CHAPTER 5

A RESEARCH ON CHANGING HOUSING PREFERENCES WITH THE COVID-19 PANDEMIC: GRAY RELATIONAL ANALYSIS TECHNIQUE

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INTRODUCTION

Housing is an asset that is preferred sometimes for consumption purposes and sometimes for investment purposes and meets the need for shelter, which is one of the basic needs of people in the most general sense. Housing preferences change and develop over time depending on the economic, social, cultural, geographical and demographic factors of each country (Aliefendioğlu and Tanrıvermiş, 2015). With the changing production paradigms and consumption habits in the 20th century, the lifestyles of societies have also changed. Urbanization, which is presented as a symbol of development, has led to a significant increase in the rate of residential user mobility. While the decrease in the preferences of living in rural areas and the increase in the demand for life in the urban area, the migration to the city affected the formation of new textures in the urban space, while the lifestyles of the people began to change with it (Haksever and Markoç, 2020). However, in the pandemic process that started in the city of Wuhan, China in December 2019, with the Covid-19 virus and still has unending effects, housing preferences have entered a different trend. The difficulty of fighting the pandemic by living in crowds in urban life has led people living in city centers to live away from the city.

The increase in the "secondary housing" trend, which was observed in almost all parts of the world during the pandemic period, was also experienced in Turkey. The concept of "secondary housing" refers to houses that people use for short periods of time at various times of the year, apart from their permanent homes. These residences are more specialized with names such as weekend house, summer house, vineyard house, country house, village house, mountain house, farm house. It has been observed that the use of secondary housing has increased with

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periods such as quarantine practices, curfew restrictions, summer holidays and weekends, and it has been observed that houses with gardens and closely related to nature are preferred (Toy, Gökmen and Büyüktopcu, 2022).

Although it is not known how long the Covid-19 process will last, it is estimated that it will continue for a while with mutations. Even if the threat of Covid-19 is completely over, it is not possible to guarantee that new pandemics will not occur. Since housing investment is not generally a short-term investment, it is possible for people to shape their preferences accordingly. It was concluded that people tended to detached houses more in the post-pandemic period than before (Gönen and Çetinkaya, 2021). In Turkey, it is seen that there is an increase in the demand for the use of the lands in rural areas as both production and settlement in the studies on the real estate sector with Covid-19. As a result of the restrictions applied within the scope of Covid- 19 measures, the interest of citizens in large land areas such as gardens, farms, hobby gardens has increased (Tanrıvermis, 2020).

During the Covid-19 pandemic, business life has also partially changed. Many sectors have accelerated digitalization, and most office workers are now working from home. So much so that many companies have announced that they will continue to work remotely, even if the pandemic is over. On the other hand, individuals who have children stated that they need a detached garden of their own. In addition, in the pre-pandemic process, it has been observed that the criterion of proximity to the children's school as well as the proximity of the person to the workplace was sought in the selection of the location of the house, but in the pandemic process, with the transition to both remote work and online education, proximity to work and school was out of the criteria of housing preference (Haksever and Markoç, 2020).

In the light of all this information, it has been observed that there has been a significant change in housing preferences with the pandemic, and it was necessary to examine the changing housing preferences with the pandemic with gray relational analysis. There are many factors that vary from person to person at the stage of housing preferences. However, it is not always possible to examine all of these criteria. At this point, the importance of using Gray Relational Analysis (GRA), which is an important part of Gray Systems Theory (GST), emerges. Gray Systems Theory, which is used to solve such problems with small sample and incomplete information, is preferred as an appropriate methodology. In the literature, the GST method is used in housing, automobile and various purchasing decisions (Özdemir and Deste, 2009; Uğur and Baykan, 2017; Avcı, Şahin and Çelik 2017; İpek and Şahin, 2018; Kökçam, Uygun and Kılıçaslan, 2018; Güler, 2021), textile, forest products industry, education and technological performance measurements (Mondal et al., 2013; Arslan, Bircan and Arslan, 2017; Wang and Li, 2018; Başakın, Özger and Ünal, 2019; Akyüz, 2021), logistics and transportation sector (Ayaydın, Durmuş and Pala, 2017; Başdeğirmen and Işıldak, 2018), banking and finance in various decision-making and performance measurements related to the industry (Peker and Baki, 2011; Baş and Çakmak, 2012; Xiufeng and Xixuan, 2014; Tayyar et al., 2014; Karakoç, Tayyar and Genç, 2016; Gülen and Sakınç, 2017; Günay, Karadeniz and Dalak, 2018; Ayçin, 2019; Uygurtürk and Bal, 2020), in the analysis of various socio-economic indicators (Belgin and Avşar, 2019; Gök Kısa, 2021; Türe, 2019; Üstünışık, 2007), risk evoulation problems (Yunna and Yan, 2014; Daniali, Rodionov and Khortabi, 2020) in studies on health indicators (Girginer, Köse and Uçkun, 2015; Kar, Özer and Avcı, 2018; Karaer and Tatlıdil, 2019).

