AN OPTIMIZATION MODEL FOR URBAN READJUSTMENT AND SUBDIVISION REGULATIONS IN TURKEY

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Abstract

Rapid urbanization in Turkey has resulted in various problems in urban spaces such as squatter houses, substandard subdivisions, and a low-quality urban environment. In order to facilitate self-motivated developments, the government has enacted various laws and bylaws and made amendments in current legal frameworks. The 18th Article (Dough Rule) of the Land and Building Development Law (İmar Kanunu) has various and extensive applications in regulating and restructuring cadastral properties. One of the major goals of this law and associated bylaw (bylaw on land readjustment) is to prepare standard high quality subdivision lots with regards to zoning plans. However, there are a series of legal and practical difficulties, and legal dilemmas in allocating the properties among various land owners: *First*, because, neither local nor the central government has the financial capability to confiscate private properties for road networks and public land uses, the government proportionally (maximum 40%) confiscates properties without paying the cost of expropriation. Implicitly, the current law assumes that land owners take the monetary advantage of being in the well-designed planned subdivision and having standard lot(s). *Second*, allocation from cadastral properties to the standard lots neither provides each owner a unique private lot(s) in the planned subdivision, and nor guarantees that every land owner acquires a piece of land in the same location (spot) as before the readjustment process. Although there are certain rules for reallocation in the bylaw, the reallocation is open to harsh disputes and often leads to court cases. This study develops a new approach to reallocate properties to minimize the adversaries and maximize the property owners' desires. The developed optimization technique, *first*, considers the main principles of the bylaw, and *second*, finds the best allocation solution for relevant property owners. As an illustrative example, three allocation problems are revisited and the differences between model and actual cases are reviewed. It has been understood that the developed optimization technique is a practical tool for this kind of problems.

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I. INTRODUCTION

Since the Second World War, especially, during the 1960-2000 period, rapid urbanization in Turkey resulted in various problems in urban spaces such as squatter houses, substandard subdivisions, and low-quality urban environment. In order to facilitate self-motivated developments, the government has enacted various laws and bylaws and made amendments in legal frameworks. As a one of those the 18th Article (Dough Rule) of the Land and Building Development Law (*İmar Kanunu*) has various and extensive applications in regulating and restructuring cadastral properties. One of the major goals of this law and associated bylaw (bylaw on land readjustment) is to prepare standard high quality subdivision lots with regards to zoning plans. However, there are a series of legal and practical difficulties, and legal dilemmas in allocating the properties among various land owners: **First**, because, neither local nor the central government has the financial capability to confiscate private properties for road networks and public land uses, the government proportionally (maximum 40%) confiscates properties without paying the cost of expropriation. Implicitly, the current law assumes that land owners take the monetary advantage of being in the well-designed planned subdivision and having standard lot(s). **Second**, allocation from cadastral properties to the standard lots neither provides each owner a unique private lot(s) in the planned subdivision, and nor guarantees that every land owner acquires a piece of land in the same location (spot) before the readjustment process. Although there are certain rules for reallocation in the bylaw, the reallocation is open to harsh disputes and often leads to court cases. This study develops a new approach to reallocate properties to minimize the adversaries and maximize the property owners' desires. The developed optimization technique, *first*, considers the main principles of the bylaw, and *second*, finds the best allocation solution for relevant property owners. As an illustrative example, three allocation problems are revisited and the differences between models and actual cases are reviewed.

II. LITERATURE

Land Readjustment (LR) is described as i) an effective planning tool for not only transforming agricultural lands into usable urban lots, but also redevelopment technique for the blight areas of urban lands, ii) an effective plan implementation technique transforming useless parcels into economically usable lots, iii) an efficient tool to provide basic public lands improving the quality of environment and quality of life for the residents of land readjustment area. According to Sorensen (2000a) "Land readjustment is a method whereby the ownership of scattered and irregular plots of agricultural land is pooled, roads and main infrastructure are built, and the land is then subdivided into urban plots." It is a technique that involved stakeholders (not only land owners but also planning and municipal authorities) are most likely to participate into the LR process; "The attractiveness of the method for landowners is based on the fact that substantial increases in the value of land may be achieved by the process, so that the value of the individual land holdings can be greatly increased, even though the remaining area is smaller. The attraction for planning authorities is that projects provide land for public facilities, rationalize patterns of property division, and build needed urban infrastructure." (Sorensen 2000a). It is a widely used planning and plan implementation technique in various parts of the world such as in Germany, France, Italy, Sweden in Europe, in India, Nepal, Thailand, Malaysia, Indonesia, South Korea, Japan, Western Australia in Asia-Pacific, Canada in America (Sorensen 2000a; Sorensen 2000b; Larson 1997). The use of LR varies country to country. While in one country effectiveness of land owners is seen, in another country state-public institutions' roles are heavily seen (Türk, 2009). Without exception, in every country, from a total of LR area, public land uses are subtracted and the remaining land is reallocated to the all land owners by their proportional shares (Türk, 2009).

Land Readjustment (LR) is also described as an effective plan implementation technique transforming useless parcels into economically usable lots (Chou ve Shen, 1982; Doebele, 1986; Doebele, 1982; Yomralıoğlu, 1992). The most important characteristics of the technique are the practical uses in very extensive areas and the reduction in duration of plan implementation (Doebele, 1982; Turk, 2007). The LR provides various advantages to both land owners and public, such as, creation of i) standard accessible lots with needed public land uses (road, park), ii) higher standard, and stable land values

which is easily traded, iii) clear and identified ownership structure, and minimized property sharing (Turk, 2009). According to Seele (1982, 1994), the main beneficiaries of LR are municipalities; municipalities save from expropriation cost by a proportional taking from land owners in order to provide public land uses and services.

Turkey has been one of the countries applying a form of LR technique dating back to the Ottoman period especially after fires destroying the wooden urban fabric. In this respect, LR, as a technique used in the western world for a long time, has been seen for nearly 150 years in this country (Turk, 2009). During the first 50 years of the Republic of Turkey, there have been several LR regulations in Laws (the Building Regulations of 1848; Road and Building Regulations of 1864; the Building Law of 1882; Law dated 1925, No. 642; Law dated 1930, No. 1663; Building and Roads Law dated 1933, No. 2290; the Reconstruction Law dated 1956, No. 6785 [Tekeli (1994) and Ersoy (2000) in eds. of Türk (2007)]); however, none of these were satisfactory to handle the post Second World War rapid urbanization. The most effective applications of LR technique have been seen in the last quarter of 20th century while hassling with rapid urbanization. Especially, the 18th Article (Dough Rule) of the Land and Building Development Law (İmar Kanunu - 3194) and associated bylaw enacted in 1985 can be considered as a major step in this respect.

