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RESEARCH ARTICLE

Service Quality Analysis and Assessment Method for European Carsharing Systems

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Abstract
The carsharing service aims to increase the utilization of the temporal capacity of the cars resulting that fewer cars and parking spaces are sufficient for the same mobility demands. The key factor of the introduction and the development of the service is to explore the features of the quality and to compare them to the expectations of the users. We have developed a service quality analysis and assessment method. Our devised compensated multicriteria method takes into consideration the properties of the service, area and population. The quality is varying both in space and time, and also depending on availability of other transportation modes. We applied the method in Budapest. A round-trip carsharing service were assessed from a user aspect. Representation of the calculated results on a dynamic map allows for the operators to plan and evaluate the quality of service both before implementation and during operation. "Average distance to the nearest unoccupied vehicle", "service type" and "parking conditions" parameters have been found as the most important service parameters.

Keywords
shared mobility, carsharing, quality, compensated multicriteria method, evaluation

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1 Introduction

The growing mobility needs in urban passenger transportation can be managed by exploiting the existing infrastructure and promoting public travel modes (Gaal et al., 2015). The development of information technology provides significant support for the modern modes of travel. At the same time, traffic patterns are also changing, and this change may also be subserved. For example, among young people between the ages of 18 and 29 it can be observed that the motorized individual transportation mode share is decreasing, while the public transportation and non-motorized individual transportation mode share is growing (Kuhnimhof and Wirtz 2012; Tóth and Ágoston, 2014). The carsharing service fits the change in travel behaviour, combining the individual and public benefits of motorized transportation. The passenger car capacity utilization can be increased in two ways, as displayed in Fig. 1:

- increasing time utilization (carsharing),
- increasing the number of passengers simultaneously delivered (carpooling).

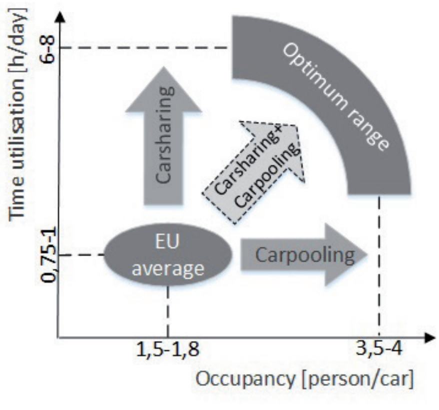

Fig. 1 Ways of increasing passenger car capacity utilization

Examples of the combination of the two modes are rare, however carsharing and carpooling are not mutually exclusive.

The objective of the research was assessing the quality of carsharing systems, which had not been addressed in the past; even though many articles dealt with the traditional public transportation quality issues (dell'Olio et al., 2011; Redman et al., 2013). On the other hand several studies have already examined the conditions of success of carsharing systems and other sharing based services in transportation like freight and warehouse exchanges (Csiszár, 2009; Kovács, 2009; Jorge et al., 2012; Krumke, 2013; Maurizio et al., 2014). Agent-based simulation techniques have been applied for analysis of the operational and control mechanisms as well as for comparison of the different scenarios of on-demand mobility services (Čertický et al., 2015). Alfian, Rhee and Yoon (2014) have devised a fuzzy classification to derive a service model that provides the highest income for service providers and the best service for customers according to performance indicators. The discrete event simulation presented in El Fassi's (2012) research also assists the decision makers by exploring areas for improvement and offering solutions that meet user expectations. Kent and Dowling (2013) proposed several practices which help to increase the acceptance and success of the carsharing system regardless of the service types. In another publication the number of potential carsharing users is determined on the basis of residence attributes, which helps to select the appropriate operation area (Coll et al., 2014). In Chaefers' (2012) research the demand structure is uncovered and motivation patterns are identified regarding carsharing. The knowledge identified during the literature review has been built into our assessment method.

There are numerous types and operational models of carsharing systems, and their application depends on the size of the settlement and the local population characteristics. Installation of a new system (or extension of an existing one) requires comprehensive scientific approach. It includes the following modelling and method development steps:

- travel demand model (choice modelling),
- installation area choice method (stages of expansion),
- vehicle fleet determining method,
- service characteristics determining method,
- business model.

