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EVALUATION OF INFLUENCE OF MOBILITY MANAGEMENT INSTRUMENTS IMPLEMENTED IN SEPARATED AREAS OF THE CITY ON THE CHANGES IN MODAL SPLIT

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Abstract: *The article presents results of research aimed at construction of the model for evaluation of potential impact of mobility management instruments implemented in areas of high volume of work related trips. The model helps forecast the impact of the instruments application on the changes in modal split. In proposed approach the potential decrease in the car share depends on the improvement of public transport accessibility of the area and its current private transport accessibility. Due to the specific nature of the analyzed problem the elements of fuzzy set theory have been used to construct the model. To determine unknown volumes of decreases results achieved during implementation of mobility plans in the European workplaces with high number of employees have been taken under consideration. Approximation of the surface received as a result of fuzzy inference has been conducted using formula of multiple linear regression. Prepared model has been applied on the example of Cracow to evaluate of potential impact of mobility plans on the change in modal split.*

Key words: *mobility management, modal split ,transport accessibility, fuzzy inference*

1. Introduction

Because of the growing size of negative occurrences related to the mobility different measures in order to reduce its scale are undertaken (Banister, 2005; Jacyna et al. 2014). One of very promising approaches indicates changes in travel behaviour, including decrease in the number of private car trips as a tool of mitigation of negative impact of travelling in cities (COM, 2007; COM, 2011; Garling and Steg, 2007; Starowicz, 2011; Rudnicki et al. 2010). Concept focused on change of transport behavior is called ***mobility management*** and is aimed at shaping demand for alternative transport modes to private cars, including public transport means, pedestrian and bicycle trips (Loukopoulos, 2007; Meyer, 1999; Starowicz, 2007; Stradling et al. 2000; Taylor and Ampt, 2003).

In the transport policy the European Commission indicates necessity of implementation of measures oriented towards changes of transport behavior of people travelling to work. In the "Green Paper" (COM, 2007) and „Action plan on urban mobility" (COM, 2009) the significant role of enterprises and public sector entities is underlined since their pro-mobility strategy may contribute with shaping transport behaviors of their employees. It is necessary to encourage companies, especially those of high number of employees to create so called mobility plans (Bojczuk, 2011; Nosal, 2009; Valiente, 2012) and implement of mobility management instruments (Loukopoulos, 2007). Exceptionally significant is cooperation of companies with transport managers and operators also in the scope of improvement of quality of public transport services and improvement of transport accessibility to workplaces. Special case are selected areas of the city, such as: business, industrial or other zones which everyday generate and absorb many trips related to work, including private cars (MoMa.BIZ; Sandyford Smarter Travel, 2012). Implementation of mobility management instruments in those zones may be a chance to convince drivers to resign of use of cars and gradually raising of competitiveness of other transport means may encourage current users to continuing.

The article presents results of research aimed at construction of the model for evaluation of potential impact of sets of mobility management instruments implemented in areas (transportation zones) of high volume of trips related to work to decrease share of car trips. Prepared model has been used to evaluate of potential impact of implementation of sets of mobility management instruments on changes in modal split in selected transport zones in Cracow as well as in trips on relations "Home-Work" in the urban area.

2. Assumptions of defining model

While constructing model for evaluation of potential impact of mobility management instruments implemented in the areas absorbing high volume of trips related to work following assumptions and annotations have been taken under consideration:

1. In trips related to work mainly public transport means may be the most competitive alternative for cars so it is assumed that implemented instruments should mainly be based on improvement of travel conditions provided in public transport and, mainly this transport mean will take over trips which so far have been carried out by car.
2. It is assumed that instruments will be implemented by employers located in the analyzed zone and by transport managers and operators cooperating with employers. Employers will mainly apply measures encouraging to travelling by public transport, including financial, information, promotional and educational instruments. Besides they will also use instruments connected with organization of parking a car, work times and encouraging for travel by other sustainable transport means. As a result of cooperation with transport managers and operators mobility management instruments devoted to improvement of accessibility of the area by the public transport means, e.g. : introduction of new public transport lines and direct connections, change of public transport routes or stops locations in order to improve access to the area or employees' places of residence as well as introduction of intermediate stops, providing separated bus lines, increasing frequency of lines' courses. It was assumed that only integrated measures contributes with increase of accessibility with public transport means and other tools may bring expected effect finally leading to the decrease in car share in trips.
3. It was assumed that the volume of expected relative decrease in car share in trips in certain areas is affected by instruments implemented by employers but mainly it is dependent on improvement of current accessibility with public transport means and on current accessibility of the area with private cars. This assumption is justified by the fact that in this case forecast volume of decrease in private car share in trips is potentially dependent on factors related to the area – not employees and employers. This is why it was necessary to indicate factors differentiating areas and influencing the volume of expected decrease. Adoption transport accessibility as a factor differentiating areas seems to be the most justifiable taking under consideration results of analysis on implementation of mobility plans in Polish workplaces which prove that improvement of travelling conditions by public transport, including reduction of travel time is necessary to achieve stimulation of changes in modal split which will result with improvement of accessibility of the area (CiViTAS CARAVEL, 2008; Nosal, 2014). Improvement of transport accessibility, including public transport means supports process of achievements in mobility management, especially if its improvement is accompanied by introduction of incentives for decrease car share in trips (Chapman and Weir, 2008; Faron, 2014; Litman, 2008). In the current research as measures differentiating areas, factors of transportation zone accessibility by public and individual transport described with formulas have been used. Those factors have been proposed by A. Szarata and the methodology of its calculation is presented further in this article.
4. The volume of relative decrease of car share in trips to work as a result of implementation of set of analyzed instruments in the scale of the specific area in Poland is not recognized. There is also a lack of detailed data in this scope in the foreign countries. Referring to this expected volume of decrease in private car share in trips has been assumed based on the data from the research on the European mobility plans for large workplaces and corrected in the reference to the area scale analysis.
5. Process of modelling volume of relative decrease in private car share in trips according to the transport accessibility of the area has been conducted using elements of fuzzy set theory. Fuzzy inference enables to analyze issues cursed

with incomplete information, phenomenon of qualitative nature and of inaccurate and ambiguous parameters (Driankov, 1996; Kacprzyk, 1986; Rutkowska, 1997; Szarata, 2013; Szarata, 2014). Modelling of changes in modal split caused by implementation of mobility management instruments is a complex and multithreaded problem which makes its description exceptionally difficult. Decision about change of transport mean is affected by many different factors including those of psychological, sociological and culture nature, and continuation of habits related to the use of car is not always predictable. Taking under consideration above it is unfounded to analyze this issue as a fuzzy concept and apply elements of fuzzy set theory in the modelling process.

6. Only internal journeys have been analyzed, external trips were not included because of lack of survey results on the suburban areas in most cities. Besides internal journeys require intervention with instruments of mobility management in the first ordering. Mobility management instruments may contribute with the highest effectiveness in reference to the internal journeys.
7. In the research trips of morning peak when obligatory trips are dominating including those, conducted to work have been analyzed.

3. Elaboration of structure of model of fuzzy interference evaluating the volume of decrease in car share in trips

Elements of theory of fuzzy sets have been used for modelling of volume of decrease in car share in trips depending on improvement of accessibility to the area by public transport and current accessibility to the area by private transport. Process of inference was supported by toolbox *Fuzzy Logic Design* – Matlab software (Wath Works, 2012), which enables to use Mamdani layout (Mamdani, 1977).

Two input data (predecessor of the rule) and one output data (successor of the rule) described by suitable fuzzy sets are assumed.

First input data (predecessor of the rule) refers to the evaluation of current volume of indicator of accessibility to the area by public transport means and is the linguistic variable called *TZ accessibility*. Although input data refers to the current volume of indicator of accessibility to the area by public transport means, it is assumed that as a result of implementation of mobility management instruments improvement of current volume of indicator will be achieved to a higher level. Decrease in share of car trips will be dependent on improved transport accessibility – not on the current one.

Second input data (predecessor of the rule) refers to the evaluation of current volume of indicator of accessibility by private transport and will be the linguistic variable: *TI accessibility*. It is assumed that any changes of current volume of accessibility by private transport will not appear and it is assumed as input data to provide reference to considerations about possible decrease in car share in trips caused by implementation of measures aimed at improvement of accessibility of the area by public transport.

Although mobility management instruments implemented by employers haven't been accepted as input data in the model of fuzzy inference directly, it is assumed that they strengthen effectiveness of measures aimed at improvement of accessibility of the area by public transport means.

Output data (successor of the rule) is evaluation of volume of relative decrease in car share in trips which may be achieved with implementation of mobility management instruments (described as a linguistic variable: *decrease*). General concept of created inference model is presented in figure 1 and its schematic diagram – in figure 2.

The following set of the linguistic terms for input data (predecessor of the rule) and output data (successor of the rule) is assumed:

– predecessor of the rule:
  „TZ accessibility” = {„very low”, „low”, average”, „high”, „very high”},
– predecessor of the rule:
  „TI accessibility” = {„very low”, „low”, average”, „high”, „very high”},
– successor of the rule:
  „Decrease” = {„very low”, „low”, average”, „high”, „very high”}.