The current literature in Turkey focuses mainly on the actualization of the techniques in terms of multiparty participation, financing, and administration. However, there are a limited number of papers focusing the technical details of reallocation and problems arising during the process of reallocation. In Turkey, every year many land reallocation applications are carried to the Administrative Courts by varying unhappy participants. Most of the complaints arise from unbalanced and inequitable (in economic and spatial sense) relocation of readjusted lands among stakeholders. Çete and Eğercioğlu (2013), Köktürk and Köktürk (2005) and Köktürk and Köktürk (2009) and Yomralıoğlu (1993), Yomralıoğlu et al. (2007), in their researches, focus on the techniques to allocate the land resources among land owners in the practices of Turkish LR. They propose value bases land reallocations rather than area based land reallocations after proportional deduction of public land uses. While Çete1 and Eğercioğlu (2013) dwell on value based evaluations, Köktürk and Köktürk (2009) propose equivalency criteria for the pre and post LR with minimum deviation principle. Nişancı (2005) and Yomralıoğlu et al. (2007) develop a pixel (raster) based land valuation and allocation system minimizing the subjectivity by means of Geographic Information System (GIS).

The technical steps of the LR practice in Turkey, which is an adapted form of German LR practices (*Umlegung*),[2] are presented in Figure 1 (Türk 2005). The **first step** (**I**) is the identification of the land and building resources and associated ownership structure, in which there are cadastral maps, existing building stocks, and land titles. In the **second step** (**II**), the total land resources are overlaid with the prepared Development Plans (scale: 1/1000) showing the necessary land use decisions containing both public and private land uses. In the **third step** (**III**), the public land uses are confiscated without any compensation, which might reach to 40% of all the LR area. In the **fifth step** (**V**), if the size of public land uses is more than the 40%, the exceeding portion is required to be expropriated via just compensation, considering the shares in total LR area. The **fourth step** (**IV**), which is the focus of this research, is a critical step that prepared urban parcels (lots) are assigned to the landlords in a way that parties are required to be satisfied with the allocation. In most cases, there are unhappy participants

[2] "Initially records and maps detailing owners, parcels and buildings are stated. From the parcel areas the total readjustment area is calculated and then reduced by a common share for streets, green places and other public areas. In the reduced area every owner gets a share in proportion to either the area or the value of his included land. Further land may be taken over by the municipality as contributions to the costs. In principle an owner cannot claim a higher value back — calculated under the new conditions — than he has left — calculated according to the old situation. Based on everyone's share, a new parcel plan is worked out, adapted to the approved building plan. The scheme, including related economic questions, is then discussed with the individual owners. After revisions, if any, preliminary boundaries are fixed for the ground and records are made of new parcels, inclusive of encumbrances and compensations incurred. This is the latest a new building plan must be approved by. The parcel plan is then displayed in the locality detailing the period of time for appeal. The legal process is then finished. The building of streets and other constructions is not included in the proceedings, they are the responsibility of the municipality and are paid for according to conventional charges." (Larson 1997)

who do not like the location and share of the lot(s) provided to them. The main reason for that is the fact that lots on the main street have more value than the lots on the minor streets. This research mainly focuses on the **fourth step** (**IV**) and introduces a transport model to allocate the urban lands to the relevant parties regarding the principles outlined in Article 10 (for the rules for creating parcels and allocating them to the involved parties) of bylaw prepared to show the details of the 18th Article (Dough Rule) of the Land and Building Development Law (*İmar Kanunu*). These principles are i) Land owners take the zoning based subdivision parcels from the closest distance to their own cadastral parcel, and ii) The created parcel(s) may be owned by more than one owner with varying shares.

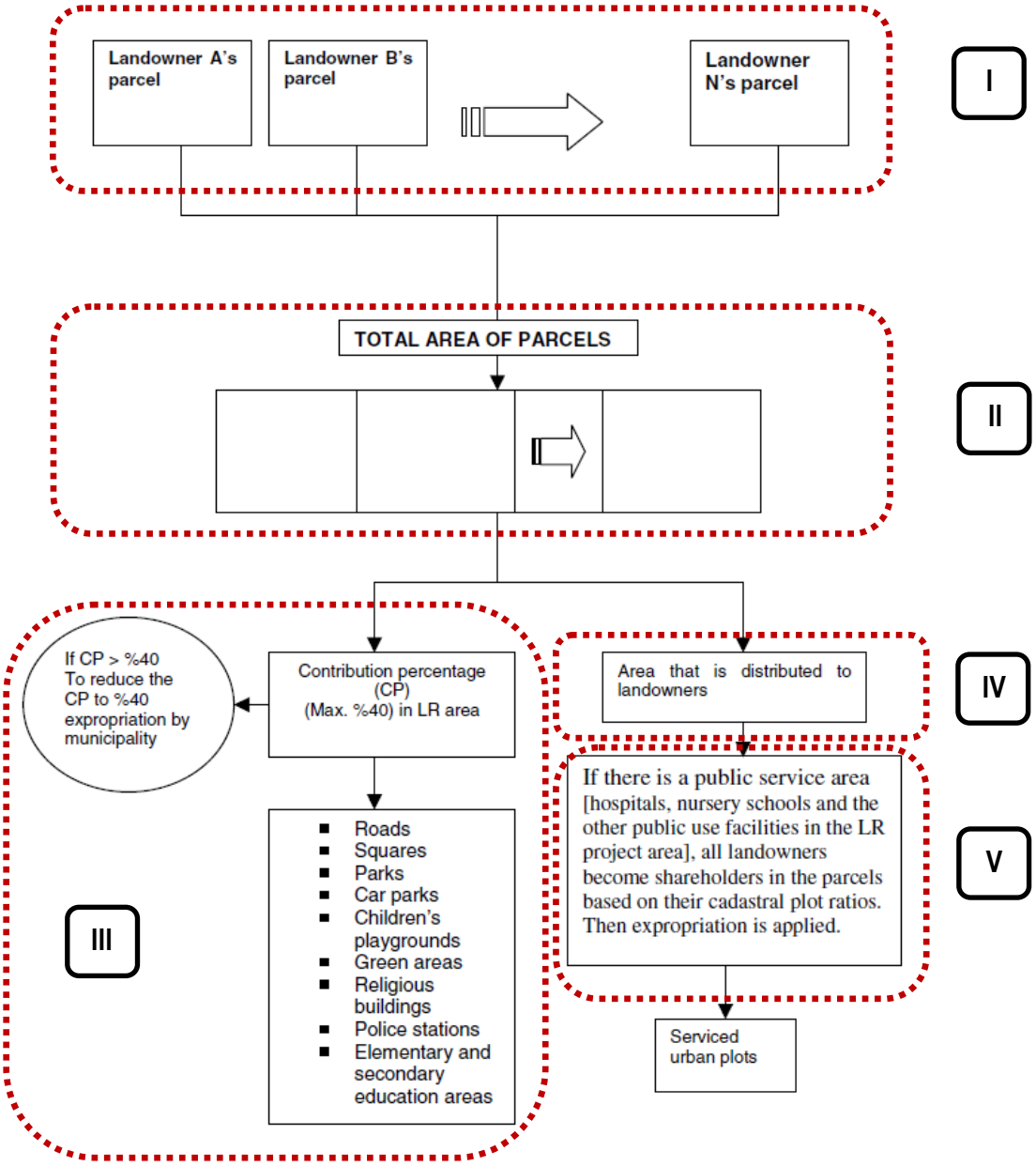

Figure 1: The steps in the land readjustment (LR) practice in Turkey (derived from Türk, 2004)