Multicriteria analysis and comparison of the current operating systems (best practices) relates to the steps above. In this paper our compensated multicriteria method is summarized, which is appropriate for determination of the level of quality of carsharing systems. The multicriteria method takes a large amount of data into consideration (Scarpellini et al., 2013), furthermore the impacts described by exact values as well as hardly or non-quantifiable factors can both be evaluated (Mándoki, 2003). It is suitable for both retro- (ex post) and prospective (ex ante) use (European Commission, 1999), and taking the individual criteria into consideration with different weights because of the compensation. However its limits are also considerable. The result significantly depends on the structure and amount of the available information, and the preference of the evaluators (Scarpellini et al., 2013). Due to the fair properties of the method, it becomes increasingly popular in ratings pertaining to transportation (Yedla and Shrestha, 2003; Tudela, Akiki and Cisternas, 2006; Awasthi and Chauhan, 2011).

Novelty of this method is aiding user decisions during both mid and long-term transport mode choice by assessing carsharing services. The method is easy-to-use because the required set of data must be publicly available. During the development of the method we were looking for the appropriate answers of questions that had occurred in the previous studies. The posed questions were:

- What are the most important service attributes regarding the service quality?
- How is it possible to be considered dynamic parameters in both mid and long-term decision makings?
- Does the quality of the service depend on the availability of other transportation modes and how?

We have assessed two carsharing services being in operation. The aim was to display the spatial variation, and to identify the most efficient way to increase the service quality. Since our method supports mid and long-term decision making, the verification of the result requires long-term data sets. It is still not available at the moment, hence the results have not been verified yet.

2 Analysis and Assessment Method

We focused on the users' (travellers') personal expectations and demands. Figure 2 summarizes the operational steps of the method:

1. Importance of user expectations is determined on the basis of the characteristics of the users.
2. The relationship between expectations and quality criteria is ascertained.
3. (The detailed definition of the attributes of the relationship is the subject of our further research, so this step is shown in a box with a lighter background).
4. Weights are determined on the basis of importance of expectations as well as the relationship between expectations and quality criteria.
5. Evaluation numbers are calculated on the basis of the carsharing system's parameters and user expectations.

The results are weighted mean values based on the weights and evaluation numbers. They can be calculated for each quality category. Quality categories are specific groups created from the criteria. The total quality of the carsharing system is calculated as an aggregation of values of the quality categories.

Our quality analysis multicriteria method can be applied in two ways:

A. in a general way: without knowing the users' priorities and only for certain areas of the city (with house number accuracy),
B. in a personalized way: incorporating the users' priorities and places into A.

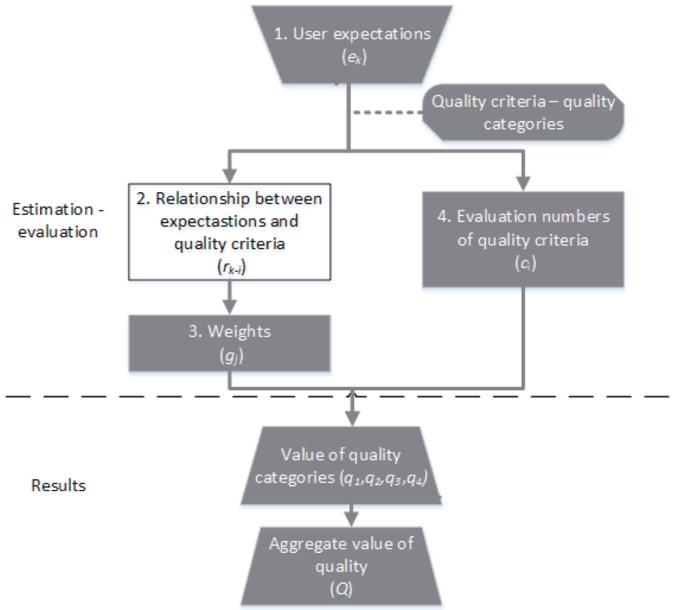

Fig. 2 Application of the analysis and assessment method

3 Quality criteria – quality categories

The determination of the carsharing service quality number is based on quality criteria. These may be either constant or spatially and/or temporally variable. We summarize the quality criteria and their evaluation numbers in Table 1. In public transportation there are widely accepted norms that allow transforming subjective parameters into objective ones. We have applied these norms only with slight modifications for carsharing systems.

