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ScienceDirect

Procedia - Social and Behavioral Sciences 111 (2014) 604 – 613

Procedia
Social and Behavioral Sciences

EWGT2013 – 16th Meeting of the EURO Working Group on Transportation

Evaluation of Residential Area Proposals Using Spatial Interaction Measure: Case Study of Denizli, Turkey

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Abstract

Spatial interaction may be defined as potentiality of people to reach the opportunities in urban areas. Land use plans or transportation plans directly affect the potential of spatial interaction. Thus, amount of spatial interaction correspondingly changes with the planning impacts. This study aims to find and utilize spatial interaction change in decision making stages of residential area proposals. Impedance matrices and land use data have been obtained from urban public transportation plan and land use plan of Denizli, Turkey. The spatial interaction of the city has been found by using potential accessibility (PA) measure for the current situation. PA has been calculated for the projection year (2030) and its change has been obtained. A land use regulation algorithm have been offered to find out the amount of area which is required to regain the decreased PA. The space which is proper for residential stock has been compared with the pretended residential area in zonal case. Thus, the zones which are proper for new residential are proposals have been determined.

Keywords: Land use; spatial interaction; potetial accessibility; urban public transport.

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1. Introduction

Land use models explain the spatial distribution land use types like residential, commercial or educational areas and generate predictions for future, in a context of transportation (Cubukcu, 1959). Land use and transportation are the most significant components of cities that have mutual interaction. Spatial interaction may be defined as the intersection point of these two components and it is realized as movement of people between origin and destination. Thus, any addition or reduction on these components may cause to change in spatial

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Selection and/or peer-review under responsibility of Scientific Committee
doi:10.1016/j.sbspro.2014.01.094

interaction. These kind of changes in the transport supply, in turn, influence the residential and work location choices of the population as well as business location decisions, thus influencing the land-use configuration (Sivamukar, 2007). These concepts are used by urban social analysts to explain why land values are high in the central areas of cities and at other easily accessible points. Measuring the changes with various models and considering them in land use planning consolidate the accuracy of the given decisions.

Gravity model has been utilized on planning field and has been identified as potential interaction with opportunities (Hansen, 1959). Potential accessibility measures (also called gravity-based measures) have been widely used in urban and geographical studies since the late 1940s; well-known studies are from Stewart (1947), Hansen (1959), Ingram (1971) and Vickerman (1974). The potential accessibility measure estimates the accessibility of opportunities in zone i to all other zones (n) in which smaller and/or more distant opportunities provide diminishing influences. Increase on spatial interaction which is a sort of potential accessibility measure may provide more people to reach the basic activities and it may increase the social benefit. It may also be possible to save time, energy and financial benefit for public when more people reach their destination. In such cases, sustainable transportation may be achieved if the demand for using transportation systems reduces. Therefore, planners may utilize these kind of measures and examine the decisions on the scope of spatial interaction measures while planning the land use. Nevertheless, accessibility is one of the best measure to ensure that transportation and land use are working together and it is one of the best measure to check if they can work together in the future (El-Geneidy, 2011).

In addition, Urban Public Transport (UPT) is an another field which directly effects transportation and land use. The UPT planning cause changes on the parameters as: Facility locations, transportation frequencies, traffic volumes, travel demands and journey times. Accessibility and spatial interaction values may then be affected by those changes. Cerdá (2009) has been stated that they can be used to guide decision-making in a more realistic and responsive manner than standard indicators of mobility. Recently, UPT planning studies are applied to passenger or mobility oriented. UPT planning results are generally overlooked in the stage of land use planning. Thus, there is a need for considering those effects in land use planning on the axis of accessibility measures since it may lead to more accurate land use proposals. These measures are useful to evaluate how investments, transportation strategies, and land-use policies affect the performance of the transportation and land-use system. Accessibility as a term has long been used by politicians and planners for descriptions of planning goals. However, accessibility as a concept has seldom been an integral part of the performance measures used to evaluate policies. Consequently, it has had little practical effect on policies. There is thus a need to translate the concept into measures of accessibility so that it can be used to evaluate different alternative policies (Makri & Folkesson,1999). Potential Accessibility (PA) is a well-known and an prior accessibility measure which is studied by many authors in several years. Although both accessibility formulations and land use decision techniques have been used before, there is still a significant gap in using accessibility measures in the decision making stages of land use planning.

