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A Multi-Criteria Optimization Model for the Allocation Process in Land Readjustment Projects

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Abstract

The main process of land readjustment (LR) can be generalized as landowners in the project border contribute some of their land for the public uses and infrastructure also more for a special land for the cost for the project. Then the remaining areas are allocated to the landowners in proportion to share in the project, based on area or value of the parcels. Allocation is one of the most important process in LR projects considering that it is re-arranging the property rights and directly related to the adaptation and the success of the project. Therefore, the decision regarding the allocation should concentrate on reaching the possible best result for every landowner in a fair, logical and mathematically explainable way. This paper presents an integrated technique by using analytical hierarchical process (AHP) and linear programming (LP) for the allocation process in LR to reach the highest value of the public interest by maximizing every landowners benefit. The benefit of the allocation for landowners can be defined and calculated mathematically via AHP. Then, the allocation design, which gives the highest benefit value, can be reached by maximizing every landowners benefit via LP. A LR project from Istanbul, Turkey is used for testing the model. As a result, the possible highest benefit value of the project is calculated by maximizing the benefit values of the landowners in a fair, logical and mathematically explainable way. Every landowner gets their new parcels from the blocks which cover the exact location of their old buildings and the landowners of the 322, 323, 324, 307, 308, 310, 326, 327, 317 and 318 parcels are allocated to their best option.

Keywords: Land readjustment, Analytic hierarchy process, Linear programming.

Introduction

This paper presents a model and a methodology for the allocation process of land readjustment (LR) projects, which provides a fair, logical and mathematically explainable implementation. Moreover, by the model presented in this paper, the time for the allocation process could be reduced, possible conflicting results between landowners could be prevented and the benefit of the landowners could be maximized.

Half of humanity now lives in cities, but by the middle of this century, 70% of the world's people will live in urban areas. Urban populations in developing countries are expected to double in the period from 2000 to 2030; the built-up areas of these countries are expected to triple in size (Un-Habitat 2012). The pressure of urbanization in most countries around the world creates a need for methods to assemble development land. LR can offer an attractive legal mechanism for land assembly, especially when public funds for compulsory purchase and infrastructure provision are limited (Home 2007). Urban development can be facilitated efficiently by LR as the infrastructure areas do not have to be purchased or compulsorily acquired, and the development costs can be covered within the project.

In LR, the most critical stage is the allocation process, which gains importance by ensuring the equality and fairness (Turk 2007). Selection of the allocation base is important for the success of any LR project, and needs a compressive evaluation. Moreover, the criteria that allocation is based on should be well-modeled (Agrawal 1999, Sorensen 2000a, Li and Li 2007, Turk 2007; 2008). It should aim achieving an equitable allocation (Sorensen 2000a), and providing acceptance of the landowners. However, agreeing with the landowners on an acceptable standard of exchange could be time-consuming (Li and Li 2007). Furthermore, every landowner expects to get the best offer resulting in a growing number of ending bids. Each bid could be legally acceptable, but every landowner in the project will be affected differently, which generally cause conflicts. Therefore, the allocation should concentrate on reaching the possible best outcome for each landowner in a fair, logical and mathematically explainable way.

An individualistic or utilitarian approach presupposes that public interest consists of the arithmetic sum of the interests of private individuals and, trying to maximize its components could also maximize it as a whole (Keleş 2011). In the scope of allocation, if the benefit of the allocation for every landowner could be identified mathematically, then public interest could be reached by maximizing the landowners' benefit. Therefore, this paper presents a methodology for the allocation process of LR projects and aims to (1) maximize every landowners benefit to reach the public interest, (2) ensure an objective basis for a fair logical and mathematically explainable allocation, (3) reduce the time used for the process.

Land Readjustment

Land readjustment is an instrument for land organization, which means provision of land needed for public purposes and the suitable formation of private land according to the rules of town planning (Seele 1982). After formal decision, LR starts with determination of the implementation area. The rights and claims of parcels within the project boundaries are mathematically added together to establish the project area. Then, land designated for public spaces is extracted from this mass and the remaining areas are allocated to landowners in proportion to share in the project based on either area (i.e. Japan, Germany, Turkey, South Korea, Taiwan, and Indonesia) or value (i.e. France Sweden, Finland, Japan, Germany, Australia, South Korea, India, and Taiwan).

