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DEVELOPING A MODEL SOFTWARE TO DETERMINE THE EFFECT OF HIGH VOLTAGE TRANSMISSION LINES (HVTL) ON THE RESIDENTIAL LAND VALUE BY USING AHP METHOD

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Abstract. Due to High Voltage Transmission Lines (HVTL), easement expropriation is made and an easement price (compensation) is paid to the property owner. Since there is not a standard method, this price is calculated inappropriately and inaccurately. Therefore, either the property owner or the government suffers material damage. The main objective of this study is to determine the impact of HVTL factors on property value using the Analytical Hierarchy Process (AHP) method. Additionally, within the scope of the study, the aim is to develop a software model that automatically detects impairment rate and easement prices. In the study, a total of 79 individuals from 21 different countries participated in the national and international survey. The weights of the factors were determined using the AHP. A model software was created by integrating the weight values and the interface software of the model was created. The model software was tested with sixty expert reports prepared by different experts collected from ten different provinces. The rate of error in the expert reports was found to be at least 0.38% and at most 84.98%. With this software, an appraisal standard that will largely eliminate the existing injustices in the determination of the easement price will be provided. In addition, the inconsistencies between the expert reports of similar parcels and easements will be reduced, and easement prices will be paid fairly.

Keywords: High Voltage Transmission Lines (HVTL), easement expropriation, residential land value, Analytical Hierarchy Process (AHP).

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1. Introduction

In Turkey, easement expropriation is conducted for every parcel over which HVTL passes, and easement price is paid to the property owner. Easement expropriation due to HVTL is carried out mostly by the Turkish Electricity Transmission Corporation (TEİAŞ) and in accordance with the Expropriation Law No. 2942 (E.L.). With this application, an easement price is given to the property owner by the institution establishing the line. Easement price is the difference between the value of the property before expropriation and the value after the easement.

HVTL reduces the property value it passes through depending on many factors. These factors that should be taken into account in the expert reports are not clear. Each expert/expert group determines the easement price according to the factors determined by themselves. Even if the same factors are taken into account in the reports, the effect size of these factors on the value is also unknown. The initiative in this matter is left entirely to the expert. And it is not possible for the expert to evaluate all the factors correctly without standard criteria. The opinion reached in one report does not coincide with the other, and very different impairment rates emerge in similar reports. Therefore, easement prices are incorrectly determined and the property owner is under- or overpaid. For this reason, objections are made by the property owners. Most of the problems that cannot be solved during the implementation are referred to the judiciary. This causes excessive accumulation of files in courts, increases the workload of the government and wastes time and labor (Marabaoğlu, 2020).

In order to clarify the uncertainties in the determination of the easement price and to prevent unfair approaches, it is aimed to determine the factors affecting the property value of HVTL and to find the effect of each factor on the property value. It is also aimed to create a standard HVTL effect-value model software that determines the easement price by reflecting this determined effect on the impairment rate of the property.

2. Literature review

The rapid change and expansion in the energy sector have sparked increasing interest and curiosity regarding the environmental impacts of HVTL, particularly their effects on property values. In this context, numerous studies have been conducted to understand and assess the impacts of HVTL on property values. Perception/attitude studies were conducted first. These studies generally investigate the perceptions and thoughts of property owners, appraisers, experts, real estate agents and tenants. Some of the studies show that HVTL affects the property value negatively (Solum, 1985; Soini et al., 2011), while some others show that it has little or no effect (Morgan et al., 1985). In studies in which it is claimed that HVTL affect the property value, the factors causing this effect are; the visual effect (the most common one), the buzzing and humming effect, safety anxiety, health effects, and fear of falling lines (Delaney & Timmons, 1992; Priestly & Evans, 1996; Sims & Dent, 2003; Elliott & Wadley, 2012; Akinjare et al., 2013; Wadley et al., 2017). In some studies, it has been found that the diagonal crossing of the HVTL over the property is a factor affecting the property value (Kinnard, 1967; Jackson, 2010). In addition, several studies have investigated the willingness of the local population to pay for the removal of HVTL (Navrud et al., 2008; Giaccaria et al., 2010; Ju & Yoo, 2014).

In the 1970s, statistical studies began to be conducted on the effect of HVTL on the value of property. These studies are based on a statistical comparison and analysis of sales prices of properties near, far and adjacent to the HVTL and/or pylons (Sims et al., 2009; Bottemiller & Wolverton, 2013; Seiler, 2014). Most of the studies show that the value of the properties adjacent to the pylon or directly facing the pylon decreases more than the properties that only see lines. In addition, it has been determined that the values of property close to the HVTL have decreased more than those far from the line (Pitts & Jackson, 2007; May et al., 2011; Han & Elliott, 2013; Wyman & Mothorpe, 2018).