III. METHODOLOGY

Optimization based a new form of LR technique is the content and contribution of this research. This technique is basically on the reassignment of land resources from cadastral to urban lots after deducting public land use shares. The developed approach for the Land Readjustment (LR) problems methodologically is a modified form of classical transportation problems. The general characteristic of a transportation problem is based on the cost minimization in the process of delivering goods from supply nodes to demand nodes. At the end, the optimal solution provides the least cost of delivery. In this study, instead of delivering goods, square meter land areas are delivered from given cadastral parcels to urban subdivision parcels. The total square meter land getting into the development site is required to be equal to the getting out of the development site. The mathematical structure of the model is presented below. Initially, the basic transportation model is introduced, then, its modified form for land readjustment problems is presented.

Transportation Problem: The transportation problem is a simple and basic form of the linear programming problems. It handles commodity flows from sources to destinations**.** The objective is to determine the amount of commodity to be transported from each source to each destination in a way that the total transportation cost is minimum. The transportation problem, no matter how large the case, carries a simple algebraic structure. In the transportation problem, the supplies at several plants and the demands at several markets for a single commodity, and the unit costs of shipping the commodity from plants to markets are provided. Then the question is that how much the shipment there should be between each plant and each market so as to minimize total transport cost. To illustrate, the transportation model provided in *A GAMS Tutorial* by Rosenthal (2008) is presented below:

Minimize

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} c_{ij} \tag{1}$$

Subject to the constraint

$$\sum_{j=1}^{n} x_{ij} \leq a_j \qquad \textit{for all } i \tag{2}$$

$$\sum_{i=1}^{m} x_{ij} \geq b_i \qquad \textit{for all } j \tag{3}$$

$$x_{ij} \geq 0 \qquad \textit{for all } i \textit{ and } j \tag{4}$$

Sets
i: plants
j: markets

Variables
Z: objective value; the total delivery cost
x_{ij}: amount of commodity to ship from plant *i* to market *j*

Parameters
a_i: supply of commodity of plant *i*
b_i: demand for commodity at market *j*
c_{ij}: cost per unit shipment between plant *i* and market *j*

Land Readjustment via Transportation Problem Solution: The Article 10 (on the rules for creating parcels and allocating them to the involved parties) of bylaw prepared to show the details of the 18th Article (Dough Rule) of the Land and Building Development Law (İmar Kanunu) requires that:[3]

> Rule 1: Land owners take the zoning based subdivision parcels from the closest distance to their own cadastral parcel.
> Rule 2: The created parcel(s) may be owned by more than one land owners with varying shares.

As adjusted to transportation problem, the land readjustment process delivers the square meter land area from one land owners to the same land owners after deducting proportional share of public land uses (road, school, government school, park, car park, public square, police station etc.). These transfers take place from the cadastral parcels for the subdivision parcels. This model is can be named as the **Land Readjustment via Transport Problem Model (LRTPM).**

Minimize

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} c_{ij} \tag{5}$$

Subject to the constraint

$$\sum_{j=1}^{n} x_{ij} \leq a_j \qquad \textit{for all } i \tag{6}$$

$$\sum_{i=1}^{m} x_{ij} \geq b_i \qquad \textit{for all } j \tag{7}$$

$$x_{ij} \geq 0 \qquad \textit{for all } i \textit{ and } j \tag{8}$$

Sets
i: cadastral parcels
j: subdivision parcels

Variables
Z: objective value; allocation distance cost.
x_{ij}: land area allocated (transferred) from cadastral parcel *i* to zoning based subdivision parcel *j*

Parameters
a_i: land area for reallocation after public uses in base cadastral parcel *i*
b_i: land area of parcel *j* after subdivision regulation,
c_{ij}: distance between centroids of cadastral parcels *i* and zoning lots *j*

$c_{ij} = d_{ij}$ is a distance matrix presenting Euclidean distance between centroids of cadastral and subdivision parcels, and is computed by the following formula (Eq. 9).

$$d_{ij} = \sqrt{(p_i^x - p_j^x)^2 + (p_i^y - p_j^y)^2} \tag{9}$$

where, p_i^x and p_i^y are the centroid coordinate (*x* and *y* value) of cadastral parcel *i*; in the same way, p_j^x and p_j^y are the centroid coordinate (*x* and *y* value) of subdivision parcel *j*. The derived distance matrix is one of the main components of the optimization model. Later, the same matrix is used in the post evaluation of results. The obtained optimization results are self-contained and sufficient to precede a land reallocation application. However, the introduced the LRTPM also can be used to evaluate actualized Article 18 applications, even it can be used to reevaluate many court cases and many misuses coming from subjective applications. In the coming section, as case studies, we have chosen

[3] http://www.mevzuat.gov.tr/

small scale land reallocation applications in various cities in order to test, evaluate, and present the strength of our proposed the LRTPM.