We focused only on operational issues in order to manage carsharing service successfully. Prediction of the exact number of users was not aim of the research. Further limitations of this methodological approach is caused by the scope and evaluation of these criteria. We mainly chose half-dynamic and static attributes of the service, although there are some dynamic parameters. The dynamic parameters have been transformed into half dynamic ones by averaging them, hence the result supports only mid and long-term decision making. Our general method has been adapted to the European practice, noting that the evaluation numbers may vary in different regions. The type of service has double effect on quality: directly by criterion c0 and indirectly by criterion c34, where the method of the evaluation is influenced by the type of service. Since wide range of various propulsion technologies of vehicles is appropriate for short trips, it has not been evaluated.

The acceptability of the system (c51) depends on the following:

- the clarity of the network and tariff system,
- the circumstances of registration and payment,
- the circumstances of vehicle booking,
- the manageability of the on board unit.

The quality of the information system (c61) is influenced by:

- information about the vehicles,
- information about road traffic and parking,
- information about public transportation.

We applied the compensated multicriteria method instead of alternative methods, since the weighted mean value allows consideration of the criteria with different levels of importance. Towards uniform scoring, we applied a 1-to-5 rating scale, where 1 is the worst and 5 is the best value. Our purpose was to assess the utmost parameters from the user's perspective. Accordingly we took into consideration the following attributes: flexibility of the service (c0), carsharing users' walking behaviour on the basis of experiences (c11: 250 m is also acceptable for short and long term parking and 800 m is the maximum distance for a long term parking according to proposal of parking place designing), temporal usage of carsharing (c12: the limits were determined on the basis of length of short and long reservations), fluctuation of the usage in time (c13, weights x, y and z), capacity of different public transportation vehicles (c31), the travel demand characteristics of each service type (c34), the length of the shortest available new vehicle and regulation of parking place designing (c42). Example for other necessary activities: opening and closing a parking barrier.

The evaluation of several criteria can be done by users' questioning related to the assessed carsharing service.

Figure 3 displays the grouping of spatially and/or temporally variable carsharing criteria. The other criteria are assumed to be constant.

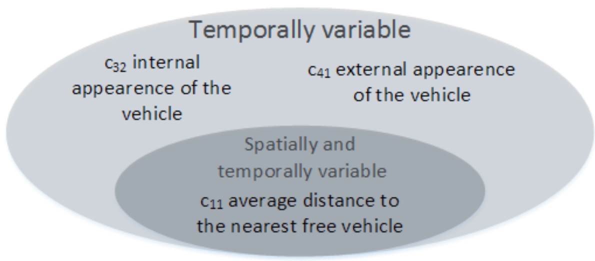

Fig. 3 Variable quality criteria

The quality of the carsharing service is a spatially and temporally variable dynamic parameter, as the average distance to the nearest vehicle (c11) is not constant, since the demand rate is different in each term (Costain et al., 2012). Fluctuations in demand are the basis of the dynamic characteristic. However both the internal (c32) and external appearance (c41) of the vehicle also gives rise to it.

