detailed location assessment method is required to support the users during decision-making of residential location selection. The main contributions of the paper are, on the one hand, the city model which is the base for assessment, and on the other hand, the multi-criteria personalized location assessment method. The result of the method is the value of location which is a complex value describing life quality and mobility quality of the assessed location. The method considers the user preferences. Life quality is described by non-mobility related attributes of the territory where the assessed location is located, thus the mobility quality is described by mobility related attributes of routes from the location to the user's frequent destinations.

Aggregated attributes are calculated expressing the common impacts of similar or related attributes. The key finding was that the method is flexible; the considered attributes can be extended depending on the available data. We faced as a lesson learnt that because of the different measurement units of the attributes, the normalization of them are required. The method can be a base of a decision support application for residential location selection.

Our further research focuses on the determination of the qualifier numbers and weight factors in a general way in order to determine general life quality and mobility quality of a city. We verify and validate the model and the methods with mapping existing territories. Based on the method we develop a decision support application for residential location selection. Consideration of multimodal travels in the travel opportunities is also our future goal. We intend to extend the method with the characteristics of a residence. In addition, our further aim is to elaborate mobility planning principles considering the attributes of a territorial unit.

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