In the evaluation process of *estimated optimal* and *actual-subjective* land reallocation results, two different types of analyses measures are pursued. The *first* one is based on **the various transfer cost (x_{ij}·c_{ij}) measures**, and the *second* one is on **the number of allocation links (count of positive x_{ij})**.

a) Transfer Cost Measures

A series of transfer cost measures are developed and presented in Eqs. (10)-(18). All measures are based on **optimization** result and **subjective** allocation presenting the square meter area transfers (x_{ij}) and input cost parameter measuring the unit cost of transferring the same square meter area (c_{ij}). Eq. (10) is for the minimized optimal total transfer cost - (TC^{OPT}); Eq. (11) is for the total transfer cost from the *subjective* land reallocation solution - (TC^{SBJ}); Eq. (12) measures the *difference* of optimal total transfer cost and subjective total transfer cost - (F); Eq. (13) finds the ratio of optimal total transfer cost to the total reallocated land area - (RA^{OPT}); in the same way, Eq. (14) computes the ratio of subjective total transfer cost to the total reallocated land area - (RA^{SBJ}); Eq. (15) leads the ratio of difference between two forms of total transfer costs (optimal and subjective) to the total reallocated land area - (RA^{F}); Eq. (16) leads the ratio of difference between two form of total transfer costs (optimal and subjective) to the total optimal transfer cost - (RTC^{OPT}); Eq. (17) assesses total deviation (DV) between optimal land reallocation transfer cost matrix and subjective reallocation transfer cost matrix, element by element in absolute value; Eq. (18) calculate the ratio of total deviation (DV) to the total land readjustment area - (RA^{DV}); and Eq. (19) gets the ratio of total deviation to the optimal total transfer cost value (RTC^{DV}).

$$TC^{OPT} = \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}^{OPT} c_{ij} \tag{10}$$

$$TC^{SBJ} = \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}^{SBJ} c_{ij} \tag{11}$$

$$F = TC^{OPT} - TC^{SBJ} \tag{12}$$

$$RA^{OPT} = TC^{OPT} / AREA \tag{13}$$

$$RA^{SBJ} = TC^{SBJ} / AREA \tag{14}$$

$$RA^{F} = F / AREA = [TC^{OPT} - TC^{SBJ}] / AREA \tag{15}$$

$$RTC^{OPT} = F / TC^{OPT} = [TC^{OPT} - TC^{SBJ}] / TC^{OPT} \tag{16}$$

$$DV = \sum_{i=1}^{m}\sum_{j=1}^{n} \left| x_{ij}^{OPT} c_{ij} - x_{ij}^{SBJ} c_{ij} \right| \tag{17}$$

$$RA^{DV} = DV / AREA \tag{18}$$

$$RTC^{DV} = DV / TC^{OPT} \tag{19}$$

b) Allocation Links Measures

A series of allocation link measures are developed and presented in Eqs. (20)-(28). All measures are based on the counts of transferred positive square meter areas ($x_{ij}>0$) of optimization and subjective allocation results. The Eq. (20) is for the count of optimal transfer links - ($TLNK^{OPT}$); The Eq. (21) is for the count of subjective transfer links - ($TLNK^{SBJ}$); Eq. (22) measures the count difference of optimal and subjective transfer link numbers - ($FLNK$); Eq. (23) finds the ratio of optimal total transfer link counts to the total reallocation matrix elements (m·n) - (RMX^{OPT}); in the same way, Eq. (24) computes the ratio of subjective transfer link counts to the total reallocation matrix elements (m·n) - (RMX^{SBJ}); Eq. (15) leads the ratio of count difference between two forms of transfer link numbers (optimal and subjective) to the total reallocation matrix elements (m·n) - (RMX^{FLNK}); Eq. (26) leads the ratio of difference between two forms of (optimal and subjective) total transfer link numbers to the

optimal total link count ($TLNK^{OPT}$) - ($RTLNK^{OPT}$); Eq. (27) transforms the element by element deviation matrix between optimal land reallocation transfer cost matrix and subjective reallocation transfer cost matrix into a total deviation link count (DV^{LNK}); Eq. (28) calculate the ratio of total deviation link count (DV^{LNK}) to the total reallocation matrix elements ($m \cdot n$) - (RMX^{DV}); and Eq. (29) gets the ratio of deviation link count (DV^{LNK}) to the total of optimal transfer link counts ($TLNK^{OPT}$) - ($RTLNK^{DV}$).

$$TLNK^{OPT} = \sum_{i=1}^{m} \sum_{j=1}^{n} \operatorname{sgn} x_{ij}^{OPT} \tag{20}$$

$$TLNK^{SBJ} = \sum_{i=1}^{m} \sum_{j=1}^{n} \operatorname{sgn} x_{ij}^{SBJ} \tag{21}$$

$$FLNK = TLNK^{OPT} - TLNK^{SBJ} \tag{22}$$

$$RMX^{OPT} = TLNK^{OPT} / (m \cdot n) \tag{23}$$

$$RMX^{SBJ} = TLNK^{SBJ} / (m \cdot n) \tag{24}$$

$$RMX^{FLNK} = FLNK / (m \cdot n) = [TLNK^{OPT} - TLNK^{SBJ}] / (m \cdot n) \tag{25}$$

$$RTLNK^{OPT} = FLNK / TLNK^{OPT} = [TLNK^{OPT} - TLNK^{SBJ}] / TLNK^{OPT} \tag{26}$$

$$DV^{LNK} = \sum_{i=1}^{m} \sum_{j=1}^{n} \left| \operatorname{sgn}(x_{ij}^{OPT} - x_{ij}^{SBJ}) \right| \tag{27}$$

$$RMX^{DV} = DV^{LNK} / (m \cdot n) \tag{28}$$

$$RTLNK^{DV} = DV^{LNK} / TLNK^{OPT} \tag{29}$$

IV. MODEL APPLICATION AND RESULTS

Model application section consists of two sequential analyses: In the *first* part, there are three allocation problems which are in different locations and sizes. The allocation results by the LRTPM are presented in matrix form together with associated distance parameters. In the *second* part, the LRTPM (optimal) application results and actual subjective land readjustment application solutions are comparatively evaluated. In this process, the computed parameters presented in Eqs. (10)-(29) are used to present the success of model and actual results. There are three different case study areas selected for the test of the LRTPM.

Case Study 1: Gökkent Region 18th Article Application

The location of development area is Gökkent Region in Kayseri **(**Picture 1). The coverage of cadastral parcels are 97,783 m^2. The total land readjustment area is 62,559 m^2 in which there are 11 cadastral parcels (Figure 2) and the total number of share holders is 38. The total number and coverage area of the produced subdivision parcels are, respectively, 11 and 35,398 m^2 (Figure 3). Figures 2 and 3 also contain the centroid points of both cadastral and subdivision parcels, respectively, and their coordinates are listed in Table 1. The public portion of the land readjustment application area is 23,599 m^2, which constitutes 37% of the total land readjustment area. Table 1 contains the inputs for the LRTPM, and Table 2 presents the LRTPM application results. The subjective-actual land readjustment matrix is presented in Table 3. Later Tables 2 and 3 are used for various comparative evaluation measures introduced in Eqs. (10)-(29) and presented in Table 10.