This study tries to make a contribution to the current state of the art of land use planning by introducing the use of the PA measure in decision making and feedback process. It offers to use PA as a feedback tool on land use decision making stages of planning. Thus this study evaluates and analyzes the effects of UPT planning to land use in a perspective of spatial interaction measures. Consequently, indicates a land use indicator for planners to audit planning decisions in the scope of feedback process. For this purpose, PA has been utilized. The spatial interaction values of zones have been analyzed in terms of land use proposals. Land use proposals in zones have been compared with the existing land use ratios in terms of PA. Travel impedance is commonly measured by distance or time, estimated by straight-line distance, network distance, network models simulating travel demand, field surveys of actual driving times or surveys of residents' perceived distance or travel time (Makri & Folkesson, 1999). For these purpose, distance impedances are considered and obtained by the help of VISUM software. In this way, land use decisions have been re-analyzed by utilizing PA and UPT planning outcomes by generating a simple algorithm. The results of this study consist of two folds:

1) Calculating zonal PA changes for a city using UPT based impedances
2) Re-establishing the land use proposals by considering PA

2. Methodology & Study Area

2.1. Methodology

PA is a location type accessibility measure and it evaluates the spatial interaction at the zonal level (Geurs, 2001). Many variables have been utilized on the models which have been generated for proposal of residential areas, such as residential stock, type, and price, amount of proper space, distance to central business district, social indicators, economical indicators and physical conditions of existing buildings. Gravity models are one of the most useful tools for studying spatial interactions and spatial flows of people, goods and information. Their appeal stems in large part from their simplicity and generality. They have used in a very wide range of applications in business, economics, engineering, geography, regional science, transportation, and other fields. Gravity Models of Spatial Interaction Behaviour is an outstanding and comprehensive treatment of gravity models (www.people.hofstra.edu).

The aim of this study is to offer an effective land use analysis model by considering PA component on decision levels of land use planning. For this purpose, a three stage model has been proposed in Figure 1.