It was taken into account that the pylon on a parcel would not only affect the house on that parcel, but also the houses in the nearby parcels, and analyzes were made accordingly. An average of 15% depreciation was found for the houses within 10 m of the pylon, and an average of 8% within 15 m of the HVTL (Colwell & Foley, 1979; Des Rosiers, 2002; Callanan, 2013; Thomas & Welke, 2017). In some studies, it was observed that the rental values increased as they moved away from HVTL (Rotimi & Joseph, 2014). It has been concluded that the effect of the HVTL is in the form of an exponential function and this effect disappears after about 100 m from HVTL. In addition, it has been determined that small sized properties are more sensitive to HVTL than large sized properties (Kroll & Priestly, 1992; Chalmers, 2012). In some studies, it has been found that HVTL does not have a significant and consistent impact on property value. owever, it has been determined that HVTLs can pose obstacles, especially in situations such as the use of heavy machinery, particularly in agricultural lands (Brown, 1976; Kinnard et al., 1997; Rigdon, 1991; Jackson, 2011). As there are no structures or trees in the area where HVTL is established, the amount of open space in this corridor increases. Several studies have shown that this open space positively influences property values in the region. It has been observed that when services such as bicycle paths, walking paths, etc., are added to these areas, housing values increase (Jackson et al., 2012; Tatos et al., 2016). In addition, studies continue to estimate the compensation amount for property and to regain land ownership in HVTL projects (Döner & Kaya, 2021; Yılmaz & Alkan, 2022; Bogdan & Barańska, in press).

Among the methods used to the factor weights affecting property values, AHP holds a significant place. AHP has been used effectively in the field of geomatics in solving a number of problems in the past years. For example; AHP has been used in creating value maps (Nisancı, 2005), sustainable land management (Sisman et al., 2023), location analysis for the most appropriate installation of natural gas pipelines (Yıldırım et al., 2017), producing object-based geographical data to determine cemetery areas (Coruhlu et al., 2021), airport location selection (Colak et al., 2020), and mapping and suitability analysis of existing election voting units (Bala et al., 2022).

3. Easement expropriation process in Turkey

Easement expropriation is explained in articles 4 and 11 of the Expropriation Law No. 2942. Article 4 states, "Instead of expropriating the ownership of real estate, if it is sufficient for the purpose, a portion of the real estate, its height, depth, or the resource may be expropriated by establishing an easement right". In Article 11, it is stated that "In the establishment of an easement right through expropriation, the reasons for the decrease in value due to this expropriation are specified for the real estate or resource. This decrease in value is the expropriation price". However, this law is insufficient for making easement expropriation practices. Since there is no regulation in the field, easement expropriation is usually guided by the Supreme Court decisions (Senol, 2012; Marabaoğlu & Uzun, 2019). The 5th Civil Chamber of the Supreme Court, in its decision with file number 2014/10160 and decision number 2014/19550 dated 02.07.2014, states that "The sum of land, (if any) tree, and structure values on the property should be taken into account, and (if any) the area for the pylon should be deducted from this area. The ratio of the decrease in value due to the passage of high voltage transmission lines in the remaining area should be determined. The easement price should be determined by multiplying the total value of the property by this ratio".

According to the precedents of the Supreme Court, it is accepted that the decrease in value due to the easement in the property where an easement is established will not exceed 35% of the ownership value (of the easement area) in land and 50% in residential land. The calculation formulas according to this provision are as follows.

$EP = IR(\%)*F*M$; (1)

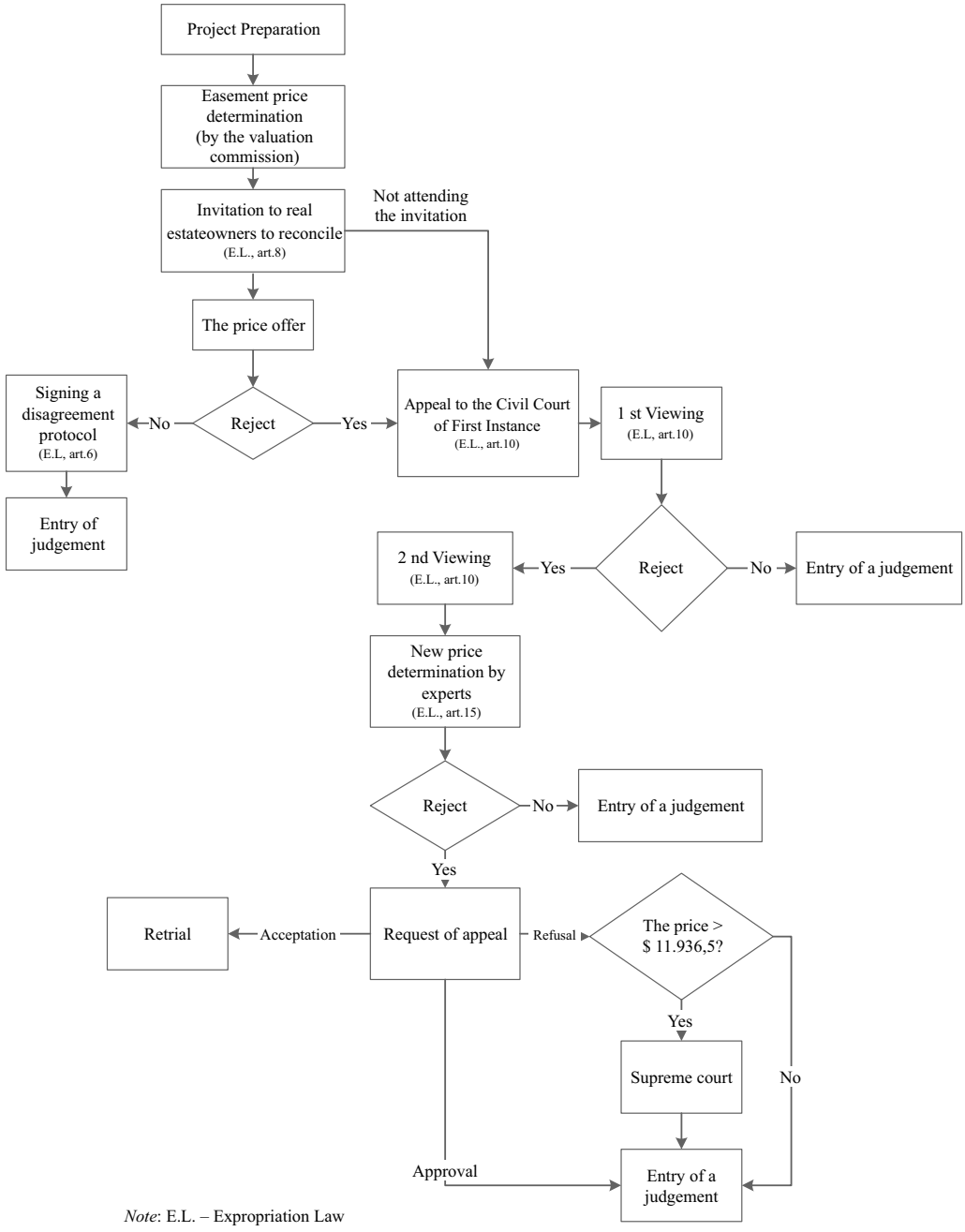
For residential land $IR = (EA * \%50) / F$; (2)