Picture 1 - Areal image of the Case Study 1

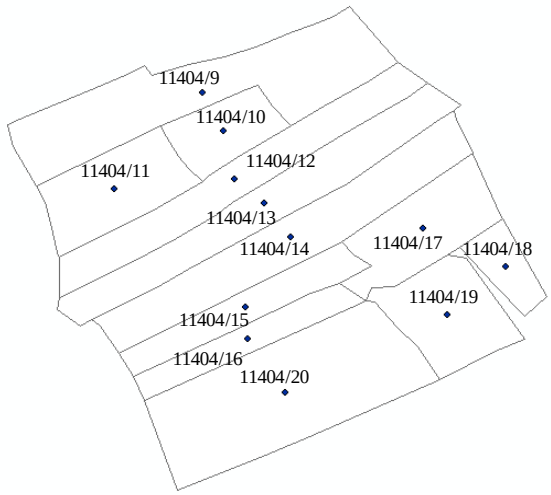

Figure 2 - Cadastral parcels and their centroids

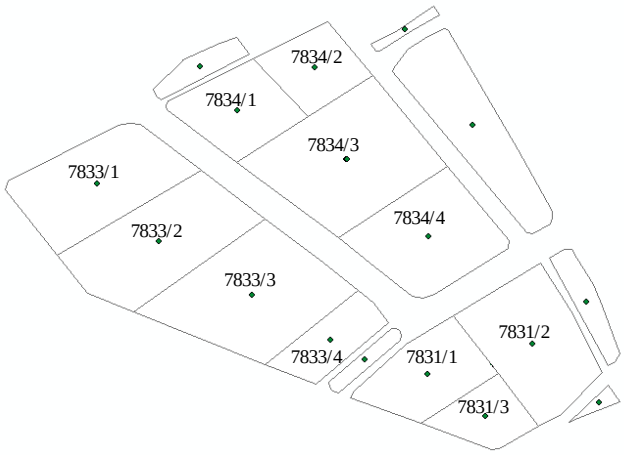

Figure 3 - Zoning based subdivision parcels and their centroids

Table 1 - Input values for urban land adjustment via transportation problem (LRTPM)

Cadastral Parcel	Size (m^2)	p_i^x	p_i^y	Subdivision Parcel	Size (m^2)	p_j^x	p_j^y
11404-9	949.91	462660.18	4290928.11	7833-1	3972.86	462543.28	4290854.01
11404-10	2338.27	462593.47	4290898.86	7833-2	4282.27	462577.42	4290821.91
11404-11	3972.86	462507.14	4290852.44	7833-3	4982.99	462628.60	4290792.58
11404-12	5231.26	462602.38	4290860.41	7833-4	1500.00	462671.88	4290767.73
11404-13	5105.38	462652.69	4290856.42	7834-1	2338.27	462620.67	4290894.70
11404-14	5543.17	462675.76	4290831.21	7834-2	1773.02	462662.79	4290917.90
11404-16	939.82	462663.03	4290757.46	7834-3	5231.26	462680.69	4290867.71
11404-17	4023.07	462750.39	4290821.55	7834-4	3642.35	462725.82	4290824.94
11404-18	1397.33	462813.98	4290787.97	7831-1	2461.51	462725.06	4290748.91
11404-19	3816.82	462770.16	4290753.14	7831-2	3816.82	462782.99	4290765.78
11404-20	2080.78	462710.00	4290731.06	7831-3	1397.33	462756.77	4290725.69
Total	35398.68			**Total**	35398.68		

Table 2 - Land reallocation matrix via LRTPM base optimization model

x(ij)	7833-1	7833-2	7833-3	7833-4	7834-1	7834-2	7834-3	7834-4	7831-1	7831-2	7831-3	Total
11404-9	0	0	0	0	0	949.91	0	0	0	0	0	**949.91**
11404-10	0	0	0	0	2338.27	0	0	0	0	0	0	**2338.27**
11404-11	3972.86	0	0	0	0	0	0	0	0	0	0	**3972.86**
11404-12	0	4282.27	948.99	0	0	0	0	0	0	0	0	**5231.26**
11404-13	0	0	0	0	0	823.11	4282.27	0	0	0	0	**5105.38**
11404-14	0	0	4034	560.18	0	0	948.99	0	0.01	0	0	**5543.18**
11404-16	0	0	0	939.82	0	0	0	0	0	0	0	**939.82**
11404-17	0	0	0	0	0	0	0	3642.35	380.72	0	0	**4023.07**
11404-18	0	0	0	0	0	0	0	0	0	1397.33	0	**1397.33**
11404-19	0	0	0	0	0	0	0	0	0	2419.49	1397.33	**3816.82**
11404-20	0	0	0	0	0	0	0	0	2080.78	0	0	**2080.78**
	3972.86	**4282.27**	**4982.99**	**1500**	**2338.27**	**1773.02**	**5231.26**	**3642.35**	**2461.51**	**3816.82**	**1397.33**	**35398.68**

Table 3 - Actual land reallocation matrix via expert judgment

x(ij)	7833-1	7833-2	7833-3	7833-4	7834-1	7834-2	7834-3	7834-4	7831-1	7831-2	7831-3	Total
11404-9	**0**	**0**	**0**	**0**	**0**	**949.91**	**0**	**0**	**0**	**0**	**0**	**949.91**
11404-10	**0**	**0**	**0**	**0**	**2338.27**	**0**	**0**	**0**	**0**	**0**	**0**	**2338.27**
11404-11	**3972.86**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3972.86**
11404-12	**0**	**0**	**0**	**0**	**0**	**0**	**5231.26**	**0**	**0**	**0**	**0**	**5231.26**
11404-13	**0**	**4282.27**	**0**	**0**	**0**	**823.11**	**0**	**0**	**0**	**0**	**0**	**5105.38**
11404-14	**0**	**0**	**4982.99**	**560.18**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5543.17**
11404-16	**0**	**0**	**0**	**939.82**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**939.82**
11404-17	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3642.35**	**380.72**	**0**	**0**	**4023.07**
11404-18	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1397.33**	**1397.33**
11404-19	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3816.82**	**0**	**3816.82**
11404-20	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2080.79**	**0**	**0**	**2080.79**
	3972.86	4282.27	4982.99	1500	2338.27	1773.02	5231.26	3642.35	2461.51	3816.82	1397.33	**35398.68**

Case Study 2: Gesi Region 18th Article Application

Gesi Region in Kayseri is the location of development area and its areal image is presented in Picture 2. The total land readjustment area is 144,204 m^2, and the total number of cadastral parcel is 2 (Figure 4) and the total number of shareholders is 10. The total coverage area of cadastral parcels is 142,547 m^2 and the total number and areal coverage of the produced subdivision parcels are respectively 16 and 76,439 m^2 (Figure 5). Figures 4 and 5 contain the centroid points of both cadastral and subdivision parcels, respectively, and their centroid coordinates are available in Table 4. The public portion of the land readjustment application area is 43,386 m^2, which constitutes 30% of the total land readjustment area. Table 4 contains the inputs for the LRTPM, and Table 5 presents optimal the LRTPM application results. The subjective-actual land readjustment matrix is presented in Table 6. Later Tables 5 and 6 are used for various comparative evaluation measures introduced in Eqs. (10)-(29) and presented in Table 10.