We omitted the users/population number per vehicle criterion, since this rate and the quality of service are not clearly related. This is proved also by observation, as the users/population number per vehicle varies widely (Loose, n.d.). The evaluation of criterion c11 (average distance to the nearest unoccupied vehicle) for systems before installation is not obvious. It is necessary to determine a utilization rate for each term and

Table 1 Quality criteria and their evaluation numbers

	Quality criteria			Evaluation number	
group	c_j	**name**		**range**	**pt.**
flexibility	c_0	type of service		round-trip	1
				one-way	4
				free-floating	5
availability	c_{11}	average distance to the nearest unoccupied vehicle*		d ≥ 800 m	1
				d ≤ 250 m	5
	c_{12}	minimum and maximum period of usage*		**UT=MIN+MAX**	
				MIN≥ 1 hour	1
				MIN≤ 0.5 hour	3.5
				MAX≤ 4 hours	0
				MAX≥ 10 hours	1.5
				MIN, MAX: lower and upper limit of usage.	
	c_{13}	operating time*		**OT=0.7x+6.7y+2z**	1-5
				OT≤60	1
				OT=100	5
				Operating time [hour]	
				between 0 and 7	*x*
				between 7 and 20	*y*
				between 20 and 24	z
reliability	c_{21}	booking		**R=F+1/m**	1-5
				no booking	*F=1*
				booking required	*F=3*
				optional booking	*F=4*
				m: Continuous range. As many hour the booking can be modified before the start of the trip.	
comfort	c_{31}	accessibility of the vehicles		**A=1+0.5B+1.5T+4U**	1-5
				Number of connection points less than 250 m away: B: bus, trolley, T: tram, train U: underground.	
	c_{32}	internal appearance of the vehicle		by users' questioning	1-5
	c_{33}	driving behaviour		by users' questioning	1-5
	c_{34}	capacity	round-trip	P <4, L <400 l	1
				P=4, L <400 l	2
				P=5, L <400 l	3
				P=5, L> 400 l	4
				P> 5	5
			one-way, free-floating	P=2	3
				P=3 or 4	4
				P≥ 5	5
				P: seats [person], L: volume of luggage-rack [l]	
	c_{35}	conditions of refuelling*		S <25 %,	1
				S ≥75 %	4
				performed by operator	5
				S: petrol stations can be used close to the service area [%].	
	c_{36}	conditions of parking		$\boldsymbol{P} = 1 + \frac{\boldsymbol{Ph_d}}{\boldsymbol{n^{\circ}_v}} + \boldsymbol{B}$ P ϵ [1..5]	
				parking place booking possible	B=1.5
				parking place booking not possible	B=0
				Phd: No of dedicated parking places n°v: No of vehicles	
	c_{37}	other necessary activities		by users' questioning	1-5
other parameters of the vehicle	c_{41}	external appearance of the vehicle		by users' questioning	1-5
	c_{42}	vehicle length *		l > 4800 mm	1
				l ≤ 2965 mm	5
	c_{43}	vehicle safety		According to EuroNCAP results: 1 star 1 point.	
	c_{44}	CO_2 emission*		$Ex_{pr} \leq Ex_{cs}$	1
				$Ex_{pr,}$ Ex_{cs}: average CO2 emission of private and carsharing vehicles [g/ km].	
				$Ex_{cs} = 0$	5
c_{51}		acceptability of the system		by users' questioning	1-5
c_{61}		information system		by users' questioning	1-5

*: Continuous range. Evaluation by linear interpolation between the two limits.

to estimate the expected spatial distribution of vehicles for one-way and free-floating systems. A simple estimation can be applied: the expected number of unoccupied cars is distributed among the zones on the basis of population and density. The latter two indicators are related to the number of users. In our simple calculation, 50 % of the vehicles are distributed on the basis of number as well as the other 50 % on the basis of the density of population in each zone. In both cases the zone attributes are compared to the aggregate attribute of all zones.

We have created four categories from the quality criteria in reference to the carsharing system on the basis of the standardized quality approach for public transportation that is used in the European Union:

- q1: quality of service,
- q2: quality of travel,
- q3: manageability,
- q4: environmental impact.

Table 3 presents the categorization of quality criteria.

4 Assessment

4.1 User expectations

Since the user characteristics are individual, the weights and the *perceived quality of service are different for each person*. The user preference is primarily influenced by the mobility patterns. The density of residence (Headicar and Banister, n.d.) and the number of household vehicles significantly affect a person's traffic patterns. The variables of user expectations (Table 2) are to be determined by questionnaire.