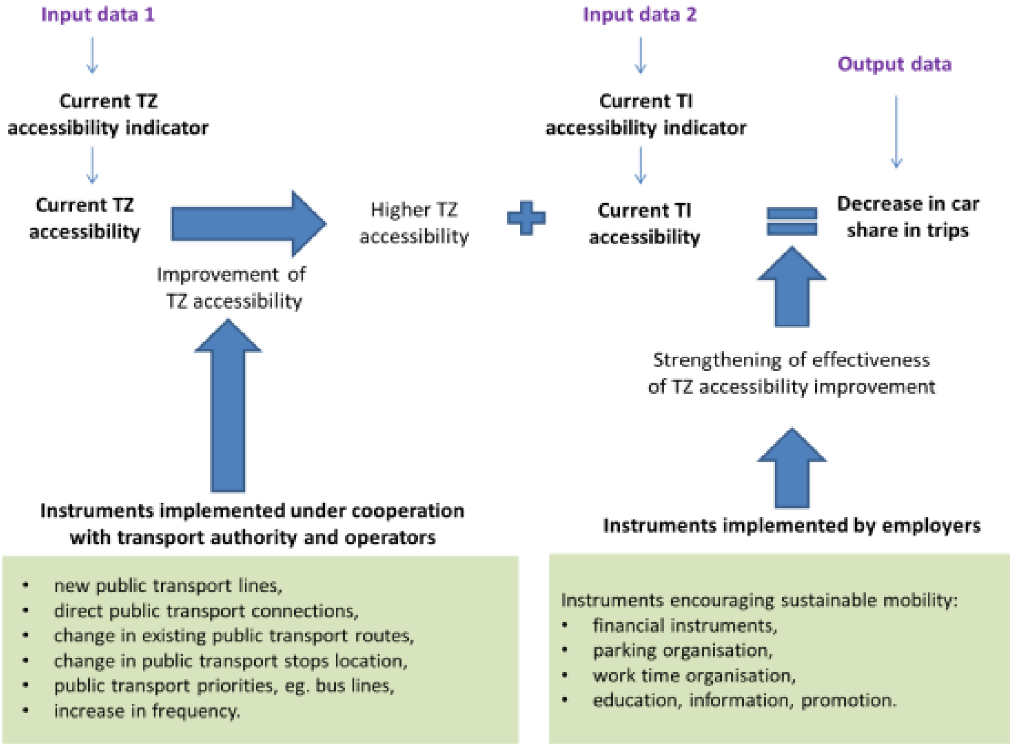

Fig. 1. General concept of created inference model.

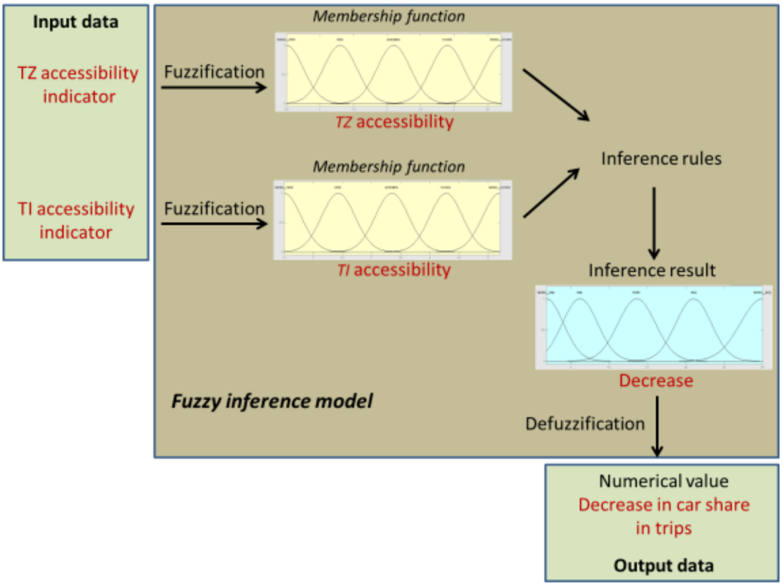

Fig. 2. Schematic diagram of the model.

4. Indication of shape of membership function for the data related to the transport accessibility and decrease in private car share

One of the key elements of the fuzzy inference is suitable selection of membership function. In this article to indicate all membership functions the Gauss function, described in the formula, is applied (The Math Works Inc., 2000):

$$f\left(x,\delta,c\right)=e^{\frac{-(x-c)^2}{2\delta^2}} \tag{1}$$

where: δ, c are function parameters (δ – standard deviation, c – mean value).