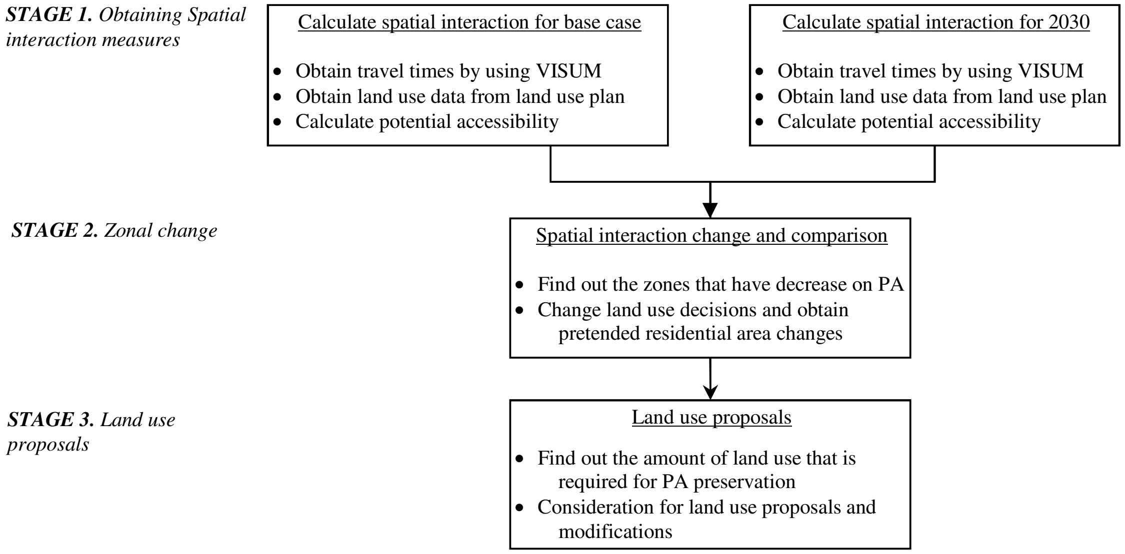

Fig. 1. Flowchart of the proposed land use analysis process

At stage 1, PA measure has been measured for base case and for the year 2030. UPT plan and transportation master plan outputs have been utilized to calculate spatial interaction measure. Travel time matrices have been obtained by using VISUM^{TM}. Land use information has been obtained from the land use plan of the city. The opportunities have been considered as residential areas. PA has been frequently used to estimate the accessibility of opportunities from a zone to others (Stewart 1947; Vickerman 1974). PA can be expressed as the sum of all zones' accessibilities and has the following form (Hansen, 1959):

$$A_i = \sum_j D_j d_{ij}^{-\alpha} \qquad (1)$$

where A_i is the accessibility measure (ha/min) of zone i to all opportunities D_j at zone j, d_{ij} is the impedance factor between zones i and j, and α is the parameter that reflects the impedance of distance.

At stage 2, zones that decrease PA values after the UPT planning are found. PA values that have been reduced are regained afterwards zonal PA values have been recalculated. The residential areas has been enhanced or reduced sequentially and PA has been recalculated until the PA values regain the previous rates. This process has been maintained until all zones have higher PA values than the base case. By this way, the required residential area has been determined. For this purpose, a five-step land use regulation algorithm has been performed in the following way:

```
        for zone i= 1 to n ← n=80
Step 1  (PA Calculation by using Eq.1)
        Calculate $PA_i(2010)$
        Calculate $PA_i(2030)$
Step 2  (PA Change)
        $PA_i(2030) - PA_i(2010) = C_i$
Step 3  (Land use decrease)
        $RA_i$ = Residential area for zone i
        If $C_i > 0$ then $RA_i(2030) - 1$
        Go to Step 1
        End if
Step 4  (Land use increase)
        If $C_i < 0$ then $RA_i(2030) + 1$
        $PA_i(2030) - PA_i(2010)$
        End if
Step 5  (Calculate land use change)
        Obtain pretended proposal $RA_i(2030)$
```

At stage 3, land use types have been offered to regain the decreased PA. Several approaches has been developed to utilize from required spatial interaction values. It is not possible to add all of the pretended residential area proposals since land use decisions are also related with social, economical and physical variables. Thus, proper spaces for residential areas in the zone have been established and pretended additions have been implemented on these zones.

2.2. Study area & Planning History

Denizli is medium scaled city which has a population of 500,000 in central part of the city, located western part of Turkey. Sectoral structure of the city depends on tourism and industry. It consists of 80 zones as in Figure 2.

Fig. 2. Zonal structure of the city

UPT demand is supplied by bus and paratransit modes. Ceylan et al. (2004) has been defined paratransit system in Denizli. There are 32 bus and 14 paratransit routes in the city. Current UPT situation has been analyzed with a timetable-based assignment. For this process, a timetable-based assignment is carried out through VISUM traffic simulation software. (see for details VISUM, 2011). Existing UPT travel demand, service routes, vehicle capacities and timetable information of the UPT services are taken into account. Afterwards, existing frequencies, roads on UPT, modes and routes have been redesigned for the year 2030, in the scope of UPT planning (TMP,2010). Thus new travel time matrices, capacities and traffic volumes have been obtained. Figure 3-a. and 3-b. show the link flows in morning peak period for the base case and for the year 2030.