LR is justified not only based on cost and efficiency but also based on its fair treatment of landowners, improvements in plan quality, savings to the community, and environmental benefits (Viitanen 2002). However, neglect of transparency in the LR process and insufficient participation of the landowners may give rise to problems that cause resistance of the actors, provoke social disturbances, and hinder implementation (Demir and Yılmaz 2012). Therefore, transparency (Agrawal 1999, Turk 2008, Mathur 2012; 2013) and active participation of the landowners (Sorensen 2000a; 2000b, Krabben and Needham 2008) should be provided. Besides, LR interferes with property rights and underestimation of social aspects cause public reaction and loss of confidence to LR. Thereby, participation of the public should be ensured in every possible step (Sorensen 2000a, Turk 2008, Karki 2004, Krabben and Needham 2008, Larsson 1997, Turk 2005; 2007, Turk and Altes 2010, Mathur 2013, Archer 1992, Agrawal 1999, Krabben and Needham 2008).

Moreover, as proposed by many researchers LR process should be quick and simple enough to respond the high demand of urban land (Home 2007, Mathur 2012, Sorensen 2000a; 2000b, Turk 2008, Karki 2004, Turk and Altes 2010, Çete 2010, Turk 2005, Mathur 2013, Agrawal 1999). However, LR has been criticized for not being an easy or rapid solution (Sorensen 2000a), mainly because of the complexity of the process, which includes project planning, implementation and particularly efforts to obtain consensus among all landowners, especially in the allocation process. LR process could be quick enough to respond the high demand of urban land by reducing the time for the allocation.

Although there has been an intensive work in the literature about supporting the allocation process of land consolidation projects by using computer aid or operational research such as Kik (1980), de Vos (1982), Lemmen and Sonnenberg (1986), Buis and Vingerhoeds (1996), Rosman and Sonnenberg (1998), Avci (1999), Ayranci (2007), Cay et al. (2010), Demetriou et al. (2010), Cay and Iscan (2011), Mihajlovic et al. (2011), and Cay and Uyan (2013) there is no study concerning land readjustment projects.

So far, this paper concentrates on the necessity of an allocation model and next section presents the methodology and the implementation of the new allocation model in the case study.

The New Allocation Model

The allocation process is basically assigning existing landowners to the blocks that are formed by the rules of town planning. The allocation decision should aim to maximize the benefit of the landowners to reach the public interest, ensure an objective basis for a fair logical and mathematically explainable allocation and reduce the time used for allocation.

For these aims, firstly the benefit for each landowner should be defined by using a set of criteria, which the allocation is based on. Then a decision support tool, namely "Analytic Hierarchy Process", could calculate the importance of these criteria. Developed by Saaty (1980) AHP uses a pair wise comparison method to allocate weights to the components at all levels and uses Saaty’s 9-point scale to measure the relative importance of these components. The result of these pair-wise comparisons indicates how much more important an objective is than the other while making a decision.

In the allocation scope, the suitability of the blocks for each landowner could be defined by AHP. After determining the most suitable blocks for each landowner, however, the process may still have conflicts. For instance, some blocks in the project area may be the best decision for more than one landowner. Consequently, the solution should concentrate on choosing the optimum allocation decision that satisfies all landowners. By using liner programming (LP), the allocation process could be represented as a mathematical formulation by providing a set of variables and constraints, which fully describes the decision. LP problems are concerned with the efficient use or allocation of limited resources to meet desired objectives. The selection of a particular solution as the optimum solution for a problem depends on some aim or over-all objective that is implied in the statement of the problem (Gaas 2010). Therefore, by using proper variables in the objective function, the model could be designed to reach the best result in the allocation by maximizing each landowner benefit. Then, the optimal value of the objective function and the variables can be calculated rapidly in a fair, transparent, and mathematically explainable way. The results of the model represent the best allocation decision that satisfies all the constraints.

The method and principle in this paper can provide a theoretical method for the allocation process of LR in a way that more consistently realizes the transparency and the public interest. As a summary, AHP is used for defining the benefit of the possible allocation decisions of each landowner mathematically, and LP is used for reaching the best allocation design by maximization of each landowner benefit in this study.