To calculate membership function for the input data *(TZ accessibility, TI accessibility)* it was necessary to define the scope of possible data. To achieve this, for both input data indicators of public transport accessibility and private transport accessibility have been calculated for each of transportation zones in Cracow with the formulas proposed by Szarata (2013). Public transport accessibility indicator for the transportation zone was calculated with the following formula (Szarata, 2013):

$$A_{i,PuT}=\frac{\sum_j T_{ij}^{PuT}}{\sum_j\left(t_{ij,t}^{PuT}\cdot T_{ij}^{PuT}\right)} \tag{2}$$

where:

$A_{i,PuT}$ - public transport accessibility indicator for the transportation zone i [h^{-1}],

$t_{ij,t}^{PuT}$ - public transport travel time between zones i and j for analysed time period t [h],

T_{ij}^{PuT} - number of trips between zones i and j realised by public transport modes.

Private transport accessibility indicator for the transportation zone was calculated with the following formula (Szarata, 2013):

$$A_{i,PrT}=\frac{\sum_j T_{ij}^{PrT}}{\sum_j\left(t_{ij,t}^{PrT}\cdot T_{ij}^{PrT}\right)} \tag{3}$$

where:

$A_{i,PrT}$ - private transport accessibility indicator for the transportation zone i [h^{-1}],

$t_{ij,t}^{PrT}$ - private transport travel time between zones i and j for analysed time period t [h],

T_{ij}^{PrT} - number of trips between zones i and j realised by private transport modes.

For calculation of the indicators simulation transport model of Cracow agglomeration, created in the Visum software (PTV AG) has been created on the basis of results of the Comprehensive Traffic Research 2013 (Konsorcjum Wykonawców, 2014). In the model matrix of journey times related to connections between transportation zones and number of trips from origin – destination matrix, separately for each of analyzed transport mean. The minimal value of the public transport accessibility indicator for transportation zones *(MIN TZ accessibility indicator)* was 0,5 [h^{-1}], and the maximum value (*MAX TZ accessibility indicator*) – 3,66 [h^{-1}]. It was assumed that scope of input data for public transport accessibility in Cracow is included in the interval: *TZ accessibility* $\in$<0,5;3,7> [h^{-1}]. Minimal value of the private transport accessibility indicator (*MIN TI accessibility indicator)* is 1,5 [h^{-1}], and the maximum value *(MAX TI accessibility indicator)* – 5,17 [h^{-1}]. Those it was assumed that scope of input data for private transport accessibility in Cracow is included in the interval: *TI accessibility* $\in$<1,5;5,2> [h^{-1}].

Shape and range of functions for specific terms describing linguistic variables *TZ accessibility* and *TI accessibility* have been indicated with intuition and own experience as well as referring to the results of research on issues connected with transport accessibility (CiViTAS CARAVEL, 2008; Faron, 2014; Nosal, 2014; Szarata, 2013). Whole range of values that can refer to the accessibility indicators was divided for 5 sections matching with accepted terms describing linguistic variables:

„TZ accessibility" = {„very low", „low", average", „high", „very high"}
„TI accessibility" = {„very low", „low", average", „high", „very high"}

Membership functions defined for all terms describing linguistic variable *TZ accessibility* are presented in figure 3, whereas functions for terms describing linguistic variable *TI accessibility* – in figure 4.

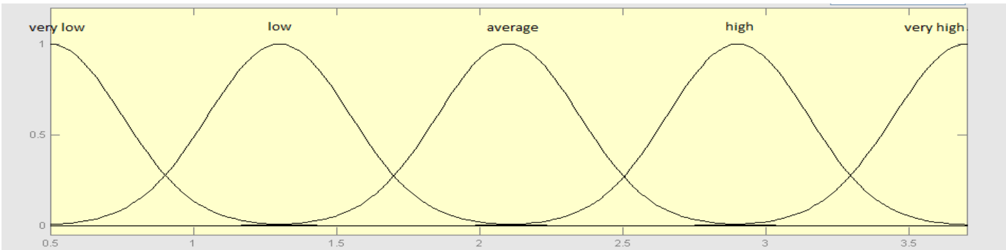

Fig. 3. Membership functions for terms describing linguistic variable *„TZ accessibility”.*