Fig. 3. (a) link flow ratios for the base case; (b) link flow ratios for the year 2030

Link flows have been increased in the 2030 case since a new design has been constituted and higher demand raised. Figure 4-a. and 4-b. show the UPT modal share for the base case and for the year 2030.

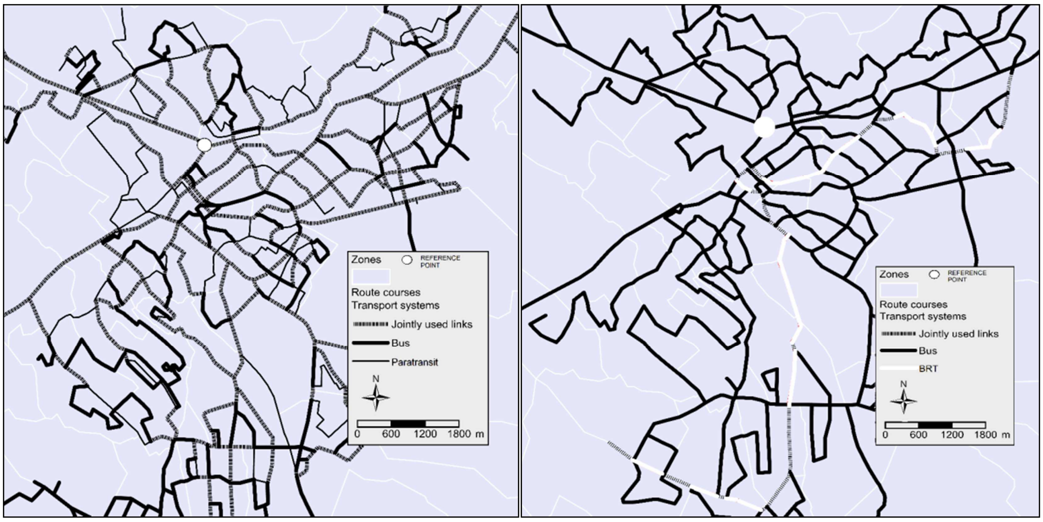

Fig. 4. (a) modal share for the base case; (b) modal share for the year 2030

3. Analyses

3.1. Accessibility measures

PA has been calculated for the current case and for the year 2030. Residential areas have been determined as opportunities and the impedance has been determined as UPT journey time. By this way, the zonal change of PA for 2030 has been obtained. Gulhan *et al.* (2009) stated that the parameter of distance impact has been found as 1.00 through a sensitivity analysis for study area. Table 1 shows PA values for the base case and for the year 2030 and zonal change.

Table 1. PA values and zonal change (ha/min)

	PA				**PA**				**PA**				**PA**		
Zone	**2010**	**2030**	**Change**	**Zone**	**2010**	**2030**	**Change**	**Zone**	**2010**	**2030**	**Change**	**Zone**	**2010**	**2030**	**Change**
1	60.6	152.0	91.4	**21**	100.8	120.2	19.4	**41**	197.3	181.0	-16.3	**61**	209.5	193.1	-16.5
2	77.5	152.6	75.1	**22**	112.4	102.3	-10.1	**42**	192.3	179.7	-12.7	**62**	173.3	155.9	-17.4
3	47.8	117.1	69.3	**23**	113.8	120.1	6.3	**43**	234.1	215.9	-18.2	**63**	165.7	152.8	-12.9
4	138.1	105.9	-32.1	**24**	94.2	157.8	63.6	**44**	198.2	213.7	15.5	**64**	167.9	150.4	-17.5
5	78.1	71.8	-6.4	**25**	99.4	247.7	148.3	**45**	163.5	146.2	-17.3	**65**	171.4	150.0	-21.4
6	76.7	64.6	-12.2	**26**	144.7	255.4	110.8	**46**	119.7	164.7	45.0	**66**	155.8	147.7	-8.1
7	82.9	69.8	-13.0	**27**	83.6	73.2	-10.3	**47**	140.2	206.5	66.3	**67**	216.7	158.0	-58.6
8	127.4	98.4	-29.0	**28**	151.3	113.1	-38.2	**48**	85.7	250.5	164.8	**68**	173.5	155.3	-18.3
9	78.6	57.3	-21.3	**29**	138.5	103.7	-34.8	**49**	164.9	201.7	36.8	**69**	203.0	176.4	-26.7
10	78.6	118.7	40.1	**30**	167.3	133.1	-34.2	**50**	171.5	191.2	19.7	**70**	144.5	148.3	3.8
11	161.6	103.4	-58.3	**31**	109.9	87.6	-22.2	**51**	150.2	172.3	22.2	**71**	182.7	186.0	3.4
12	51.4	44.0	-7.4	**32**	159.8	139.8	-20.0	**52**	160.8	135.1	-25.7	**72**	140.3	147.7	7.4