Table 2 User expectations

Symbol (e_i)	Name
e_1	Freedom, independence
e_2	Free parking place
e_3	Connection with public transportation
e_4	Reliability
e_5	Comfort, easy-to-use
e_6	Sustainability
e_7	Information about the service
e_8	Belonging to a community
e_9	Security

Although the reasonable rate is an important user expectation, we did not address it yet. However in our further research we are going to reveal the coherence between the quality and rate. When the individual user preferences are unknown and the 'A' type of assessment method is applied, average preference values are to be determined on the basis of local knowledge.

4.2 Relations between expectations and quality criteria

The weights (g_i) can be determined on the basis of the importance of user expectations and the strength of the relationship between expectations and quality criteria. Our assessment method indirectly contains the properties of the trips (e.g. destination), because the weights are derived from the individual user preferences, what is influenced by the general trip attributes. The strength of a relationship ($r_{i,j}$) indicates how the expectations (j) are fulfilled by a criterion (i). Table 3 displays the presence of the relationships between quality criteria and user expectations by quality categories. As the exact determination of the strength of the relationships requires 'deeper' research, we only performed estimations in absence of the exact knowledge.

For example $r_{13,1}$ indicates the strength of the relationship between criterion 13 (operating time) and expectation *1* (freedom, independence).

4.3 Calculation of Weights

The weights are calculated in two steps on the basis of Eq. (1) and (2):

$$g_j = \sum_{i=1}^{9} g_{i,j} \tag{1}$$

$$g_{i,j} = \frac{r_{i,j}}{\sum_j r_{i,j}} \cdot \frac{e_i}{\sum_i e_i} \cdot 100 \tag{2}$$

Where:

- i: the index number of quality criteria (0, 11, ..., 61),
- j: the index number of expectation (1, …, 9).

According to Eq. (1), if a quality criterion is in relationship with several user expectations, the resultant weight (g_j) is the sum of partial weights of each expectation. The partial weight of one criterion and one expectation can be calculated on the basis of Eq. (2). The numerator of the first fraction is the strength of the relationship; the denominator is the sum of strengths of the relationships subject to the same expectation. The numerator of the second factor is the importance of the expectation; the denominator is the sum of the importance of every expectation. It is *impossible to determine a weighting system that is uniformly valid everywhere* since the preferences are different, however the expectations of real and potential users are the same. Furthermore the following two constraints must be met:

- $0 \leq g_j \leq 100, \forall g_j$
- $\sum g_j = 100$.

The weighting system can be derived with consideration to either average or individual preferences of users. In the latter case, *personalized quality level* is determined, which

Table 3 Relationships between expectations and quality criteria

$r_{i,j}$		e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9
	c_0	$r_{0,1}$								
	c_{11}					$r_{11,5}$				
	c_{12}	$r_{12,1}$								
q_1	c_{13}	$r_{13,1}$								
	c_{21}				$r_{21,4}$					
	c_{31}					$r_{31,5}$				
	c_{41}								$r_{41,8}$	
	c_{32}					$r_{32,5}$				
	c_{33}					$r_{33,5}$				
	c_{34}					$r_{34,5}$				
q_2	c_{35}					$r_{35,5}$				
	c_{36}		$r_{36,2}$							
	c_{37}					$r_{37,5}$				
	c_{42}		$r_{42,2}$			$r_{42,5}$				
	c_{43}									$r_{43,9}$
q_3	c_{51}					$r_{51,5}$				
	c_{61}			$r_{61,3}$	$r_{61,4}$			$r_{61,7}$		
q_4	c_{44}						$r_{44,6}$			

significantly supports the decision-making. The values of the weighting system are considered as constants, noting that the importance of a free parking place depends on the actual number of free parking places, which is different for each term.

4.4 Evaluation numbers of quality criteria - evaluation

Guide to the determination of the evaluation numbers is given in Table 1.

There are three input sources of data required for the evaluation:

- user characteristics (c_{11}, c_{32}, c_{33}, c_{37}, c_{41}, c_{51}, c_{61}),
- properties of carsharing service (for each criterion),
- areal properties (c_{31}).