Picture 2 - Areal image of the Case Study 1

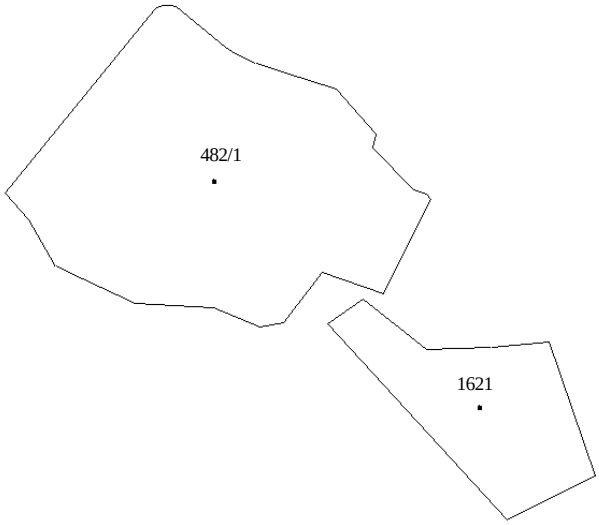

Figure 4 - Cadastral parcels and their centroids

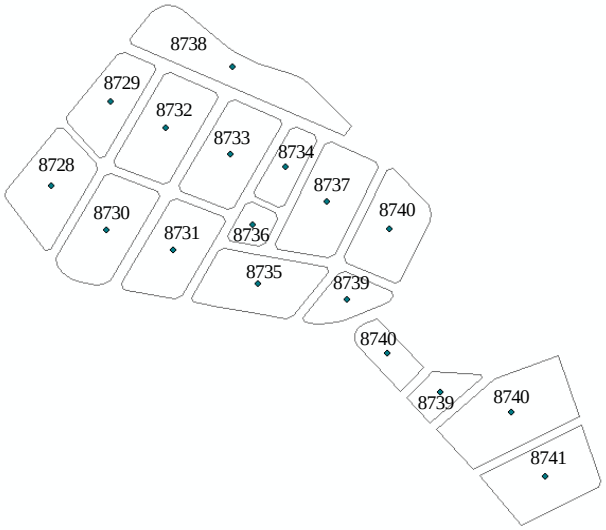

Figure 5 - Zoning based subdivision parcels and their centroids

Table 4 - Input values for urban land adjustment via transportation problem (LRTPM)

Cadastral Parcel	Size (m^2)	p_i^x	p_i^y	Subdivision Parcel	Size (m^2)	p_j^x	p_j^y
482-1	55919.86	116461.9	111400.91	8728/1	7511.76	116278.06	111399.84
1621	20520.00	116766.02	111141.17	8730/1	8019.18	116338.54	111350.80
				8731/1	7224.45	116413.67	111327.96
				8732/1	7747.74	116405.16	111464.97
				8733/1	7547.81	116477.03	111435.30
				8735/1	2434.59	116547.83	111283.25
				8735/2	3130.08	116506.56	111292.07
				8735/3	2224.70	116465.19	111298.16
				8736/1	1761.66	116502.27	111356.36
				8737/1	4228.54	116599.19	111409.49
				8737/2	4001.51	116569.84	111353.11
				8740/1	3758.74	116659.35	111370.81
				8740/2	3410.78	116642.31	111328.42
				8741/1	2969.62	116651.62	111213.09
				8742/1	2522.43	116710.97	111169.60
				8744/1	7946.27	116827.42	111074.76
Total	76439.86			**Total**	76439.86		

Table 5 - Land reallocation matrix via LRTPM base optimization model

x(ij)	8728-1	8730-1	8731-1	8732-1	8733-1	8735-1	8735-2	8735-3	8736-1	8737-1	8737-2	8740-1	8740-2	8741-1	8742-1	8744-1
482-1	7511.76	8019.18	7224.45	7747.74	7547.81	2434.59	3130.08	2224.7	1761.66	4228.54	4001.51	87.84	0	0	0	0
1621	0	0	0	0	0	0.00	0.00	0	0	0	0	3670.9	3410.78	2969.62	2522.43	7946.27
	7511.76	**8019.18**	**7224.45**	**7747.74**	**7547.81**	**2434.59**	**3130.08**	**2224.7**	**1761.66**	**4228.54**	**4001.51**	**3758.74**	**3410.78**	**2969.62**	**2522.43**	**7946.27**

Table 6 - Actual land reallocation matrix via expert judgment

x(ij)	8728-1	8730-1	8731-1	8732-1	8733-1	8735-1	8735-2	8735-3	8736-1	8737-1	8737-2	8740-1	8740-2	8741-1	8742-1	8744-1
482-1	7511.76	8019.18	7224.45	7747.74	7547.81	795.34	3130.08	2224.7	1761.66	4228.54	4001.51	0	0	0	1727.09	0
1621	0	0	0	0	0	1639.25	0.00	0	0	0	0	3758.74	3410.78	2969.62	795.34	7946.27
	7511.76	**8019.18**	**7224.45**	**7747.74**	**7547.81**	**2434.59**	**3130.08**	**2224.7**	**1761.66**	**4228.54**	**4001.51**	**3758.74**	**3410.78**	**2969.62**	**2522.43**	**7946.27**

Case Study 3: Esenyurt Region 18th Article Application

Esenyurt Region in Kayseri is the third case study area. The areal image of development area is presented in Picture 3. The total land readjustment area is 2,297,338 m^2, the total number of cadastral parcel is 7 (Figure 6), the total number of share holders is 15. The coverage of cadastral parcels is

2,298 m^2. The total number and area of the produced subdivision parcels are respectively 6 and 2,167 m^2 (Figure 7). Figures 6 and 7 contain the centroid points of both cadastral and subdivision parcels, respectively, and their coordinates are listed in Table 7. The public portion of the land readjustment is 130.71 m^2, which constitutes 5.7% of the total land readjustment area. Table 7 contains the inputs for the LRTPM, and Table 8 presents the LRTPM application results. The subjective-actual land readjustment matrix is presented in Table 9. Afterward Tables 5 and 6 are used for various comparative evaluation measures introduced in Eqs. (10)-(29) and presented in Table 10.