13	162.6	115.4	-47.3	**33**	173.7	144.6	-29.1	**53**	178.9	182.9	4.1	**73**	132.3	144.7	12.4
14	198.0	155.2	-42.8	**34**	237.8	210.8	-27.0	**54**	144.0	196.1	52.1	**74**	178.2	162.2	-16.0
15	246.3	207.3	-39.0	**35**	223.1	157.5	-65.6	**55**	169.9	176.8	6.9	**75**	156.6	150.8	-5.9
16	130.9	154.7	23.8	**36**	142.5	142.2	-0.2	**56**	144.7	160.8	16.1	**76**	168.3	167.4	-1.0
17	157.5	187.6	30.1	**37**	158.3	154.3	-4.0	**57**	109.1	95.6	-13.5	**77**	187.1	145.7	-41.3
18	202.1	223.3	21.2	**38**	212.4	167.2	-45.3	**58**	101.1	125.1	23.9	**78**	141.8	142.2	0.5
19	214.8	200.2	-14.6	**39**	214.9	188.8	-26.2	**59**	181.5	153.1	-28.4	**79**	133.5	149.2	15.7
20	85.5	176.3	90.9	**40**	178.3	156.7	-21.7	**60**	168.8	119.9	-49.0	**80**	135.5	159.5	24.0

Table 1 indicates that planning change directly affects the PA values in zones.

PA values diminish or increase in various zones and some of them are constant. This difference causes change on amount of spatial interaction in zonal base. Note that, travel time values have been obtained from the UPT planning of the city thus residential area is the only variable to change PA. Consequently, there is a need to increase the decreased PA values. Zonal PA change for base case and 2030 has been showed visually in Figure 5.

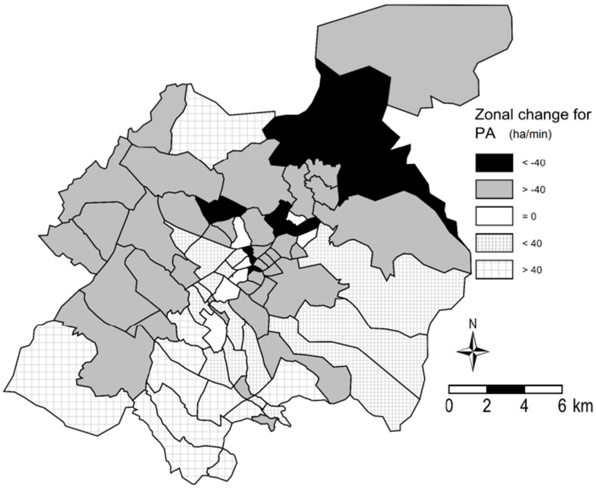

Fig. 5. Visual demonstration of zonal PA change

3.2. Regulation of land use proposals

Required residential are addition to regain the decreased PA values have been calculated by performing a simple algorithm method. Table 2 shows the required residential area to provide amount of spatial interaction.