After a smooth introduction into the methods, only relevant modifications of AHP and the LP are described to enable a very simple and efficient application of the method in land allocation. More detail and information can be found in Saaty (1980; 2008), Vaidya and Kumar (2006) about AHP and in Chvátal (1983), Vanderbei (2007), and Gaas (2010) about LP. An urban land readjustment allocation problem from Istanbul, Turkey is used to test the model, which is described in the next section.

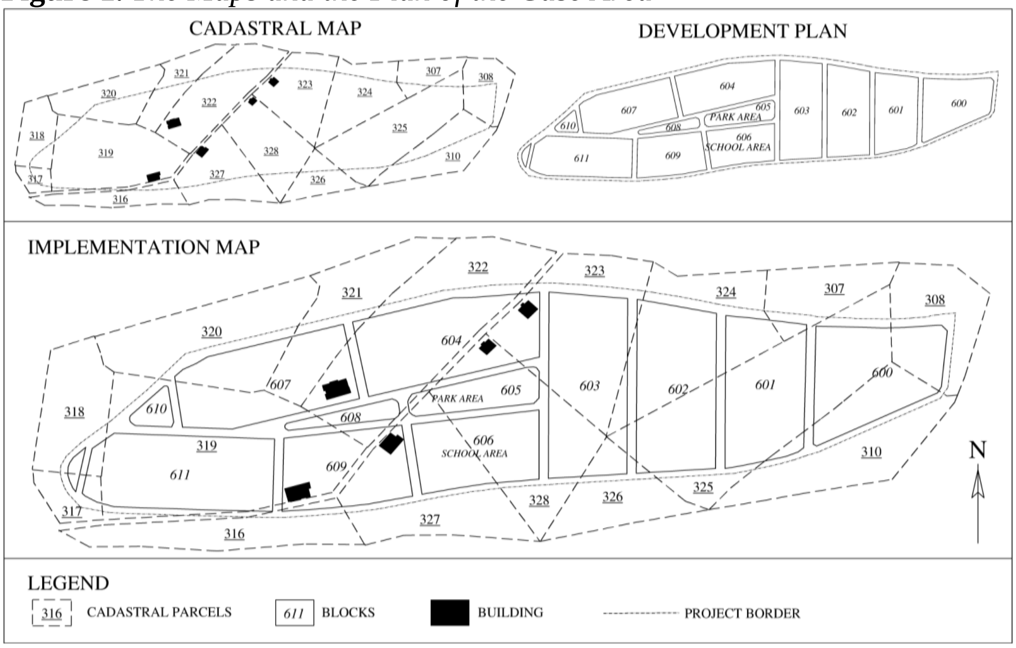
Calculations and the Case Study

An urban land readjustment project from Istanbul, Turkey is used to test the model (Figure 1 and Table 1). Table 1 indicates the area of the parcels before and after LR, and the area and functions of the blocks.

Table 1. *Properties of the Parcels and the Blocks*

Parcels			**Blocks**		
Number	**LR$_{Before}$**	**LR$_{After}$**	**Number**	**Area**	**Function**
307	553.06	386.91	**600**	7284.24	Residential
308	2325.34	1626.76	**601**	6892.12	Residential
310	3660.98	2561.15	**602**	8026.70	Residential
316	549.67	384.54	**603**	8730.74	Residential
317	710.39	496.98	**604**	8282.56	Residential
318	849.00	593.94	**605**	2391.72	Park Area
319	16630.79	11634.59	**606**	5186.52	School Area
320	3054.56	2136.91	**607**	7988.14	Residential
321	2725.77	1906.90	**608**	970.92	Park Area
322	9718.34	6798.77	**609**	5673.31	Residential
323	8481.81	5933.72	**610**	691.01	Park Area
324	7726.63	5405.41	**611**	8181.09	Residential
325	13938.12	9750.85	**612**	231.57	Park Area
326	1111.04	777.26	Urban Road	18327.18	
327	6040.18	4225.60	∑	88857.82	
328	9203.51	6438.60			
Rural Roads	1578.63	-			
∑	88857.82	61058.90			

Figure 1. *The Maps and the Plan of the Case Area*



The process of the new allocation model is classified into four steps, which are; defining the allocation criteria, AHP calculations, LP calculations and parcellation, which are described below.