After the introduction part of the study, Gray Relational Analysis method will be introduced. Afterwards, the findings of the study will be conveyed under the title of application and the study will be completed with the conclusions.

GRAY RELATIONAL ANALYSIS (GRA)

Gray systems theory is a mathematical method developed by Professor Ju-Long Deng in 1982, based on the analysis of uncertain and incomplete data (Deng, 1982; 1989). Compared to other mathematical approaches, the fact that it can be easily applied to problems in many different fields without the need for complex formulas brings this method to the fore and makes it more effective (Köse, Temiz and Erol, 2011). Gray systems theory is basically a method that is frequently used in the analysis, modeling, estimation and decision stages of the relationship between systems (Üstünışık, 2007).

Gray relational analysis, which is one of the application areas of gray systems theory, is a grading, classification and decision-making technique that has taken its place in scientific studies (Lin, Mian-yun and Liu, 2004; Wen, 2004; Liu and Lin, 2006; Li, Yamaguchi and Nagai, 2007). Although the first formula for the calculations of the GRA method was created by Ju-Long Deng, Professor Qingyin Wang revealed the C-type relational formula in the following years (Wang, 1999). Wuxiang Tang also developed the T-type relational calculation for GRA calculations (Tang, 1995). Xinping Xiao also conducted studies that improved gray relational calculation methods and introduced the concept of gray relativity (Zhang, Lin and Peng, 2009). Mei Zhenguo made measurements for the gray absolute degree of correlation (Zhenguo, 1992). The first methodological introduction of

GRA, which is an important part of gray systems theory, was in 1984, two years after the theory was published (Deng, 1984; Wang, Zhang and Hu, 2010). One of the questions that come to mind about this method is the differences or common points of the GRA method, which reveals the relationships between unknown systems and variables, and the regression analysis method, which allows to measure the relationship between two or more quantitative variables. Ng (1994)'s explanation of the differences between gray systems theory and regression analysis is quite revealing.

According to Ng (1994), the differences between GRA and regression analysis are as follows:

- GRA and regression analysis differ in their theoretical basis. While GRA is based on the gray processes of the gray systems theory, the regression analysis is based on the random processes of the probability theory.
- While GRA compares and calculates the dynamic causality of the subsystems of the given systems, the regression analysis focuses on the grouped values of the random variables.
- A small amount of raw data is needed (minimum 4) to apply the GRA method, but large sample datasets are required to apply the regression analysis.
- While GRA mainly investigates the dynamic processes of the system, regression analysis examines the static behavior of the system.

Gray Relational Analysis aims to analyze the uncertainties in multi-criteria decision making problems (Feng and Wang, 2000). Gray relational analysis stands out in that it allows many criteria to be examined at the same time, is effective even in cases where the number of data is low and can be used in situations where the distribution is not known or there is no normal distribution (Liu and Forrest, 2007).

STEPS OF GRAY RELATIONAL ANALYSIS

The application steps of gray relational analysis are described in detail below (Wen, 2004; Zhai, Khoo and Zhong, 2009; Sarraf and Nejad, 2020; Zuo et al., 2020).

Step 1: Creating the Decision Matrix

$$x_i = (x_i(j), \dots, x_i(n)),\ i = 1,2, \dots, m;\ \ j = 1,2, \dots, n$$

$x_i(j)$ describes the value of the alternative "i" for the criterion "j".