5 Calculation of Results

The service quality (q_1), travel quality (q_2), manageability (q_3) and environmental impact (q_4) can be calculated separately on the basis of the Eqs. (3)-(6). The aggregated result is a weighted mean value, which can be calculated on the basis of Eq. (7).

$$q_1 = \frac{\sum_j g_j c_j}{\sum_j g_j}, \forall j \in S_1 \tag{3}$$

$$q_2 = \frac{\sum_j g_j c_j}{\sum_j g_j}, \forall j \in S_2 \tag{4}$$

$$q_3 = \frac{\sum_j g_j c_j}{\sum_j g_j}, \forall j \in S_3 \tag{5}$$

$$q_4 = \frac{\sum_j g_j c_j}{\sum_j g_j}, \forall j \in S_4 \tag{6}$$

$$Q = \frac{\sum_j g_j c_j}{100} \tag{7}$$

The values of the quality categories and the aggregated quality number are beneficial for potential users in decision making, because the carsharing systems are comparable by these results.

Spatial representation of the service quality is appropriate for the identification of areas where the quality of service is low as a consequence of the long average distance to the nearest unoccupied vehicle. Patterns of use become visible by representing the temporally variable distribution of unoccupied vehicles on a dynamic map. The areas can be recognized where either the number of vehicles is low or development is required. The ranking of development options also can be determined on the basis of the results. Furthermore our quality analysis method makes evaluation of the assumed conditions after the interventions also possible.

6 Application of the method in Budapest

We applied the method without the knowledge of individual user preferences (type 'A') to estimate the summer 2014 conditions of a fix-floating carsharing system, which has been in operation in Budapest since 2013. As part of that:

- The importance of user preferences on the basis of local features has been determined.
- The strength of the relations between expectations and quality criteria has been estimated.
- The weights have been calculated.
- Evaluation numbers have been determined on the basis of service attributes.

Table 4 summarizes the evaluation numbers and weights, the evaluation numbers are based on the information gathered from the website of the service. The weights are independent of service type of carsharing.

Results calculated on the basis of values in Table 4 are the following:

$$q_2=3.55;\ q_3=4.42;\ q_4=1.5.$$

The value of q_1 is spatially variable due to quality criterion c_{11} and c_{31} . Consequently the value of Q is also not spatially constant. On the observed area the value of q_1 ranges from 2.45 to 3.82, whereas the value of Q ranges between 3.08 and 3.68. Fig. 4 displays the spatial change of Q. In our case it is unnecessary to investigate the temporal change of quality due to the low vehicle and user number.