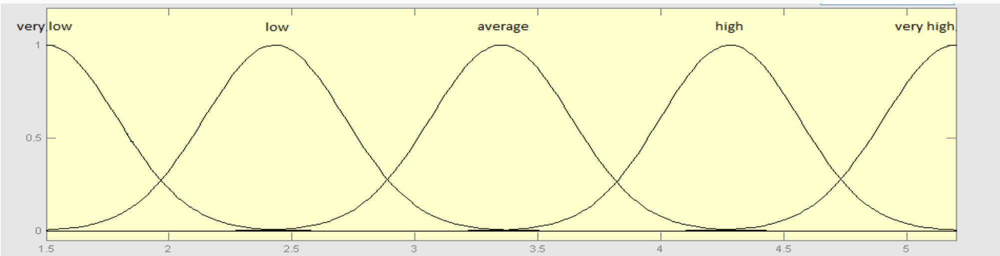

Fig 4. Membership functions for terms describing linguistic variable *„TI accessibility”.*

Indicating membership functions for output data it is necessary to bear in mind restriction connected with the lack of detailed data about volume of decrease in share private car in trips to work in the area. Information about implementation of those type of initiatives may be found in the European sources (CiViTAS ARCHIMEDES; CiViTAS MODERN; INVOLVE; LEPT; Valiente, 2012). Although they refer to different aspects of implementation they do not include detailed data concerning achieved/expected decreases. Few examples found in available sources inform about results of implementation of the instruments and achieved relative decrease in car share in trips on the level of 27% (IDAE, 2002) and 7% (OECD, 2014). Each example illustrates implementation of instruments which consequently has provided growth of public transport accessibility to the areas. Acceptation of the membership function just on the basis of those two examples has been not sufficient so that the results of 18 mobility plans for the European workplaces employing more than 1000 employees (number of travelers to work in the area comparable with number of employees in large workplaces) have been used as well.

In the scope of those plans instruments for improvement of workplace accessibility by the means of public transport. For each of 20 examples for variable related to the relative decrease in car share in trips, the values referring to the average and individual percentiles have been indicated. Indicated values are presented in the table 1.

Table 1. Percentiles and mean value for variable: relative decrease in car share in trips for 20 analyzed cases of mobility plans.

Percentile/mean	Relative decrease in car share [%]
percentile 1	1,8
percentile 10	3,1
percentile 25	6,2
percentile 50	9,0
mean	13,6
percentile 75	21,0
percentile 90	30,0
percentile 99	41,8

Taking under consideration information included in the table 1, as a low limit of the area covering values of expected relative decreases of car share in trips, the value of 1,8% describing percentile 1 has been proposed. Basing on experience and taking under consideration zonal scale of conducted research, extreme value describing the percentile 99 and as a top limit of the area the value of 30% describing percentile 90 has been proposed. The area of consideration has been restricted in the section <1,8;30,0>%. Whole scale of expected relative decrease – possible to achieve with mobility

management instruments – has been divided into 5 sections referring to accepted terms describing linguistic variable *decrease:*
„Decrease” = {„very low”, „low”, average”, „high”, „very high”}.
Membership functions for individual terms have been described with the Gauss curve equation (formula 1) taking under consideration information on average value and values describing individual percentiles presented in the table 1. Elaborated membership functions defined for all terms describing linguistic variable *decrease* were presented in figure 5.
Determining shape of the membership function has been based on the intuition and knowledge of researchers experienced in researches on analyzed phenomenon. Thanks this proposed model may be characterized with versatility of application but at the same time this method of determining membership function is burdened with some subjectivism of the evaluation. To verify assumption concerning use of elaborated membership function analysis of sensitivity has been conducted and shapes of function have been modified (values of standard deviation δ), both for input and output data. Results of sensitivity analysis proved that average differences appearing in the volumes of decreases calculated with use of model with basic functions and accepted scenarios of modifications of function are very small and does not exceed 0,26 of percentage point. It is to be expected that even bigger modification of shapes of membership function then determined for sensitivity analysis wouldn't cause significant differences in the calculated volumes of decreases. It has confirmed possibility to use of determined membership functions for the purposes of created model.

5. Elaboration of inference rules and determination of the scope of possible results of the model describing volume of expected decrease in car share

The last component of created model of fuzzy inference is block of inference rules, including set of rules type: IF...THEN. For the requires of current research semantics of rules is fixed with conjunction AND in predecessor of inference rules and then set of all possible rules has been created. Number of all possible inference rules is: R=5*5*5 =125 (five terms describing linguistic variable *TZ accessibility*, five terms describing linguistic variable *TI accessibility* and five terms describing linguistic variable *decrease*). Among generated rules those illogical and those which seemed to be improbable have been rejected. Finally 25 inference rules have been accepted. Constructing rules has been based on the assumption that current accessibility to the area with public transport would be improved as a result of implementation of mobility management instruments (fig. 1). For example, even if current *TZ accessibility* is „*low*", implementation of instruments will bring some improvement so that *TZ accessibility* becomes „*average*". While taking into account current *"low" TI accessibility* the effect of *"average" decrease* car share in trips to work in this area may be expected. For all rules value of 1,0 was assumed so that they are treated in the same way in the whole process of inference.
Next phase of the fuzzy inference process implemented with the Matlab software (Wath Works, 2012), was related to the aggregation and defuzzification of the output data. Those operations are resulted with the output data as figure numerical value of relative decrease in car share in trips.