Criteria Definition

Selection of the appropriate criteria for land allocation can be done by the decision maker alone or as a group decision together with the actors. It can be guided by the project aims, legislation rules and the landowner's demands. If a detailed evaluation is needed, then it is possible to define different sets of criteria for each landowner. However, this option will take much more time, and it is logical when there are either few landowners or few criteria. The presented study offers one criteria cluster that is valid for all landowners to reduce the time used for allocation.

Generally, the allocation of the readjusted plot should be provided in its original location, or close to its original location, or if this is impossible, within the LR area. Moreover, new parcels should be allocated to the same place if the landowner has an existing building fulfilling requirements of the development plan. Therefore, in the case study, criteria to be used in the allocation are chosen as; C1: to allocate the area in the same or nearby blocks that corresponds to the cadastral parcel and C2: to allocate the landowner in the block that covers his/her building. These criteria are chosen for the case studies and can be changed for different projects. After defining the criteria, calculations related with AHP could be done, which are described below.

AHP Calculations

The main aim in this stage is to determine the most suitable block for each landowner. Therefore, the present study offers using AHP calculations in a three-step process, which are criteria comparisons with respect to the project's aims, block comparisons with respect to the criteria and the evaluation.

First step starts with pairwise comparisons of the criteria to determine the weights of the criteria ([WC]). For the case study, the relative importance of C_1 over C_2 is expressed and the weights of the criterion [W_C] derived from the pairwise comparisons (Table 2).

Table 2. *Weights of the Criteria*

W_{Ci}	C_1	C_2	[W_C]
C_1	1	0,333	**0,25**
C_2	3	1	**0,75**

As can be seen from Table 2, in our estimation, C_2 is significantly more important than C_1. In the second step, so as to determine the most suitable block for each landowner, blocks are compared with respect to the criteria and as a result weights of the blocks are gathered ($[WB]_{Cn}$).

In the case study, the evaluation of C_1 is based on the intersection area of the blocks with the parcels. Moreover, if the blocks does not intersect with the parcels, then proximity of the blocks to each parcel is taken into account.

Based on the intersection area and proximity, the blocks are compared and the weights are derived.

For the evaluation of the C_2, the blocks that cover the landowners existing building are determined. These blocks are assumed as the most suitable option for the related landowner. This step should be done for every landowner in the projects to determine the most suitable block for each landowner. For the landowner of the parcel 307, the pairwise comparisons and the weights of the blocks with respect to C_1 are given in the Table 3.

Table 3. *Weights of the Blocks With Respect to C1 for Landowner 307*

$[WB]_{C1}$	**B_{600}**	**B_{601}**	**B_{602}**	**B_{603}**	**B_{604}**	**B_{607}**	**B_{609}**	**B_{611}**	**$[WB]_{C1}$**
B_{600}	1.00	0.13	2.00	3.00	4.00	4.00	4.00	4.00	**0.116**
B_{601}	8.00	1.00	9.00	9.00	0.00	0.00	0.00	0.00	**0.655**
B_{602}	0.50	0.11	1.00	0.00	0.00	0.00	0.00	0.00	**0.064**
B_{603}	0.33	0.11	0.00	1.00	0.00	0.00	0.00	0.00	**0.054**
B_{604}	0.25	0.00	0.00	0.00	1.00	0.00	0.00	0.00	**0.028**
B_{607}	0.25	0.00	0.00	0.00	0.00	1.00	0.00	0.00	**0.028**
B_{609}	0.25	0.00	0.00	0.00	0.00	0.00	1.00	0.00	**0.028**
B_{611}	0.25	0.00	0.00	0.00	0.00	0.00	0.00	1.00	**0.028**

Table 4 shows the comparisons of the blocks and the result together. For landowner 307 the most suitable block is the B_{601} based on the C_1. Similar calculations are done for C_2 and the overall [WB] matrix is formed for each landowner.