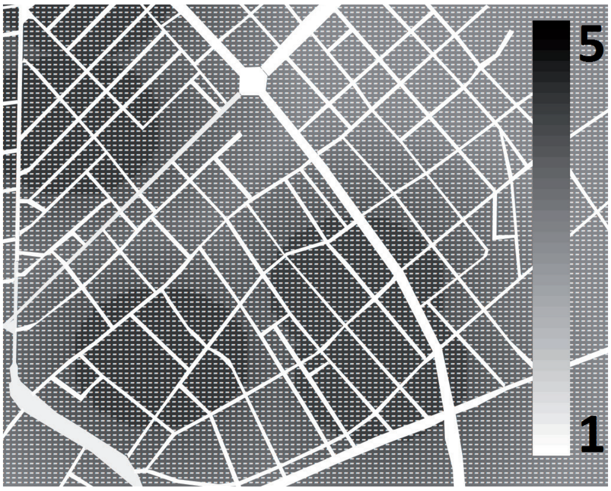

Fig. 4 Spatial change of Q on the observed area with 5 stations

Table 4 Evaluation of carsharing service in Budapest

evaluation number			weight	
symbol	**attributes**	**value**	**symbol**	**value**
c_0	Fix-floating	1	g_0	10
c_{11}	5 vehicle	spatially variable	g_{11}	15
c_{12}	MIN= 0.5 h, MAX>10 h	5	g_{12}	4
c_{13}	Operation 0-24	5	g_{13}	3
c_{21}	Booking required	3	g_{21}	6
c_{31}	Depends on the location	spatially variable	g_{31}	4
c_{32}	New, aesthetic (Opel Corsa D)	5	g_{32}	5
c_{33}	85 hp, adequate	4	g_{33}	3
c_{34}	P=5 person, L<400 l	3	g_{34}	2
c_{35}	S≈19% (only MOL), also performed by operator	(1+5)/2=3	g_{35}	5
c_{36}	Ph_d=1, booking not possible	2	g_{36}	9
c_{37}	Looking for damage before departure	5	g_{37}	4
c_{41}	Aesthetic (Oples Corsa D, red)	5	g_{41}	2
c_{42}	l= 3999 mm	2.75	g_{42}	5
c_{43}	5 stars	5	g_{43}	5
c_{44}	Ex_{pr}=147.7 Ex_{cs}= 129 g/km	1.5	g_{44}	5
c_{51}	Clear, simple, easy to use, quick registration	5	g_{51}	8
c_{61}	Little information, navigations system in vehicle	3.5	g_{61}	5

In this example, disregarding the service type and average distance to the nearest free vehicle, the weak points of the system are: CO_2 emission (c_{44}, 1.5 point) and conditions of parking (c_{36}, 2 point). Among these criteria the c_{36} has the largest weight, hence the most efficient way to increase the service quality is to establish dedicated parking places.

7 Conclusion

The main contributions of the paper are:

- method for analysing and evaluating carsharing services, that takes into consideration individual user preferences and location,
- evaluation of the changes in service quality over time,
- graphical representation of the results (decision support).

The key findings of the paper are:

- the most important attributes for the users are reliability and conditions of parking,
- carsharing services also offer a more effective and sustainable way of car usage for organizations,
- the most appropriate area for a carsharing service is a high density area with good public transportation.

The lessons learnt:

- carsharing service cannot be successful in isolation from other transportation modes,
- since the carsharing serves also latent demands it is necessary to influence the users' travel behaviour.

Further research directions:

- apply the evaluation method to other transportation modes. In this way the users can compare them and take into consideration the personal preferences, cost, and quality (personal decision support),
- development of a decision support information application on the basis of theoretical terms.

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References

Alfian, G., Rhee, J., Yoon, B. (2014) A simulation tool for prioritizing product-service system (PSS) models in a carsharing service. *Computers & Industrial Engineering*. 70, pp. 59-73. DOI: 10.1016/j.cie.2014.01.007

Awasthi, A., Chauhan, S. (2011) Using AHP and Dempster-Shafer theory for evaluation sustainable transport solutions. *Environmental Modelling and Software*. 26(6), pp. 787-796. DOI: 10.1016/j.envsoft.2010.11.010

Čertický, M., Jakob, M., Píbil, R. (2015) Analyzing On-demand Mobility Services by Agent-based Simulation. *Journal of Ubiquitous Systems & Pervasive Networks*. 6(1), pp. 17-26. DOI: 10.5383/juspn.06.01.003

Chaefers, T. (2012) Exploring carsharing usage motives: A hierarchical means-end chain analysis. *Transportation Research Part A: Policy and Practice*. 47, pp. 69-77. DOI: 10.1016/j.tra.2012.10.024

Coll, M.-H., Vandersmissen, M.-H., Thériault, M. (2014) Modelling spatio-temporal diffusion of carsharing membership in Québec City. *Journal of Transport Geography*. 38, pp. 22-37. DOI: 10.1016/j.jtrangeo.2014.04.017

Costain, C., Ardron, C., Habib, K. N. (2012) Synopsis of users' behaviour of a carsharing program: A case study in Toronto. *Transportation Research Part A: Policy and Practice*. 46(3), pp. 421-434. DOI: 10.1016/j.tra.2011.11.005

Csiszár, Cs. (2009) Operating carsharing systems based on telematics. *Városi Közlekedés*. 49(4), pp. 213-220. (in Hungarian)

dell'Olio, L., Ibeas, A., Cecin, P. (2011) The quality of service desired by public transport users. *Transport Policy*. 18(1), pp. 217-227. DOI: 10.1016/j.tranpol.2010.08.005

El Fassi, A., Awasthi, A., Viviani, M. (2012) Evaluation of carsharing network's growth strategies through discrete event simulation. *Expert Systems with Applications*. 39(8), pp. 6692-6705. DOI: 10.1016/j.eswa.2011.11.071

European Commission (1999) *MEANS collection: evaluating socio-economic programmes*. Luxembourg: Office for Official Publications of the European Communities Inc.