The m x n decision matrix is as follows, where m represents the alternatives and n the criteria.

$$X = \begin{bmatrix} X_1(1) & X_1(2) & \dots & X_1(n) \\ X_2(1) & X_2(2) & \cdots & X_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ X_m(1) & X_m(1) & \dots & X_m(n) \end{bmatrix} \quad (1)$$

Step 2: Creating Reference Series

The reference series is expressed as

$$X_0 = (X_0(1), X_0(2), \dots, X_0(j), \dots X_0(n))$$

$X_0(j)$ shows the largest value of the criterion j within the normalized values. The comparison matrix is created by adding the reference series as the first row to the decision matrix.

Step 3: Generating the Normalization Matrix

Since the series used in decision problems are measured in different units, normalization should be done to make them comparable with each other. In other words, if the series in question are in wide intervals, "normalization" should be applied by pulling them into smaller intervals. In the normalization process, three different equations are used depending on whether the benefit, cost or optimal value is preferred (Babacan, 2021). Since the criteria are measured differently, standardization (normalization) is done to make them comparable with each other (Tayyar et al., 2014).

The normalization process is performed in three different ways.

If a high criteria value is appropriate to result from the operation of normalization, the formula (2) is used.

$$X_i^* = [X_i(j) - \min_j X_i(j)] / [\max_j X_i(j) - \min_j X_i(j)] \quad (2)$$

If a low criteria value is appropriate to result from the operation of normalization, the formula (3) is used.

$$X_i^* = [\max_j X_i(j) - X_i(j)] / [\max_j X_i(j) - \min_j X_i(j)] \quad (3)$$

A third situation would be an average value being appropriate to result from the operation of normalization, in this case the formula (4) is used.

$$X_i^* = [X_i(j) - X_{ob}(j)] / [\max_j X_i(j) - \min_j X_i(j)] \quad (4)$$

$\min_j X_i(j)$ describes the minimum value for criteria, $\max_j X_i(j)$ describes the maximum value for criteria and $X_{ob}(j)$ is the target value of the j-th criterion.

After these processes, the decision matrix numbered (1) takes the form of number (5) below.

$$X^* = \begin{bmatrix} X_1^*(1) & X_1^*(2) & \dots & X_1^*(n) \\ X_2^*(1) & X_2^*(2) & \cdots & X_2^*(n) \\ \vdots & \vdots & \ddots & \vdots \\ X_m^*(1) & X_m^*(1) & \dots & X_m^*(n) \end{bmatrix} \quad (5)$$

Step 4: The Formation of Absolute Value Table

During the creation of the absolute value table, the coefficient differences should be calculated. The coefficient difference expresses the difference between the number of rows and the reference value is formulated below.

$$\Delta_{0i} = |X_0^*(j) - X_i^*(j)| \quad i=1,2,\dots,m \text{ and } j=1,2,\dots,n \quad (6)$$

$$\Delta_{0i} = \begin{bmatrix} \Delta_{01}(1) & \Delta_{01}(2) & \dots & \Delta_{01}(n) \\ \Delta_{02}(1) & \Delta_{02}(2) & \cdots & \Delta_{02}(n) \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{0m}(1) & \Delta_{0m}(2) & \dots & \Delta_{0m}(n) \end{bmatrix} \quad (7)$$

Step 5: The Formation of Gray Relational Coefficient Matrix

"ξ" is the discriminant coefficient and it varies between 0-1. It is recommended to be taken as 0.5 in transactions (Zuo et al., 2020). The coefficient matrix is determined with the help of the formula (8).

$$\gamma_{0i}(j) = \frac{\Delta\min + \xi\Delta\max}{\Delta_{0i}(j) + \xi\Delta\max} \quad (8)$$

Δ_{max} and Δ_{min} and in the formula are calculated as follows.

$$\Delta_{\max} = \max_i \max_j \Delta_{0i}(j) \text{ and } \Delta_{\min} = \min_i \min_j \Delta_{0i}(j)$$

Step 6: The Calculation of Degree of Gray Relation

Gray relational degrees were formulated in two different ways according to the ratios of the criteria. "Γ_{0i}" shows the degree of gray relation of the element "i" and the formula (9) is used when criteria are assumed to be equally important.

$$\Gamma_{0i} = \frac{1}{n}\sum_{j=1}^{n} \gamma_{0i}(j) \quad (9)$$

If different weights of criteria are in question, the formula (10) is used.

$$\Gamma_{0i} = \sum_{j=1}^{n} [w_i(j).\gamma_{0i}(j)] \quad (10)$$

Weights were determined by Delphi technique. During the implementation of the technique, experts were interviewed and the factors affecting the housing preferences that changed with the pandemic were scored according to the degree of importance.