For land $IR = (EA * \%35) / F$, (3)

where: F – area of the property; M – unit value per m² of the property; EA – easement area; EP – Easement Price; IR – Impairment Rate.

The Supreme Court is the highest level judicial authority in Turkey's judicial system. The main duty of the Supreme Court is to examine the decisions made by local courts and evaluate the legality of these decisions. The decisions of the Supreme Court, which plays a critical role in ensuring justice in Turkey, greatly affect the country's legal system and judicial practice.

In easement expropriation, the administration establishes a right of easement in favor of itself in a certain part (height, depth or above) of the relevant property instead of taking over the ownership of it. There is no guide showing the steps to be followed in order to establish this right on the property. A workflow chart has been created where users can clearly follow the administrative and judicial processes. The diagram, created by interviewing judges and lawyers, is given in Figure 1. The amount of 11.936,5 USD in the figure has been determined for the year 2023.



Note: E.L. – Expropriation Law

Figure 1. Easement expropriation workflow chart in Turkey

In easement expropriation, first of all, the block/parcels within the scope of the prepared project are determined and the land registry records are provided. Afterwards, in case of extraordinary circumstances according to Article 27 of the E.L., the easement price is determined by the experts to be selected by the court (at the request of the relevant administration). This price is the urgent expropriation price. Transactions other than valuation are completed later. The price is deposited in the bank. An easement price is also determined by the valuation commission in the institution that established the HVTL. Notifications are sent to the owners in accordance with Article 8 of the E.L. in order to agree on the easement price determined by the relevant institution. In the event that an agreement cannot be reached on the price, a lawsuit can be filed in the Civil Court of First Instance in accordance with Article 10 of the E.L. Based on the survey of the land and expert reports, an easement price is determined by the judge. This price is the easement price determined by the court. Thus, three different easement prices arise for the same property. For the same parcels within the borders of Trabzon province, the urgent expropriation price, the easement price determined by the institution and the easement price determined by the court are shown in Table 1.

Table 1. Urgent expropriation price, easement prices determined by the institution and the court

Parcel No.	Urgent expropriation price ($)	Price determined by the institution ($)	Price determined by the court ($)
1	217,79	1062,82	5182,62
2	840,26	592,48	1242,01
3	3724,61	736,63	4215,75
4	2652,07	1459,55	2905,01
5	1379,04	729,16	1630,65
6	3520,63	1599,03	4043,38
7	2167,37	1307,25	2459,22
8	1239,64	2224,40	3549,10
9	6006,95	5300,71	7059,48
10	6745,84	2383,47	8892,36

As can be seen in Table 1, the three easement prices determined for the same parcels are different from each other. In parcel No. 1, the price determined by the court is approximately 5 times the easement price determined by the institution and approximately 25 times the urgent expropriation price. The fact that there are great differences between the easement prices of the same parcels is a clear evidence that there is no standard in this regard.

4. Material and methods

4.1. Legislation review and determination of HVTL factors

HVTL is established according to the safety distances (horizontal and vertical) specified in the Electrical High Current Facilities Regulation published in the Official Gazette No. 24246 on 30.11.2000, the easement area is determined and easement expropriation is carried out. Expropriation Law No. 2942 is insufficient in the implementation of easement expropriation. For this reason, easement expropriation is guided by the decisions of the Supreme Court.