Table 2. Required residential area addition (ha)

	Residential area					**Residential area**					**Residential area**					**Residential area**			
Zone	**2010**	**2030**	**Req.**	**Space**	**Zone**	**2010**	**2030**	**Req.**	**Space**	**Zone**	**2010**	**2030**	**Req.**	**Space**	**Zone**	**2010**	**2030**	**Req.**	**Space**
***1**	11.4	51	0	151	***21**	12.8	12.8	3.8	25	**41**	58.7	58.7	64.7	31	**61**	79.7	79.7	86.7	31
***2**	18	71.3	25.3	350	**22**	15.1	15.1	34.1	20	**42**	55.7	55.7	61.7	30	**62**	20	20	26	21
***3**	13.2	41.2	0	256	***23**	13.6	13.6	13.6	18	**43**	50	79	100	48	**63**	20.9	20.9	25.9	15
***4**	30.9	30.9	61.9	305	**24**	32.9	62.9	20.9	16	***44**	44.7	87.2	85.2	86	**64**	18.4	18.4	24.4	10

***5**	6.2	6.2	11.2	250	***25**	18.5	151.6	39.6	55	**45**	25.3	25.3	62.3	12	**65**	21.7	21.7	30.7	8
***6**	0	0	8	1541	***26**	52.5	142.4	62.4	200	***46**	19.2	37.7	12.7	20	**66**	13.1	13.1	14.1	11
***7**	0	0	8	89	***27**	1.1	1.1	9.1	36	**47**	43.2	73.2	32.2	30	**67**	0.2	0.2	52.2	12
***8**	26.5	26.5	51.5	111	***28**	6.1	6.1	43.1	121	***48**	13.1	143.1	9.1	38	**68**	31.5	31.5	41.5	13
***9**	0	0	21	81	***29**	28.7	28.7	61.7	80	**49**	69.9	91.9	73.9	39	**69**	38.4	38.4	65.4	11
***10**	18.5	64.5	37.5	121	***30**	59.4	59.4	91.4	94	**50**	31.9	59.9	52.9	30	***70**	9.6	9.6	4.6	17
***11**	6.5	6.5	47.5	200	***31**	18.2	18.2	36.2	136	***51**	32	56.7	43.7	50	**71**	61.7	61.7	59.7	16
***12**	0	0	5	331	***32**	34.9	34.9	43.9	61	**52**	15.5	15.5	45.5	21	***72**	23	23	19	20
***13**	10.7	10.7	31.7	166	***33**	37.7	37.7	50.7	69	**53**	73	91.2	93.2	33	***73**	31.7	31.7	22.7	38
***14**	57.6	57.6	83.6	118	**34**	93.8	93.8	103.8	36	**54**	69.7	109.7	70.7	41	**74**	55.6	55.6	65.6	24
***15**	88.9	88.9	109.9	201	**35**	32.6	32.6	87.6	21	**55**	60.7	60.7	57.7	30	**75**	47.2	47.2	50.2	17
***16**	38.4	38.4	16.4	116	**36**	20.9	20.9	14.9	12	***56**	25.6	25.6	15.6	21	**76**	61.6	61.6	61.6	20
***17**	89.8	89.8	72.8	110	**37**	28.3	28.3	26.3	18	***57**	0	0	10	50	**77**	8	8	35	12
18	69	89	77	50	**38**	55.5	55.5	91.5	31	***58**	0	37.6	21.6	30	***78**	9.6	9.6	5.6	11
***19**	80	95	118	244	**39**	50.3	50.3	62.3	12	**59**	59.4	59.4	83.4	71	***79**	0	0	0	16
***20**	23	83.1	13.1	201	**40**	27.7	27.7	39.7	16	**60**	33.2	33.2	79.2	40	***80**	13.1	13.1	0	20

** zones which have proper space for pretended addition*

Figure 6-a. shows the pretended increase of PA and 6-b. shows the visual demonstration of pretended residential area addition.