Picture 3 - Areal image of the Case Study 1

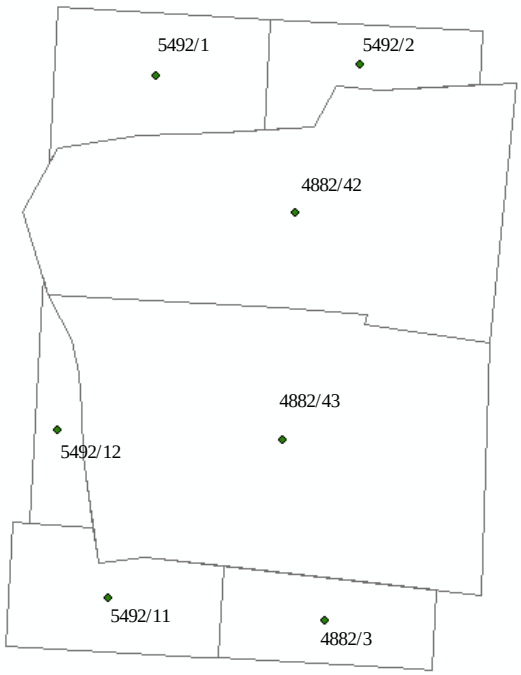

Figure 6 - Cadastral parcels and their centroids

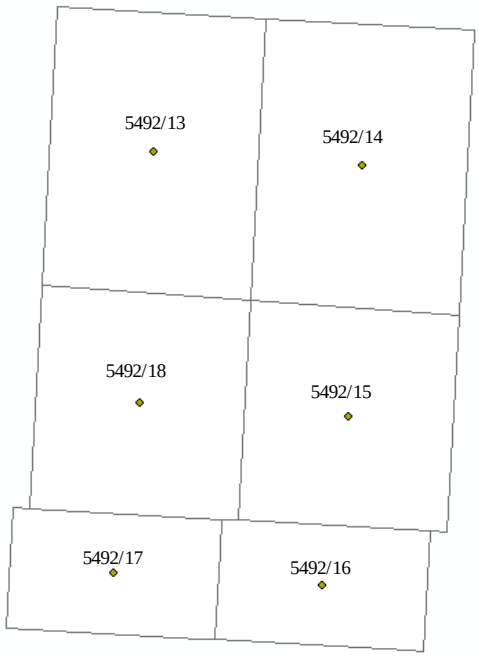

Figure 7 - Zoning based subdivision parcels and their centroids

Table 7 - Input values for urban land adjustment via transportation problem (LRTPM)

Cadastral Parcel	Size (m^2)	p_i^x	p_i^y	Subdivision Parcel	Size (m^2)	p_j^x	p_j^y
5492/1	209.61	454929.88	4285185.62	13	486.83	454929.88	4285178.34
5492/2	125.01	454948.03	4285186.63	14	493.78	454948.86	4285177.13
5492/3	144.82	454944.92	4285137.08	15	381.59	454947.56	4285154.18
5492/11	178.33	454925.58	4285139.11	16	209.24	454945.23	4285138.75
5492/12	78.43	454921.13	4285154.03	17	209.00	454926.26	4285139.80
4882/42	651.40	454942.30	4285173.42	18	386.90	454928.59	4285155.38
4882/43	779.74	454941.13	4285153.10				
Total	2167.34			**Total**	2167.34		

Table 8 - Land reallocation matrix via LRTPM base optimization model

x(ij)	13	14	15	16	17	18	Total
5492/1	209.61	0	0	0	0	0	209.61
5492/2	0	125.01	0	0	0	0	125.01
5492/3	0	0	0	144.82	0	0	144.82
5492/11	0	0	0	0	178.33	0	178.33
5492/12	0	0	0	0	0	78.43	78.43
4882/42	277.22	368.77	0	0	0	5.41	651.4
4882/43	0	0	381.59	64.42	30.67	303.06	779.74
	486.83	493.78	381.59	209.24	209	386.9	2167.34

Table 9 - Actual land reallocation matrix via expert judgment

x(ij)	13	14	15	16	17	18	Total
5492/1	209.61	0	0	0	0	0	209.61
5492/2	108.43	0	0	16.58	0	0	125.01
5492/3	0	0	0	144.82	0	0	144.82
5492/11	0	0	0	0	178.33	0	178.33
5492/12	0	0	0	47.79	30.64	0	78.43
4882/42	163.74	487.78	0	0	0	0	651.4
4882/43	0	0	381.59	0	0	398.16	779.74
	486.83	493.78	381.59	209.24	209	386.9	2167.34

Table 10 - Evaluation Measures via Transfer Cost

Equations		Descriptive Information and Computed Indices	Case1	Case2	Case3
		Land readjustment (LR) area (Sq. Metter and %)	62,559	142,547	2,298
		Public share of the LR: (Sq. Metter and %)	23.599 ≡ 37%	43,386 ≡ 30%	130.71 ≡ 5.7%
		Private share of the LR: (Sq. meter AREA after public shares)	35,398	76,439	2,167
a)	Eq.10	$TC^{OPT} = \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}^{OPT} C_{ij}$	1,301,059	9,127,526	18,263
	Eq.11	$TC^{SBJ} = \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}^{SBJ} C_{ij}$	1,742,603	9,800,241	20,161
	Eq.12	$F = TC^{OPT} - TC^{SBJ}$	-441,544	-672,715	-1,898
	Eq.13	$RA^{OPT} = TC^{OPT} / AREA$	36.8	119.4	8.4
	Eq.14	$RA^{SBJ} = TC^{SBJ} / AREA$	49.2	128.2	9.3
	Eq.15	$RA^{F} = F / AREA = [TC^{OPT} - TC^{SBJ}] / AREA$	-12.5	-8.8	-0.9
	Eq.16 (%)	$RTC^{OPT} = F / TC^{OPT} = [TC^{OPT} - TC^{SBJ}] / TC^{OPT}$	-33.9	-7.4	-10.4
	Eq.17	$DV = \sum_{i=1}^{m}\sum_{j=1}^{n} \left\| x_{ij}^{OPT} C_{ij} - x_{ij}^{SBJ} C_{ij} \right\|$	26,514	6,908	835
	Eq.18	$RA^{DV} = DV / AREA$	0.75	0.09	0.39
	Eq.19 (%)	$100 \times RTC^{DV} = DV / TC^{OPT}$	2.04	0.08	4.57
b)	Eq.20	$TLNK^{OPT} = \sum_{i=1}^{m}\sum_{j=1}^{n} \mathrm{sgn}\, x_{ij}^{OPT}$	18	17	12
	Eq.21	$TLNK^{SBJ} = \sum_{i=1}^{m}\sum_{j=1}^{n} \mathrm{sgn}\, x_{ij}^{SBJ}$	14	18	11
	Eq.22	$FLNK = TLNK^{OPT} - TLNK^{SBJ}$	4	-1	1
	Eq.23 (%)	$RMX^{OPT} = TLNK^{OPT} / (m \cdot n)$	14.9	53.1	28.6
	Eq.24 (%)	$RMX^{SBJ} = TLNK^{SBJ} / (m \cdot n)$	11.6	56.3	26.2
	Eq.25 (%)	$RMX^{FLNK} = FLNK / (m \cdot n) = [TLNK^{OPT} - TLNK^{SBJ}] / (m \cdot n)$	3.3	-3.1	2.4
	Eq.26 (%)	$RTLNK^{OPT} = FLNK / TLNK^{OPT} = [TLNK^{OPT} - TLNK^{SBJ}] / TLNK^{OPT}$	22.2	-5.9	8.3
	Eq.27	$DV^{LNK} = \sum_{i=1}^{m}\sum_{j=1}^{n} \left\| \mathrm{sgn}(x_{ij}^{OPT} - x_{ij}^{SBJ}) \right\|$	13	6	12
	Eq.28 (%)	$RMX^{DV} = DV^{LNK} / (m \cdot n)$	10.7	18.8	28.6
	Eq.29 (%)	$RTLNK^{DV} = DV^{LNK} / TLNK^{OPT}$	72.2	35.3	100.0