In the precedents of the Supreme Court, it is stated that the easement price consists of the difference between the value of the property before expropriation and its value after the passage of the easement. In the decision with file number 2014/6332 and decision number 2014/20316 dated 09.09.2014 of the 5th Civil Chamber of the Supreme Court, the factors to be taken into account in determining the ratio of the decrease in value due to the easement in the property are specified. In this decision, it is stated that "Considering the nature of the property, its entire area, geometry, and the route of the HVTL, the ratio of the decrease in value should be determined in order to determine the compensation for the easement right".

In the context of right of easement and easement expropriation, the factors affecting the easement price have been determined by examining the laws, rules, regulations, circulars and Supreme Court decisions regarding the effect of HVTL on the property value. The factors taken into account in the expert reports have also been determined.

4.2. National and international surveys

Both national and international surveys were conducted. The national survey was applied to judges, lawyers, real estate appraisers, experts and academics who provide consultancy in the field in Turkey. Thirty-five people participated in the survey. The international survey was applied to geomatic engineers in different sectors who participated in the International Federation of Surveyors (FIG) Congress held in 2018 in İstanbul, Turkey. Forty-four people from twenty different countries participated in this survey. The study was conducted face-to-face to ensure the reliability of the surveys and to prevent misunderstandings in the questions. In both surveys, the participants were asked to score the HVTL factors affecting the property value by using Analytical Hierarchical Process (AHP) importance scale. For this reason, no analysis was performed to calculate the sample size before the study. The average of the scores provided by the participants was calculated, and based on these values, pairwise comparison matrices were created. AHP was used to determine the relative weights of the determined factors.

4.3. Weighting the factors with AHP

The most widely used multi-criteria decision-making (MCDM) method in decision-making processes is AHP developed by Thomas L. Saaty (1980). This method classifies complex problems into hierarchies and synthesizes each factor both separately and as a whole. Figure 2 shows the working principle of AHP.

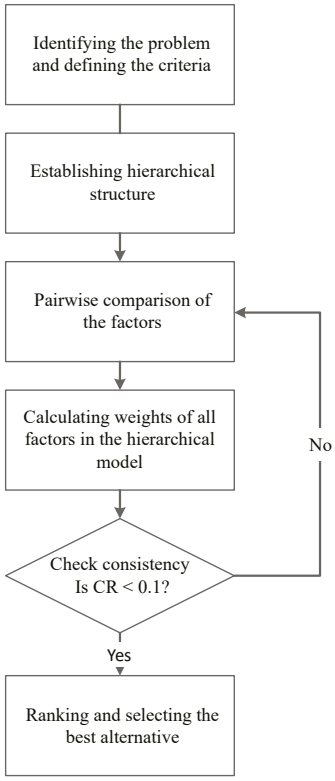


Figure 2. AHP working principle (Yap et al., 2018)

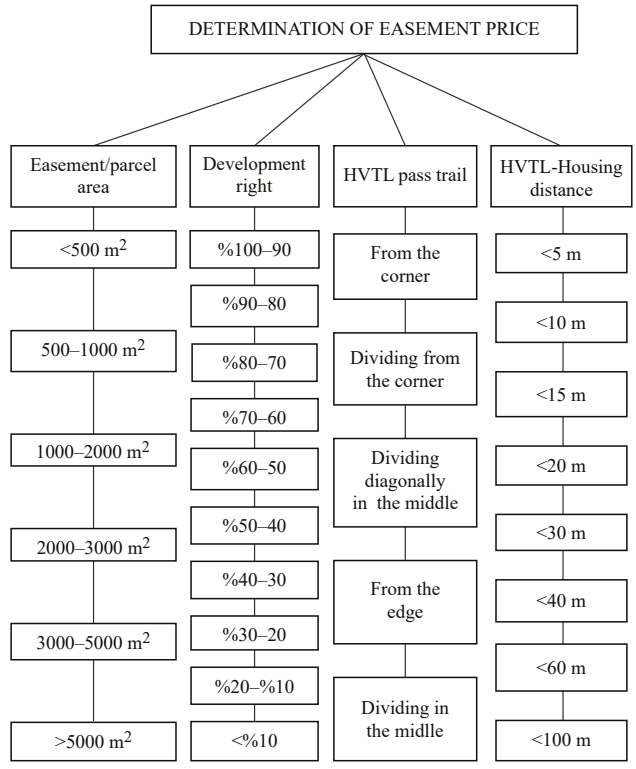


Figure 3. The hierarchical structure of decision-making process

Step 1: Identifying the problem and defining the criteria

In order to confirm the main and sub-criteria used in the evaluation with AHP, it is necessary to interview with decision-makers in the field. Therefore, two different surveys were conducted with decision-makers.

The factors taken into account in the expropriation decisions of the 5th and 18th Civil Chambers of the Supreme Court, in scientific publications and expert reports have been determined. As a result of the interviews with the appraisers, the factors were diversified or narrowed.

Step 2: Establishing the hierarchical structure

The identified problem is divided into multiple hierarchical levels after dividing into different criteria. In total, 4 main criteria and 29 sub-criteria were determined. Subcriteria were created under the main criteria. The hierarchical structure was created as in Figure 3.