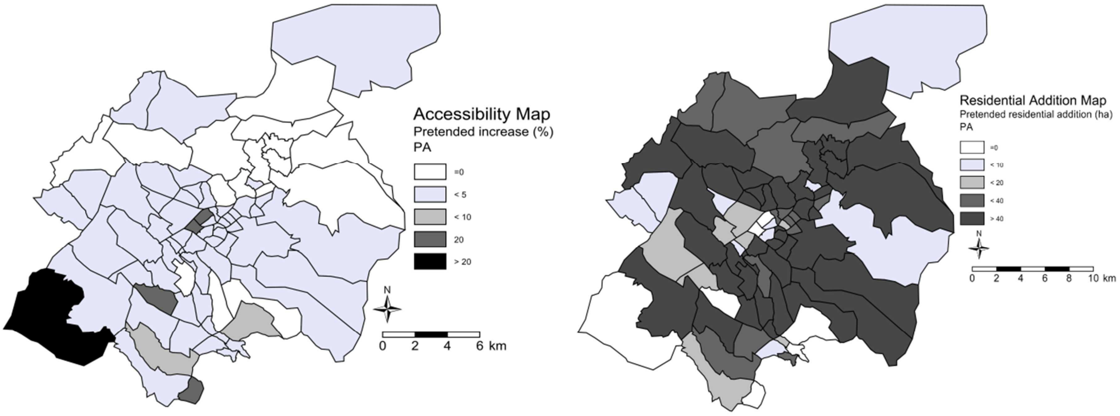

Fig. 6. (a) Pretended PA increase (b) pretended residential area regulation

3.3. Operationalization of pretended land use proposals

The proper empty spaces in zones are basic determiner if the pretended residential area addition is possible for respective zone. If the social, economical and physical conditions allows, pretended residential addition can be implemented as in Figure 7.

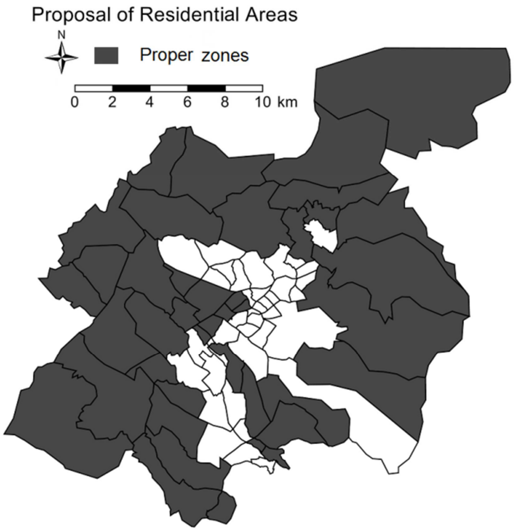

Fig. 7. Proper zones to implement the pretended residential area regulation

4. Conclusions

In this paper, the residential area decisions in land use plan have been investigated by evaluating spatial interaction and accessibility measures. Effects of UPT planning of the city to zonal spatial interaction has been calculated and reflected to recent land use proposals. It is crucial to note that, land use decisions are determined by evaluating many parameters as structure of society, economical situation of the citizens in the zone, proper empty spaces for land use, political axis of the city, existing population, projection population, decisions that have been taken before, geological structure, soil quality, land form, environmental effect etc.

It is found that effect of spatial interaction may be evaluated as one of decision-making parameters in the determining process of land use decisions. Spatial interaction measure may be utilized at determining all kinds of land use decisions. Commercial, cultural and recreational areas can be examined with the same three stage model. It is also concluded that measuring zonal spatial interaction on the axis of UPT provides investigation chance for land use decisions and provides a revision tool if needed.

Acknowledgements

Authors are grateful to the Municipality of Denizli for providing references for the background of this paper. They also thank Dr.Yıldırım ORAL for his valuable critiques and suggestions. The Scientific Research Foundation of Pamukkale University, Project No. 2010-FBE-060, is also acknowledged.

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