Table 4. *Weights of the Blocks for Landowner 307*

$[WB]LO_{307}$	**C_1**	**C_2**
B_{600}	0.1160	0.1250
B_{601}	0.6546	0.1250
B_{602}	0.0639	0.1250
B_{603}	0.0545	0.1250
B_{604}	0.0277	0.1250
B_{607}	0.0277	0.1250
B_{609}	0.0277	0.1250
B_{611}	0.0277	0.1250

In the last step, the weighted allocation matrix for each landowner ($[WAM]_{LOi}$) is calculated by multiplying the weights of the criteria (Table 2) with the weight of the blocks (Table 3 & Table 4). As it is indicated in the equation 1, for the landowner of the parcel 307, the $[WAM]_{LO307}$ is calculated by multiplying the $[WB]_{LO307}$ with the [WC]. The result is given in Table 5.

$$[WAM]_{LOi} = [WB]_{LOi} \text{ X } [WC] \qquad \text{(Eq. 1)}$$

Table 5. *Weighted Allocation Matrix for Landowner 307*

	$[WAM]_{LO307}$
B_{600}	0.1214
B_{601}	0.3369
B_{602}	0.1006
B_{603}	0.0968
B_{604}	0.0861
B_{607}	0.0861
B_{609}	0.0861
B_{611}	0.0861

Table 5 indicates suitability of the blocks for the landowner 307. As it can be seen from the table; for the landowner 307, the most suitable block is B_{601}. After repeating these calculations for each landowner, the overall [WAM] can be formed by combining together the inversion of $[WAM]_{LOi}$ matrixes as given in Table 6. The entries of the [WAM] matrix indicates the allocation suitability of the blocks for each landowner. It can be easily seen that from the eight blocks, six of them is the best option for more than one landowner and only two blocks is the best option for only one landowner (B_{602} for LO_{324} and B_{603} for LO_{326}) which may cause conflicts between the landowners. Therefore, to overcome these problems, the allocation decision should concentrate on reaching the possible best result for each landowner mathematically which is described in the next section.

Table 6. *Weighted Allocation Matrix for All Landowners*

[WAM]	B_{600}	B_{601}	B_{602}	B_{603}	B_{604}	B_{607}	B_{609}	B_{611}
LO_{307}	0.1214	0.3369	0.1006	0.0968	0.0861	0.0861	0.0861	0.0861
LO_{308}	0.3108	0.1266	0.1105	0.0995	0.0882	0.0882	0.0882	0.0882
LO_{310}	0.2504	0.1924	0.1134	0.1014	0.0848	0.0848	0.0848	0.0880
LO_{316}	0.0882	0.0882	0.0882	0.0882	0.0995	0.1105	0.3108	0.1266
LO_{317}	0.0882	0.0882	0.0882	0.0882	0.0995	0.1266	0.1105	0.3108
LO_{318}	0.0882	0.0882	0.0882	0.0882	0.0995	0.1266	0.1105	0.3108
LO_{319}	0.0515	0.0515	0.0515	0.0515	0.0768	0.1154	0.4038	0.1980
LO_{320}	0.0882	0.0882	0.0882	0.0882	0.0995	0.3108	0.1105	0.1266
LO_{321}	0.0849	0.0849	0.0849	0.0849	0.1933	0.2519	0.1137	0.1016
LO_{322}	0.0515	0.0515	0.0515	0.0768	0.1980	0.4038	0.1154	0.0515
LO_{323}	0.0515	0.0768	0.1154	0.1980	0.4038	0.0515	0.0515	0.0515
LO_{324}	0.1090	0.1788	0.2301	0.1475	0.0837	0.0837	0.0837	0.0837
LO_{325}	0.1446	0.2240	0.1747	0.1232	0.0833	0.0833	0.0833	0.0836
LO_{326}	0.0849	0.1138	0.1937	0.2524	0.0849	0.0849	0.1017	0.0837
LO_{327}	0.0566	0.0566	0.0566	0.0798	0.0966	0.0566	0.5455	0.0519
LO_{328}	0.0528	0.0528	0.0817	0.2203	0.4187	0.0528	0.0695	0.0515

LP Calculations

In the allocation process, every landowner expects to get the best offer resulting in a growing number of ending bids. Each ending bid could be legally acceptable however; each landowner in the project will be affected differently, which generally cause conflicts. Therefore, the allocation should concentrate on reaching the possible best outcome for each landowner in a fair, logical and mathematically explainable way.