Step 3: Calculation of pairwise comparison matrices and factor weights

The weights of all criteria at each level are calculated by making pairwise comparisons. The importance scale in Table 2 called the Saaty Scale is used to measure the weights. The comparison matrix is created by the decision-maker using the importance scale, as in Table 3.

$$a_{ij} = 1 / a_{ij}. \quad (4)$$

In the formula, a_{ij} is the relative importance of the x criterion compared to the decision-maker's j criterion. If the criteria i and j are of equal relative importance, $a_{ij} = a_{ji} = 1$.

In order to calculate the factor weights, the matrix is first normalized. The elements of each column of the matrix are divided by the total value of that column and the normalized matrix is formed. In this matrix, the sum of the columns is equal to 1. Normalization is done according to the following equation.

Table 2. AHP importance scale (Saaty, 1980)

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6 and 8	Moderate values

Table 3. Pairwise comparison matrix

Criterion	C_1	C_2	C_3	...	C_n
C_1	1	a_{12}	a_{13}	...	a_{1n}
C_2	a_{21}	1	a_{23}	...	
C_3	a_{31}	a_{32}	a_{33}	...	a_{3n}
...	...	...	...	...	...
C_n	a_{n1}	a_{n2}	a_{n3}		1

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}. \quad (5)$$

The weights obtained using the normalized matrix are calculated according to the following equation.

$$W_i = \frac{\sum_{j=1}^{n} a_{ij}^{*}}{n}. \quad (6)$$

Step 4: Checking the consistency ratio (CR)

This step determines whether the experts are consistent in determining the relative importance of the criteria. In AHP, this process is calculated with CR.

The weighted total vector is obtained by multiplying the priority vector with the comparison matrices. The elements of the weighted sum vector are divided into the elements of the priority vector. The arithmetic average of the result is taken. This is the mean λ_{max}.

$$\lambda_{max} = \frac{\left(a_1 + a_2 + a_3 + \ldots + a_n\right)}{n}, \quad (7)$$

where: λ_{max} – largest eigenvalue; (a_1, a_2, a_3, ..., a_n) – ratio of weighted total vector to priority values; n – number of elements.

Before CR, the Consistency index (CI) is calculated with the following formula.

$$CI = \frac{\lambda_{max} - n}{n-1}, \quad (8)$$

were: CI – Consistency Index; n – number of parameters compared.

$$CR = \frac{CI}{RI}, \quad (9)$$

where: CR – Consistency Ratio; RI – Random Index.

RI is an experimental value that depends on n (Table 4).

AHP does not require perfect consistency. A decision is accepted if CR ≤ 0.10. Otherwise, AHP application should be performed again (Lee & Chan, 2008).

5. Results and discussion

5.1. AHP analysis

The main and sub-criteria created in the AHP were compared. Weight values of main (Table 5) and sub-criteria (Table 6) were calculated.

5.2. Design of HVTL effect-value software

In Turkey, an easement price is given to the owner of the real estate on which the HVTL is located by the institution that installed the line. Since the current legal regulations complied with in this process are insufficient, easement prices are often determined as insufficient or excessive. A model software has been created to determine easement prices as close to reality as possible and to prevent unfair practices. This model software was created by integrating the weights of the factors determined by AHP. The interface of the software was created using Node.js, Electron, TypeScript, React, Ant Design and Webpack. The software calculates the Impairment Rate (IR) and Easement Price (EP) automatically by using the factors such as the size of the parcel over which HVTL passes, the area of the easement on the parcel, whether HVTL restricts the development right of the parcel, the HVTL passing over on the parcel, and the distance of the house on the parcel to

Table 5. Weight values of the main criteria

	Criteria	Weight value
Main criteria	Easement/Parcel area	0.25
CR = 0.022 < 0.1	Development right	0.30
	HVTL passing over	0.25
	HVTL-housing distance	0.20

Table 6. Weight values of sub criteria

Main criteria	Sub criteria	Weight value
Easement/Parcel area	<500 m^2	0.20
	500–1000 m^2	0.19
CR = 0.017 < 0.1	1000–2000 m^2	0.17
	2000–3000 m^2	0.16
	3000–5000 m^2	0.14
	>5000 m^2	0.14
Development right	<%100	0.21
	<%90	0.18
CR = 0.014 < 0.1	<%80	0.15
	<%70	0.12
	<%60	0.09
	<%50	0.07
	<%40	0.06
	<%30	0.05
	<%20	0.04
	<%10	0.03
HVTL passing over	From the corner	0.08
	Dividing from the corner	0.14
CR = 0.007 < 0.1	Dividing diagonally in the middle	0.31
	From the edge	0.17
	Dividing in the middle	0.29
HVTL-housing distance	≤5 m	0.24
	≤10 m	0.21
CR = 0.024 < 0.1	≤15 m	0.19
	≤20 m	0.13
	≤30 m	0.10
	≤40 m	0.07
	≤60 m	0.04
	≤100 m	0.02

Table 4. The random index values (Saaty, 1980)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

the HVTL. The mathematical computation formula of the software model is formulated as follows.

$$IR = a_1 * b_1 + a_2 * b_2 + a_3 * b_3 + a_4 * b_4, \quad (10)$$

where: IR – Impairment Rate; a_1, a_2, a_3, a_4 – weight values of the main criteria; b_1, b_2, b_3, b_4 – automatically determined sub-criterion weights based on the entered values in the model.

$$EP = (F * M + K) * IR, \quad (11)$$

where: EP – Easement Price; F – area of the property; M – unit value per m^2 of the property; K – housing value (if any); IR – Impairment Rate.