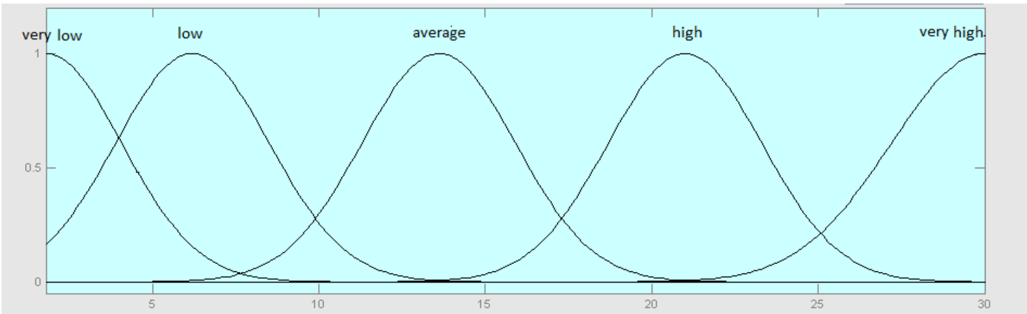

Fig 5. Membership functions for terms describing linguistic variable *„decrease”.*

Inclusion of the inference system in the Matlab software enables to receive a set of results as the surface of solutions for each possible set of input data (*TZ accessibility indicator* and *TI accessibility indicator*). This surface, created in the three-dimensional spatial arrangement, present connection between current public transport accessibility indicator of the transportation zone (assuming that the indicator is the subject of improvement as a result of implementation of mobility management instruments), current private transport accessibility indicator to the zone and expected relative decrease in car share in trips to work in the zone (fig. 6).

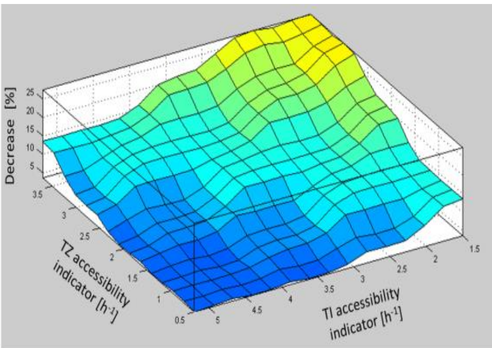

Fig. 6. Surface of the fuzzy inference model.

While analyzing received surface it may be noted that in the process of fuzzy inference extreme volumes of decreases have been eliminated, very close 1,8% and very close 30%. Volumes of potential decreases of car share in trips to work range between 3,5% in the least favorable conditions (value of indicator of public transport accessibility is on the lowest level) and 27,7% in the most favorable conditions (value of indicator of public transport accessibility is on the highest level and indicator of individual transport accessibility – on the lowest level).

6. Approximation of the resulting surface of the model of fuzzy inference describing volume of expected decrease in car share

Application of the elaborated model in practice requires mathematical description of received resulting surface. Looking for suitable formula following activities have been undertaken: from the created inference system coordinates of points which create surface presented in the figure 6 have been determined, then using the Statgraphics program (StatPoint Inc.), attempt of approximation of the function which described this has been undertaken. After many attempts model of linear, multiple regression and formula describing relation between volume of expected decrease in car share in trips and current public transport accessibility indicator of the transportation zone (assuming that improvement of the indicator is a result of mobility management instruments) and current private transport accessibility indicator is:

$$Decrease_i = 16{,}22 + 4{,}57 \cdot wd\,TZ_i - 3{,}95 \cdot wd\,TI_i \quad (4)$$

where:

$Decrease_i$ – expected relative decrease in car share in work related trips to the transportation zone *i*, received as a result of the mobility management instruments implementation [%],

$wd\,TZ_i$ – current public transport accessibility indicator for the transportation zone *i* [h^{-1}],

$wd\,TI_i$ – current private transport accessibility indicator for the transportation zone *i* [h^{-1}].

Evaluation of the quality of the model has been conducted on the level of significance 0,05. Quality of received results of approximation of resulting surface is described with parameters: R^2 = 93,13 [%], Rs^2= 93,01 [%], SEE = 1,8 [%], MAE = 1,4 [%]. It seems that taking under consideration the subject of analysis values of received parameters are the most sufficient.