*AREA presents the LR area after public land uses deducted.

For the three case studies, the results are converted in a form of summary values presented by Eqs. (10)-(29) and results are listed in Table 10. The (a) segment of Table 10 is for ***Transfer Cost Measures*** based on area and cost based calculations, and (b) segment of Table 10 is for ***Allocation Links Measures*** based on the count of matrix cell values different from zero. For the three case studies, the following results are obtained:

(a) Transfer Cost Measures[4]

- Optimization based LR allocation (by the LRTPM) provides minimum cost for the transfer of cadastral square meters to the lots in the development plans. Regarding the total cost values, the optimal allocation results (TC^{OPT}) are lower than subjective allocation results (TC^{SBJ}), which are available on the lines for Eqs. (10) and (11) in Table 10. The differences between subjective and optimization allocation results (F) are presented on the line for Eq. (12) in the same table. All the values are negative, which shows that optimization based allocation costs are systematically lower than subjective approach.
- The results obtained for Eqs. (13) and (14) in Table 10 provide the ratios of total transfer costs (in m^2) to the application area for both optimization (RA^{OPT}) and subjective (RA^{SBJ}) assignments respectively. It can be seen that the ratio of total cost to the total area is higher in subjective approach. This indicates that introduced optimization technique provides lower transport cost and better allocation decisions as compared to subjective approach. The ratio of differences of Eqs. (13) and (14) to the total area (Eq. 15) are systematically negative. In the same way, the ratio of differences of Eqs. (13) and (14) to the total cost (Eq. 16) are also systematically negative. Both results also present the same advantage of optimization approach (the LRTPM) as compared to subjective assignment approach.
- The sums of cell based difference (DV) between optimization and subjective assignment approach are presented on line for Eq. (17) in Table 10. Eq. (18) normalizes these totals (DV) with regard to the AREA of LR. The obtained value is the highest for the first case. Similarly, Eq. (19) normalizes the same values (DV) with regard to the total cost values of each case. These normalized values in Eqs. (17) and (18) can be used to compare different cases areas and to derive certain summary characteristics of LR applications. In this study, there are a limited number of cases.

(b) Allocation Links Measures

- As presented in the allocation matrices, most of the cells are zero, however, the positive values presents the allocation from cadastral to urban lots. Every positive value in the subjective and optimal square meter assignments are counted on line for Eqs. (20) and (21) in Table 10. The number of counts presents the optimal extent of allocation. The larger the number the more scattered the allocation in LR. The counts in the optimal land reallocation are slightly more than subjective allocation for the first case and the last case in Eq. (22) line. The reason for that subjective land allocation leads single owners rather than shared property owners. For the second case in Eq. (22) line, it can be seen that subjective allocation is not only scatters the allocation but also creates an additional assignment. Subjective assignment is different from optimal assignments in creating single owner parcels rather than shared parcels by multiple owners. Single owner parcel assignments may lead unfair land allocation and increases the transport cost, in other word violation Article 10 (in the same or the nearest location).
- Eqs. (23) and (24) normalizes the counts regarding the size of matrix. The results are similar to the results in lines of Eqs. (20) and (21) in Table 10. In the second case study, half of the land allocation matrix cells are different from zero. The third case study has nearly 30% and the first case has nearly 15% positive value. These percent values can be used to identify and characterize the LR project in the prospective studies.
- Eq. (25) presents the ratio of difference between subjective and optimal assignment counts to the total number of matrix cells. The difference is between -3.1 to 3.3 % of matrix sizes. Similarly, Eq. (26) computes the same value as reference to optimal number of links instead of total cell number in allocation matrices. Eq. (26) shows that there are nearly 22.2%, -5.9%, and 8.3% difference between optimal and subjective LR assignments for the first second and third case studies.

[4] '*AREA'* in the equations presents the LR area after public uses deducted.

- Eq. (27) presents the actual deviated value counts (links may be same but assigned transfer values can be different) between optimal and subjective assignments. The ratio of deviation to the size of matrix presented in line for Eq. (28) increases respectively for the first, second, and third cases. The ratio of deviated value counts to the optimal link numbers is presented in line for Eq. (29) and the largest number is obtained for the third case.

V. CONCLUSION

Planning is a tool to manage the growth; however, it is a socially and economically daunting task to apply capital improvement and zoning plans. Although there is mechanism to confiscate necessary public lands (roads, parks, school lands, public squares, car parks, recreation centers etc.), *taking* is a very expensive mechanism that many municipalities suffer from raising necessary funds for public land uses. In order to solve this problem, the 18th Article of Land and Building Development Law is enacted to lay a base for confiscation by sharing the necessary public burdens to all land owners.

In this research, after taking (removing) the necessary public share from all cadastral land, the remaining parts of land area (in square meter) are reallocated to the relevant land owners by reallocating areas into subdivision parcels. The reallocation is pursued via developed *Land Readjustment via Transport Problem Model (LRTPM),* minimizing the transferred square meters' distance from cadastral to subdivision parcels. In the selected three case studies, the optimal and actual-subjective allocation results are compared by means of developed measures. The results have shown that the LRTPM is an efficient technique to handle Article 18 applications. Besides, many court cases and actualized Article 18 applications can be revisited to measure the integrity and success of applications. In most cases, doubts raising from land readjustment remain and applications suffer from subjectivity. The results have shown that transport model can be easily adopted for urban land readjustment and reallocation problems, and the developed LRTPM can be considered as an objective tool to handle this kind of problems. For the prospect, the LRTPM can be improved by adding various objectives and so constraints such as forcing the model to collect the scattered properties into unified parcels and their impacts.

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