APPLICATION ON CHANGING HOUSING PREFERENCES WITH THE COVID-19 PANDEMIC

Material and Method

This research was carried out to determine the possible options to buy a house in Adana city according to the changing housing needs with the Covid-19 pandemic. In this direction, the criteria for housing options were established by taking the opinions of the customers, real estate agents, individual sellers and experts and by scanning the relevant literature. An evaluation was made as a result of the customer's demands, real estate agents and experts' evaluations and experiences of the housing market, and ten preferences were presented for the final valuation process. It is requested to make a ranking in order to determine the most suitable one among these preferences. For this purpose, the gray relational analysis method, which is one of the multi-criteria decision-making methods, was preferred. There are many factors for changing housing preference decisions with the pandemic, but limited information about the options is available.

Gray systems theory is a suitable methodology for solving problems with small samples and missing information. In the analysis phase, the steps of the gray relational analysis method given in the gray relational analysis section were applied and the findings were conveyed.

Decision makers focused on five criteria based on the information they could reach. Table 1 shows the criteria and explanations for housing preferences.

Table 1. Criteria and Explanations for Housing Preferences

Criteria		Explanation
C1	Housing type	A weight of 1 is given for an apartment, 2 for a detached house, and 3 for a villa.
C2	Housing age	It represents the age of the building and the smaller one will be preferred.
C3	Housing price	Housing prices are in TL and are divided by 10^6 at the analysis stage. And the lower priced one will be preferred.
C4	Housing size	The housing with the highest net usage area will be preferred.
C5	Number of rooms	The housing with the most rooms will be preferred.

Since the C1 criterion has the feature of being quantitative data, it has been digitized and processed for ease of calculation.

Findings

The mxn decision matrix created in step 1 is given in Table 2 and Pi' s indicate preferences, with i=1,…,10.

Table 2. Decision Matrix

	C1	C2	C3	C4	C5
P1	1	1	2,1	140	3
P2	1	0	2,4	180	4
P3	2	3	1,6	132	3
P4	3	3	4,2	250	5
P5	2	7	1,3	120	3
P6	3	2	2,9	230	4
P7	3	1	4,8	285	5
P8	1	5	1,8	142	3
P9	2	0	2,3	165	4
P10	3	2	3,7	220	4

In step 2, the reference series must be created to find the comparable series closest to the reference series. The comparison matrix is created by adding the reference series as the first row to the decision matrix in Table 3.

Table 3. Reference Series

	C1	C2	C3	C4	C5
	Max	**Min**	**Min**	**Max**	**Max**
RS	3	0	1,3	285	5
P1	1	1	2,1	140	3
P2	1	0	2,4	180	4
P3	2	3	1,6	132	3
P4	3	3	4,2	250	5
P5	2	7	1,3	120	3
P6	3	2	2,9	230	4
P7	3	1	4,8	285	5
P8	1	5	1,8	142	3
P9	2	0	2,3	165	4
P10	3	2	3,7	220	4

In step 3, formulas (2) and (3) were used to normalize the data and the normalization matrix is given in Table 4.

Table 4. Normalization Matrix

	C1	C2	C3	C4	C5
RS	1,000	1,000	1,000	1,000	1,000
P1	0,000	0,857	0,771	0,121	0,000
P2	0,000	1,000	0,685	0,363	0,500
P3	0,500	0,571	0,914	0,072	0,000
P4	1,000	0,571	0,171	0,787	1,000
P5	0,500	0,000	1,000	0,000	0,000
P6	1,000	0,714	0,542	0,666	0,500
P7	1,000	0,857	0,000	1,000	1,000
P8	0,000	0,285	0,857	0,133	0,000
P9	0,500	1,000	0,714	0,272	0,500
P10	1,000	0,714	0,228	0,606	0,500

In the step 4, the calculation of the absolute differences of the normalized reference series value and the normalized alternative values was performed with the help of equation (6) and the obtained values are given in Table 5.