Scope of model application is limited to the values of defined indicators of accessibility to the transportation zones in Cracow. In the case of public transport accessibility indicator the scope of model application is between 0,5 and 3,7 [h^{-1}], and for individual transport accessibility indicator – from 1,5 to 5,2 [h^{-1}].

Volumes of potential decreases in car share in trips, possible to determine with accepted model range between -2,0% and 27,2%, so it may be noted that adaptation of approximated equation on the base of received resulting surface caused – comparing to the results of fuzzy inference system – slight increase including volumes of expected decreases. It seems that it made real the results, especially for the least beneficial cases which volumes of decreases may take negative value.

Possibility to receive negative values points out significant regularity – in situation when individual transport accessibility to the area is very high and public transport accessibility very low even its slight growth may not cause required changes if it is not accompanied by additional activities.

7. Application of the model for evaluation of implemented sets of instruments impact in the selected areas in Cracow on changes in modal split

80 transportation zones in Cracow absorbing the biggest internal traffic flows related to work in the morning peak hours have been selected to apply created model for evaluation of instruments impact on changes in modal split. Selection of zones was based on the results of the Comprehensive Traffic Research 2013 (Konsorcjum Wykonawców, 2014). Using formulas (2) and (3), public and private transport accessibility indicators for separate analyzed zones have been determined and using accepted model (4) – volume of relative decreases in car share in trips to zones achievable as a result of implementation of set of mobility management instruments have been determined. Determined values of indicators and calculated volume of decreases for exemplary ten zones have been listed in the table 2. Those values are differential and visibly dependent on accepted values of accessibility indicators. Average value of relative decrease for all analyzed 80 transportation zones in Cracow was 14,95%, the minimum value – 9,89%, the maximum value – 19,86%.

Data concerning indicated decreases has been used for testing scenarios related to potential changes in modal split achievable in dependence on percentage of employers implementing mobility management set of instruments (independently and in cooperation with transport managers and operators). 5 scenarios have been assumed:

- V20 – 20% of employers located in the transportation zone implement instruments independently and in cooperation with transport managers and operators,
- V40 – 40% of employers located in the transportation zone implement instruments independently and in cooperation with transport managers and operators,
- V60 – 60% of employers located in the transportation zone implement instruments independently and in cooperation with transport managers and operators,
- V80 – 80% of employers located in the transportation zone implement instruments independently and in cooperation with transport managers and operators,
- V100 – 100% of employers located in the transportation zone implement instruments independently and in cooperation with transport managers and operators.

Results received for specific scenarios concerning volume of car share in trips to selected 10 zones are presented in the table 2. Also differences between volumes of shares indicated for base scenario V0 where non instruments are implemented and for considered scenarios V20-V100 (differences are expressed in percentage points) are presented in this table. It is noticeable that together with percentage of employers implementing instruments, effectiveness of measures undertaken in the area is growing.

Bearing in mind assumed scenarios impact of sets has been also considered in the relation to the potential number of transportation zones where instruments would be implemented (assuming that instruments would be implemented firstly in zones of the highest number of trips related to work). Results of calculation concerning potential changes in car share in all internal trips in the morning peak hours in the relation Home-Work are presented in the table 3.

Analyzing results listed in the table 3 it is noticed that – in the least favorable situation, if instruments are implemented in only 10 transportation zones by 20% employers (independently and in cooperation with transport managers and operators) car share in internal trips in the relation Home-Work in the morning peak hours could decrease from 48,9% to 48,7% (decrease in 0,2 percentage point). In the most favorable situation (80 transportation zones, 100% employers implementing instruments) car share could be decreased from 48,9% to 43,7% (5,2 percentage point). Thus even the smallest intervention with mobility management instruments in the areas absorbing large traffic flows related to work contributes with beneficial changes in modal split in the city scale – in trips in the relation Home-Work in the morning peak hours.

Table 2. Potential volume of car share in Home-Work trips (internal traffic) to the chosen 10 transportation zones, received as a result of the mobility management instruments implementation.