In the software model, the code writing example for the "HVTL Passing Over" factor is shown in Figure 4.

When HVTL effect-value software is started, the main screen is seen as in Figure 5.

There are 5 sections on the main screen. In the first three sections, information about property, easement and housing will be entered by users. In the first part, the area and m^2 value of the parcel on which HVTL is located, and the area of the pylon are requested. The pylon area box is optional. If there is a pylon on the property, the pylon area is entered in this box, otherwise the box is left blank or 0 (zero) is written. The total value of the parcel is calculated automatically (if there is a pylon, by subtracting the pylon area from the total parcel area).

In the second section, information about the easement (area, passing over the parcel) and the development right restriction on the parcel is requested. The "Development Rights Restriction" box is optional. If the development right of the parcel is restricted, write in this box what percentage of the development right of the parcel is restricted. For instance, while the parcel had five floors of development rights, the development right was reduced to four floors due to the passing of HVTL. Accordingly, the development right of the parcel is limited by 20%. In this case, the value 20 should be entered in the relevant box. If the development right of the parcel is not restricted, this box is left blank or 0 (zero) is written. "Choose Shape" pane is clicked on to select the passing over of the easement on the property. Five passing over images appear on the screen as in Figure 6. The appropriate passing over image is selected. The selected image is displayed on the main screen.

In the third section; if there is a house on the parcel, information about the house is requested. Otherwise, the section should be deactivated with the switch button. This section has been designed in case there is only one housing on the property. If there is more than one housing, the total value of all housings on the property should be entered in the "Housing Value" box and the average value of the distance of all housings to the HVTL should be entered in the "Distance to HVTL" box.

In the fourth section, the weights (%) showing the effect of the factors on the property value are calculated and displayed automatically according to the information entered in the first three sections.

In the fifth section, "Impairment Rate" and "Easement Price" that occur on the parcel due to HVTL are calculated simultaneously. If there is a pylon on the parcel, the ownership cost of the pylon area is automatically added to the easement price.

Example 1: The proximity effect of the property to HVTL

In most expert reports, it is stated that the safety of life and property is reduced due to line-pylon contact, line breakage, pylon overturning, etc. Therefore, an impairment rate for the property is calculated and shown in the reports. However, since there is no certain standard, each expert calculates this rate according to his own conviction. In the created model, the HVTL-housing distance was taken as a maximum of 100 m. Because most scientific studies show that houses more than 100 m away from the lines are little or not affected at all (Callanan, 2013; Thomas & Welke, 2017).

Two houses, 5 m and 100 m from HVTL, are shown in Figure 7 (6000 m^2 land, m^2: 50 USD). All the features of the houses are the same and the value is 625.000 USD. In the model, impairment rate and easement price were calculated based only on the distance to HVTL. It is seen that 17.093,67 USD more easement price should be paid to the house which is closer to HVTL due to buzzing, humming,

```
const p3 = AnaAgirliklar.G11 / 10;
const a3 = (() => {
    let Key = { Letter: '!', Number: -1 };

    const E18 = valE18_IrtifakSekli;
    if (E18 == IrtifakGecisSekli.A_Kosesinden) Key = { Letter: 'J', Number: 9 };
    else if (E18 == IrtifakGecisSekli.B_KosedenBolerek) Key = { Letter: 'J', Number: 10 };
    else if (E18 == IrtifakGecisSekli.C_CaprazBolerek) Key = { Letter: 'J', Number: 11 };
    else if (E18 == IrtifakGecisSekli.D_Kenarindan) Key = { Letter: 'J', Number: 12 };
    else if (E18 == IrtifakGecisSekli.E_OrtadanBolerek) Key = { Letter: 'J', Number: 13 };
    else Key = { Letter: '!', Number: -1 };

    return AgirlikGecisSekli[Key.Letter + Key.Number] || 0.0;
})();
const s3 = p3 * a3;
setValFGecisSekli((isNaN(s3) || s3 < 0) ? 0 : s3);
```