Gaal, G., Horváth, E., Török, Á., Csete, M. (2015) Analysis of Public Transport Performance in Budapest, Hungary. *Periodica Polytechnica Social and Management Sciences*. 23(1), pp. 68-72. DOI: 10.3311/PPso.7724

Headicar, P., Banister, D. (2014) Land Use and Transport: Settlement Patterns and the Demand for Travel. Planning for Sustainable Travel. [Online] Available from: http://www.plan4sustainabletravel.org/downloads/cfit_background_report.pdf [Accessed: 22th November 2014]

Jorge, D., Correia, G., Barnhart, C. (2012) Testing the validity of the MIP approach for locating carsharing stations in one-way systems. *Procedia – Social and Behavioral Sciences*. 54, pp. 138-148. DOI: 10.1016/j.sbspro.2012.09.733

Kent, J. L., Dowling, R. (2013) Puncturing automobility? Carsharing practices. *Journal of Transport Geography*. 32, pp. 86-92. DOI: 10.1016/j.jtrangeo.2013.08.014

Kovács, G. (2009) The structure, modules, services, and operational process of modern electronic freight and warehouse exchanges. *Periodica Polytechnica Transportation Engineering*. 37(1-2), pp. 33-38. DOI: 10.3311/pp.tr.2009-1-2.06

Krumke, S. O., Quilliot, A., Wagler, A. K., Wegener, J.-T. (2013). Models and Algorithms for Carsharing Systems and Related Problems. Electronic Notes in Discrete Mathematics 44, pp. 201-206. DOI: 10.1016/j.endm.2013.10.031

Kuhnimhof, T. G., Wirtz, M. (2012) From generation golf to the generation multimodal. *Nahverkehr*. 30(10), pp. 7-12. (in German)

Loose, W. The State of European Car-sharing. Eltis. [Online] Available from: http://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/momo_car-sharing_the_state_of_european_car_sharing_en.pdf [Accessed: 7th September 2014]

Mándoki, P. (2003) Estimation methods of public transportation systems. *Városi Közlekedés*. 43(4), pp. 189-194. (in Hungarian)

Maurizio, B., Alberto, C., Alessandro, L. (2014) The relocation problem for the one-way electric vehicle sharing. *Networks*. 64(4), pp. 292-305. DOI: 10.1002/net.21585

Redman, L., Friman, M., Gärling, T., Hartig, T. (2013) Quality attributes of public transport that attract car users: A research review. *Transport Policy*. 25, pp. 119-127. DOI: 10.1016/j.tranpol.2012.11.005

Scarpellini, S., Valero, A., Llera, E., Aranda, A. (2013) Multicriteria analysis for the assessment of energy innovations in the transport sector. *Energy*. 57, pp. 160-168. DOI: 10.1016/j.energy.2012.12.004

Tóth, Cs., Ágoston, Gy. (2014) *Az informatika korszerű technikái - Developement opportunities of carpooling in Hungary*. Új Mandátum Könyvkiadó, Budapest. (in Hungarian)

Tudela, A., Akiki, N., Cisternas, R. (2006) Comparing the output of cost-benefit and multicriteria analysis: An application to urban transport investment. *Transportation Research Part A: Policy and Practice*. 40(5), pp. 414-423. DOI: 10.1016/j.tra.2005.08.002

Yedla, S., Shrestha, M. (2003) Multi-criteria approach for the selection of alternative options for environmentally sustainable transport system in Delhi. *Transportation Research Part A: Policy and Practice*. 37(8), pp. 717-729. DOI: 10.1016/S0965-8564(03)00027-2