Item number	TZ accessibility indicator [h^{-1}]	TI accessibility indicator [h^{-1}]	Relative decrease in car share [%]	Volume of car share in trips to the transportation zone [%]						Difference [percentage point]				
				Scenario V0	Scenario V20	Scenario V40	Scenario V60	Scenario V80	Scenario V100	V20 - V0	V40 – V0	V60 – V0	V80 – V0	V100 – V0
1	3,11	3,88	15,12	34	33	32	31	30	29	-1	-2	-3	-4	-5
2	3,34	5,01	11,70	34	33	32	31	31	30	-1	-2	-3	-3	-4
3	3,59	4,50	14,83	51	50	48	46	45	43	-1	-3	-5	-6	-8
4	2,70	2,60	18,28	34	33	32	30	29	28	-1	-2	-4	-5	-6
5	3,05	3,23	17,40	51	49	48	46	44	42	-2	-3	-5	-7	-9
6	3,08	5,17	9,89	53	52	51	50	49	47	-1	-2	-3	-4	-6
7	3,32	4,71	12,75	41	40	39	38	37	36	-1	-2	-3	-4	-5
8	2,09	3,58	11,64	57	56	55	53	52	51	-1	-2	-4	-5	-6
9	2,56	2,32	18,78	56	54	52	49	47	45	-2	-4	-7	-9	-11
10	3,52	4,49	14,56	33	32	31	30	29	28	-1	-2	-3	-4	-5

Table 3. Potential volume of car share in Home-Work trips in morning peak hour (internal traffic), received as a result of instruments implementation in chosen transportation zones in Cracow.

The number of transportation zones	Volume of car share in trips/ Difference relative to the base scenario V0*	Scenarios				
		V20	V40	V60	V80	V100
10	Volume of car share in trips [%]	48,7	48,4	48,2	47,9	47,7
	Difference relative to the base scenario V0 [p.p.]	-0,2	-0,5	-0,7	-1,0	-1,2
20	Volume of car share in trips [%]	48,5	48,0	47,6	47,1	46,7
	Difference relative to the base scenario V0 [p.p.]	-0,4	-0,9	-1,3	-1,8	-2,2
30	Volume of car share in trips [%]	48,3	47,7	47,2	46,6	46,0
	Difference relative to the base scenario V0 [p.p.]	-0,6	-1,2	-1,7	-2,3	-2,9
40	Volume of car share in trips [%]	48,2	47,5	46,9	46,2	45,5
	Difference relative to the base scenario V0 [p.p.]	-0,7	-1,4	-2,0	-2,7	-3,4
50	Volume of car share in trips [%]	48,1	47,3	46,5	45,7	44,9
	Difference relative to the base scenario V0 [p.p.]	-0,8	-1,6	-2,4	-3,2	-4,0
60	Volume of car share in trips [%]	48,0	47,2	46,3	45,4	44,6
	Difference relative to the base scenario V0 [p.p.]	-0,9	-1,7	-2,6	-3,5	-4,3
70	Volume of car share in trips [%]	47,9	47,0	46,0	45,1	44,1
	Difference relative to the base scenario V0 [p.p.]	-1,0	-1,9	-2,9	-3,8	-4,8
80	Volume of car share in trips [%]	47,9	46,8	45,8	44,7	43,7
	Difference relative to the base scenario V0 [p.p.]	-1,0	-2,1	-3,1	-4,2	-5,2
* Volume of car share in Home-Work trips in morning peak hour (internal traffic) for base scenario **V0 = 48,9%**.						

8. Conclusions

Estimation of the number of persons who resign to travel by car to work in the scale of the area gains a particular importance, especially because of growing interest in the application of mobility management instruments to ease the negative impact of mobility. In the proposed approach, relative decrease in care share in trips to the zone of high number of working people are dependent on the improvement in the accessibility by the public transport and current accessibility by the individual transport. It was also assumed that the instruments implemented by employers strengthen effectiveness of instruments focused on the improvement of public transport accessibility. In the analysis elements of fuzzy inference have been applied as well own intuition, knowledge and experiences in this scope have been used. To determine unknown volumes of decreases results achieved during implementation of mobility plans in the European workplaces with high number of employees have been taken under consideration. Affiliation functions of input data and given output have been elaborated and final adoption of those functions has been enabled by results of sensitivity analysis not revealing significant differences in the case of modification of shape function.

Approximation of the surface received as a result of fuzzy inference has been conducted using formula of multiple linear regression which enabled adoption of model describing analyzed phenomenon. Interpretation of importance of accepted formula requires to take into account its contractual nature indicating expected decrease in care share in trips to work.

Application of accepted model on the example of Cracow has confirmed the influence of sets of mobility management instruments on the changes in modal split in zones where they are implemented as well as in trips in the city. Results of the research prove that mobility management instruments have multidimensional effectiveness and contribute with improvement of accessibility of urban areas with public transport means and confirm legitimacy its application by public and private sector entities.

Although construction of the model has been based on Cracow data, it is possible to apply it in conditions of different cities using suitable healing indicators, created by the authors but not described in the article due to its size. Next phase of the research on the effectiveness of mobility management instruments implemented in the areas absorbing large traffic flows related to work will be an attempt at verification of the created model.

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