The land allocation decision can be taken by linear programming which is able to define and maximize each landowners benefit via using the allocations $[A_{ij}]$ and the [WAM] matrix as given in the equation 2.

$$\text{Benefit}_{LO} = \sum_{\substack{1 \le i \le m \\ 1 \le j \le n}} [WAM_{ij}] \times [A_{ij}] \qquad \text{(Eq. 2)}$$

In the equation; $[A_{ij}]$ is the area of the land given to the landowner (i) from the blocks (j). $[WAM_{ij}]$ is the landowners (i) allocation suitability from the block (j), n is the number of the landowners and m is the number of blocks. Then the total benefit of the project, which is assumed as the public interest, can be calculated mathematically by summing up the each landowners (Eq. 3). The model calculates the allocation area (A_{ij}) for each landowner, which enables the maximum value of the public interest.

$$\text{Max (Z)} = \sum_{\substack{1 \le i \le m \\ 1 \le j \le n}} [WAM_{ij}] \times [A_{ij}] \qquad \text{(Eq. 3)}$$

For conflicts between landowners, the model calculates and takes into account the landowner who contributes more to the public interest. The objective function should be subject to constraints to exactly define the allocation problem. Therefore, in the case study, the objective function is subject to 4 constraints: (1) Block area constrain: for each block, the sum of the total land given from the blocks has to be equal to the block area; (2) Allocation area constrain: for each landowner, the sum of the total land given from the blocks has to be equal to the allocation area; (3) Minimum parcel area constrain: the minimum parcel area (MPA) is a restriction that is established by the zoning laws or the development plan. Each parcel created in the block has to be at least equal or bigger than the block's MPA. Also so as to be able to establish a sole ownership with the allocation, the area assigned to the landowners from each block has to be either zero or at least equal to the block's MPA if it is possible. When the landowner's allocation area in a block is less than the blocks MPA, then adding this constrain will cause infeasibility in the model. So the constrain should only be written for the landowners that have a bigger allocation area than the blocks MPA. (4) Non-negativity constraint: It is a restriction in linear programming that negative values for physical quantities cannot exist in a solution. The proposed model is given in the Figure 2 and calculated with the Lingo 13 software.

Figure 2. *The Allocation Model*

```
Model: ! Land Allocation for LR;
Sets: Landowners: Landowner_Area; Blocks: Block_Area; Links (Landowners, Blocks): WAM, Allocation;
End Sets
Data: Landowners = LO307 LO308 LO310 LO316 LO317 LO318 LO319 LO320 LO321 LO322 LO323 LO324 LO325
LO326 LO327 LO328;
Blocks = B600 B601 B602 B603 B604 B607 B609 B611;
WAM =       0.1214  0.3369  0.1006  0.0968  0.0861  0.0861  0.0861  0.0861
            0.3108  0.1266  0.1105  0.0995  0.0882  0.0882  0.0882  0.0882
            0.2504  0.1924  0.1134  0.1014  0.0848  0.0848  0.0848  0.0880
            0.0882  0.0882  0.0882  0.0882  0.0995  0.1105  0.3108  0.1266
            0.0882  0.0882  0.0882  0.0882  0.0995  0.1266  0.1105  0.3108
            0.0882  0.0882  0.0882  0.0882  0.0995  0.1266  0.1105  0.3108
            0.0515  0.0515  0.0515  0.0515  0.0768  0.1154  0.4038  0.1980
            0.0882  0.0882  0.0882  0.0882  0.0995  0.3108  0.1105  0.1266
            0.0849  0.0849  0.0849  0.0849  0.1933  0.2519  0.1137  0.1016
            0.0515  0.0515  0.0515  0.0768  0.1980  0.4038  0.1154  0.0515
            0.0515  0.0768  0.1154  0.1980  0.4038  0.0515  0.0515  0.0515
            0.1090  0.1788  0.2301  0.1475  0.0837  0.0837  0.0837  0.0837
            0.1446  0.2240  0.1747  0.1232  0.0833  0.0833  0.0833  0.0836
            0.0849  0.1138  0.1937  0.2524  0.0849  0.0849  0.1017  0.0837
            0.0566  0.0566  0.0566  0.0798  0.0966  0.0566  0.5455  0.0519
            0.0528  0.0528  0.0817  0.2203  0.4187  0.0528  0.0695  0.0515;
Landowner_Area = 386.98  162.70  2561.59  384.61  497.06  591.18  11636.59  2125.53 1907.23  6799.93
5934.74  5406.34  9756.67  777.40  4226.32  6439.70;
Block_Area = 7284.24  6892.12  8026.70  8730.74  8282.56  7988.14  5673.31  8181.09;
End Data
! Objective Function; Max = @Sum (Links (i,j) : Wam (i,j) * Allocation (i,j) );
! Block Area Constrain; @For (Blocks (j) : @Sum (Landowners (i) : Allocation (i,j) ) = Block_Area (j) );
! Allocation Area Constrain; @For (Landowners(i):@Sum(Blocks(j):Allocation(i,j))=Landowner_Area(i));
! Minimum Parcel Area Constrain; @For (Links: @SEMIC (300, Allocation, 1000));
End
```