Figure 4. Code writing example

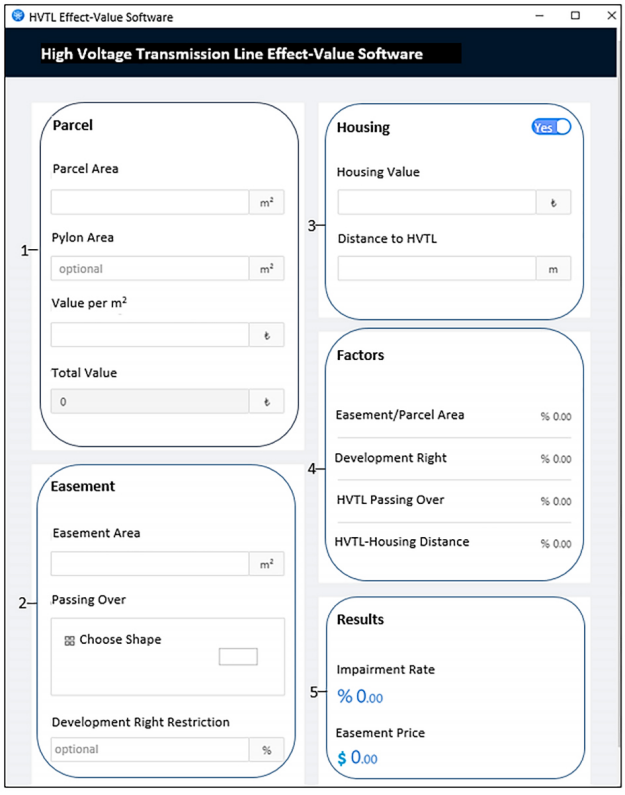


Figure 5. Main screen of the software

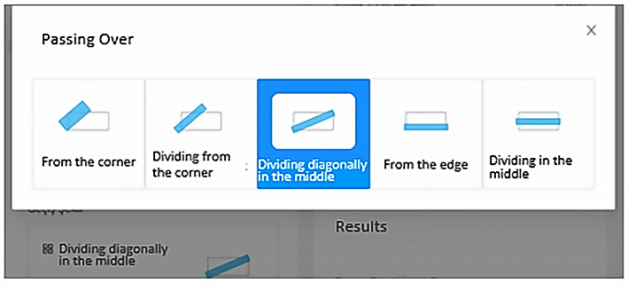


Figure 6. Selecting the passing over of the easement

risk of line breakage, fire hazard, possible health effects, etc.

Example 2: The effect of HVTL passing over the property on easement price

In the example, only the effect of HVTL passing over on the property value was taken into account.

Two samples were selected from the expert reports and are shown in Figure 8. The square meter of both properties is 5 USD. HVTL passing over is different for both properties. In the model, IR and EP of both properties were calculated. According to the results compared, there is a 2.24% IR and an EP of 8456,53 USD between the two properties (only due to HVTL passing over).

Example 3: Development right restriction by HVTL

In the example, only development right restriction by HVTL was taken into account as a factor. On the parcel in Figure 9, there is a development right for 5 floors (house no. A). After HVTL, the right decreased to 3 floors (house no. B) due to the proximity to the lines. In other words, the development right of the property was restricted by 40%. Accordingly, IR and EP were calculated in the model, and it was seen that the restriction caused 17.12% impairment in the property.

5.3. Testing the HVTL effect-value software

The created software has been tested with expert reports collected from various provinces of Turkey in order to give reliable results. A total of sixty reports collected from the provinces of Trabzon, Artvin, Amasya, İzmir, Antalya, Afyon, İstanbul, Erzurum, Şanlıurfa and Kahramanmaraş and each report prepared by a different expert were used in the test. Impairment Rates (IR) and Easement Prices (EP) determined in the expert reports were recalculated according to the software created. Also, the under- or overpaid costs of the easement price and the margins of error in the expert reports were compared with the results obtained in the

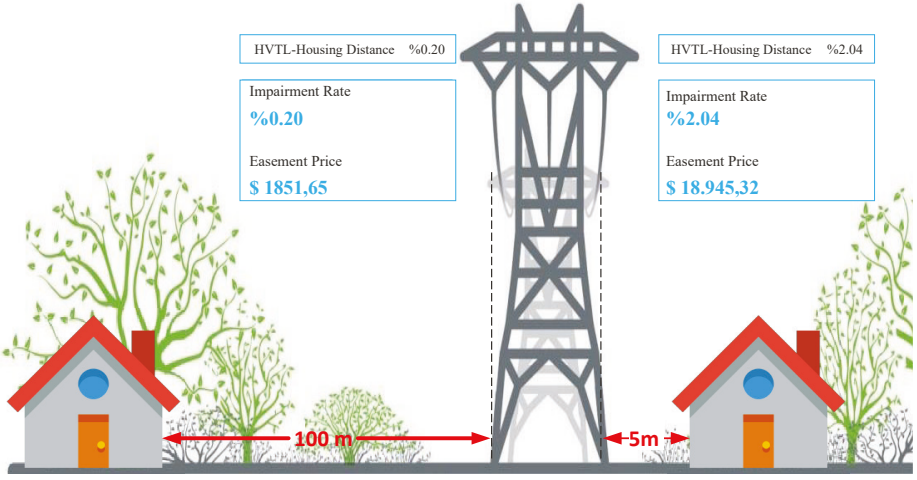


Figure 7. HVTL-housing distance

Table 7. IR, EP and margins of error

Expert report number	(In the expert report)		(In the software)		Margins of error		
	IR	EP ($)	IR	EP ($)	Underpaid cost ($)	Overpaid cost ($)	Percent (%)
1	0,0341	13449,26	0,0305	12053,79		1395,48	11,58
2	0,1261	2852,24	0,1047	2368,20		484,04	20,44
3	0,1844	5134,43	0,1837	5114,94		19,49	0,38
4	0,0461	2727,72	0,0354	2128,03		599,69	28,18
5	0,0185	532,59	0,0190	546,45	–13,87		–2,54
6	0,0250	719,02	0,0338	938,23	–219,22		–23,36
7	0,0760	7282,61	0,0628	6040,62		1241,99	20,56
8	0,0701	11223,09	0,0501	8055,24		3167,86	39,33
9	0,0450	2236,90	0,1805	8972,46	–6735,56		–75,07
10	0,0100	656,46	0,0666	4372,02	–3715,56		–84,98

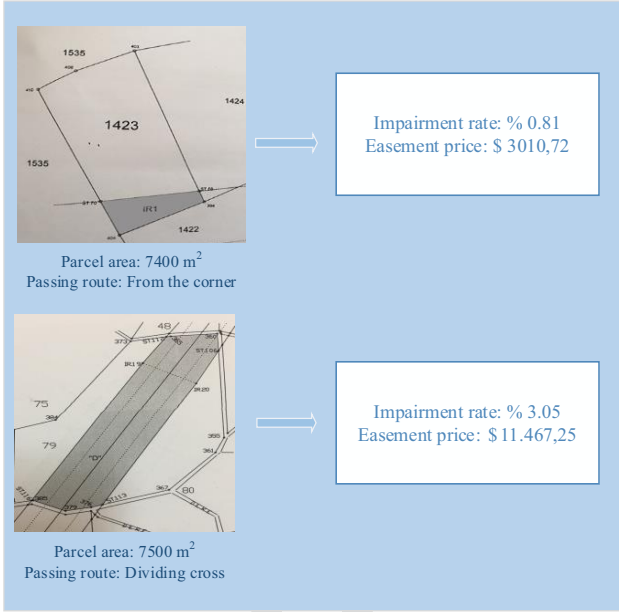


Figure 8. The effect of HVTL passing over from the property

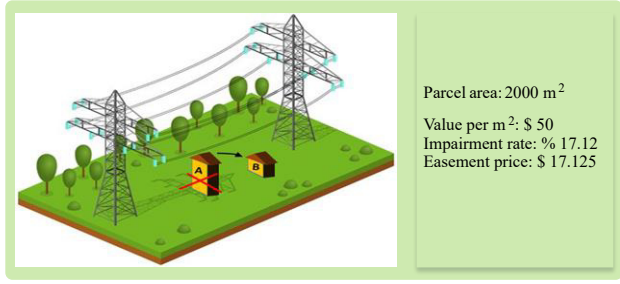


Figure 9. Development right restriction of the property

software. These data belonging to 10 reports are shown in Table 7.

The software has been tested with sixty expert reports collected from various provinces in Turkey. The margin of error in the expert reports was found to be at least 0.38% and at most 84.98%. For example; According to the model, while the easement price was paid more than 3167,86 USD to the owner of the immovable in the report numbered 8, 6735,56 USD was paid less in the report numbered 9. As a result, the absence of a standard to determine the easement price in Turkey puts the property owner or the state in financial damage.

6. Conclusions and recommendations

The main reason for the increase in the case of determination and registration of the easement price filed with the Civil Court of First Instance is the inability to determine the easement price correctly. Due to the inadequacy of the E.L. and the absence of a regulation, experts take into account different criteria (with different weights) when determining the price. Thus, there are great differences between the easement prices calculated for similar files (similar parcel and similar easement). It is important that the easement price is determined fairly so that the sense of trust in the judiciary is not damaged, the property owner does not suffer from injustices and the required time and workforce are reduced.

TEİAŞ conducts property (substation and pylon) expropriation on an average of three million m^2 per year and easement expropriation on an average of 140 million m^2 per year. In TEİAŞ, an average of 15% of the total appropriation is allocated for expropriation every year. In 2019, the appropriation allocated for expropriation is around 86 million USD (Turkish Electricity Transmission Corporation [TEİAŞ], 2019). From this budget, payments are made to the property owners on which the HVTL is located. As a matter of fairness, payment must be made in proportion to the impact of HVTL on the property.

In this study, the HVTL impact value model software has been developed to determine the easement price as accurately and automatically as possible. This model software was tested with sixty expert reports collected from various provinces. As a result of the tests conducted, the rate of error found in the expert reports ranges from 0.38% to 84.98%. This result indicates that some reports are

closer to reality and consistent with the developed model, while others are significantly distant. This model will reduce the government's workload, prevent time wastage, and resolve easement-related issues before they escalate to the judiciary. The significant discrepancies in easement prices calculated in similar files will largely decrease. The use of this model in courts and expert reports will provide a foundational framework and increase consistency among decisions rendered. Developing a comprehensive program aimed at the education of individuals involved in determining the easement price and introducing this software model will contribute to making more fair and consistent decisions. Improvements to the model can be made based on user feedback. This automation model can be further enhanced by adding more factors related to parcels, housing and easements. For instance, while calculating the value depreciation concerning a house in this model, only the distance of the residence to HVTL has been considered. Additionally, factors such as the degree of visibility of the house to the HVTL or pylon (seeing half of the HVTL, etc.), distance to the pylon, and from which side (front, back, side) the residence sees the pylon or line could be integrated into the automation for more accurate IR and easement price calculations. Moreover, this automation model can be integrated with Geographic Information Systems, enabling calculations based on changes in graphical data for each parcel. Additionally, the algorithms of the model can be enhanced with machine learning and artificial intelligence techniques to create more advanced and effective prediction models. Furthermore, updating the model considering market conditions, legal regulations, and technological advancements is crucial for long-term success.

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