The result of the model is given in Table 7. The model assigns all landowners to the blocks and the highest value of the public interest is reached.

Table 7. *The Result of the Allocation*

	B_{600}	B_{601}	B_{602}	B_{603}	B_{604}	B_{607}	B_{609}	B_{611}
LO_{307}		386.98						
LO_{308}	1627.04							
LO_{310}	2561.59							
LO_{316}				384.61				
LO_{317}								497.06
LO_{318}								591.18
LO_{319}	2464.45			632.31			1446.99	7092.85
LO_{320}				937.32		1188.21		
LO_{321}				1907.23				
LO_{322}						6799.93		
LO_{323}					5934.74			
LO_{324}			5406.34					
LO_{325}	631.17	6505.14	2620.37					
LO_{326}				777.40				
LO_{327}							4226.32	
LO_{328}				4091.88	2347.82			

After calculating landowner’s allocation assignments to the blocks, the parcellation procedure could start by dividing the allocated area into parcels that will fit to the blocks. In this process landowner's perceptions such as the number, shape and location of the parcels in the block can be taken account.

Results and Conclusions

The aim of this paper is to present a methodology for the allocation process of land readjustment (LR) projects, in order to both serve the public interest and maximize every landowner's benefits. It also ensures an objective basis for a fair logical and mathematically explainable allocation, and reduces the time used for the allocation process.

As a result of the case study all landowners get their allocation area and all blocks are distributed with the allocation. Landowners get their new parcels from the blocks, which cover the exact location of their old buildings, which is the most important criteria in the case study. Furthermore, sole ownership is provided for every landowner, as the allocation areas given to the landowners from all blocks are bigger than the related block's MPA.

When WAM is examined (Table 6), there was a threat of conflict situations before the allocation as only two blocks was the best option for only one landowner (B_{602} for LO_{324} and B_{603} for LO_{326}) and from eight blocks, six of them were the best option for more than one landowner. The model chose to allocate the blocks to the ones, which adds more to the public interest. As a summary, LO_{322}, LO_{323}, LO_{324}, LO_{307}, LO_{308}, LO_{310}, LO_{326}, LO_{327}, LO_{317} and LO_{318} (62.5% in number and 47.2 % in area of the total) are allocated to their best options. Only 4 landowner (LO_{316}, LO_{321}, LO_{319} and LO_{320}) are assigned to their second or third option.

By the given methodology, the benefit value of each landowner is calculated by using allocation criteria and their importance. Then the highest benefit value of the public interest is reached by maximizing every landowners benefit in a fair, transparent and mathematically explainable way. Moreover, the model solves the conflict situations between the landowners in the allocation, and the process takes less time than the classical methods.

AHP has the potential for prioritizing and ranking the criteria for land allocation. Selection of the criteria for the allocation should be project-dependent because the influencing factors are changeable.

Moreover, the total benefit value of the allocation can be used as a performance indicator for measuring the success of different allocation methods, which can be done in further studies.

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