Table 5. Absolute Value Table

	C1	C2	C3	C4	C5
RS	1,000	1,000	1,000	1,000	1,000
P1	1,000	0,143	0,229	0,879	1,000
P2	1,000	0,000	0,315	0,637	0,950
P3	0,500	0,429	0,086	0,928	1,000
P4	0,000	0,429	0,829	0,213	0,000
P5	0,500	1,000	0,000	1,000	1,000
P6	0,000	0,286	0,458	0,334	0,950
P7	0,000	0,143	1,000	0,000	0,000
P8	1,000	0,715	0,143	0,867	1,000
P9	0,500	0,000	0,286	0,728	0,950
P10	0,000	0,286	0,772	0,394	0,950

In the step 5, using the formula (8), the gray correlation coefficients were calculated and the gray correlation coefficient matrix given in Table 6 was created.

Table 6. Gray Correlation Coefficient Matrix

	C1	C2	C3	C4	C5
P1	0,333	0,777	0,685	0,362	0,333
P2	0,333	1,000	0,613	0,439	0,344
P3	0,500	0,538	0,853	0,350	0,333
P4	1,000	0,538	0,376	0,701	1,000
P5	0,500	0,333	1,000	0,333	0,333
P6	1,000	0,636	0,521	0,599	0,344
P7	1,000	0,777	0,333	1,000	1,000
P8	0,333	0,411	0,777	0,365	0,333
P9	0,333	1,000	0,636	0,407	0,344
P10	1,000	0,636	0,393	0,559	0,344

In step 6, gray relational degrees were determined in Table 7 by using the gray relational data coefficients in Table 6. These data are values without any weight assignment for the criteria (that is, the weights of all criteria are considered equal to each other). According to these data, the options were ranked, with the option with the highest value in the first place. In this case, preference 7 takes the first place, preference 4 takes the second place and preference 6 takes the third place. Preference 8 is in last place.

Table 7. Gray Relational Degrees for Equal Weighted Criteria and Alternative Rankings

	C1	C2	C3	C4	C5	Γ_{0i}	Ranking
P1	0,333	0,777	0,685	0,362	0,333	0,498	9
P2	0,333	1,000	0,613	0,439	0,344	0,545	5
P3	0,500	0,538	0,853	0,350	0,333	0,514	7
P4	1,000	0,538	0,376	0,701	1,000	0,723	2
P5	0,500	0,333	1,000	0,333	0,333	0,499	8
P6	1,000	0,636	0,521	0,599	0,344	0,620	3
P7	1,000	0,777	0,333	1,000	1,000	0,822	1
P8	0,333	0,411	0,777	0,365	0,333	0,443	10
P9	0,333	1,000	0,636	0,407	0,344	0,544	6
P10	1,000	0,636	0,393	0,559	0,344	0,586	4

In cases where the importance levels of the criteria differ, the criteria values (wi) weighted by the decision makers are given in Table 8. In this case, the gray relational degrees are equal to the product sum of the relational coefficients with wi. According to these data, the preferences were ranked, with the preerence with the highest value in the first place. In this case, preference 7 takes the first place, preference 4 takes the second place, preference 5 takes the third place. In this ranking, preference 1 took the last place. Therefore, different rankings were formed by making different calculations in response to the equal and different weights of the criteria.

Table 8: Gray Relational Degrees for Weighted Criteria and Alternative Rankings

	C1	C2	C3	C4	C5	Γ_{0i}	Ranking
wi	0,200	0,100	0,400	0,150	0,150		
P1	0,333	0,777	0,685	0,362	0,333	0,522	10
P2	0,333	1,000	0,613	0,439	0,344	0,529	8
P3	0,500	0,538	0,853	0,350	0,333	0,597	5
P4	1,000	0,538	0,376	0,701	1,000	0,659	2
P5	0,500	0,333	1,000	0,333	0,333	0,633	3
P6	1,000	0,636	0,521	0,599	0,344	0,613	4
P7	1,000	0,777	0,333	1,000	1,000	0,710	1
P8	0,333	0,411	0,777	0,365	0,333	0,523	9
P9	0,333	1,000	0,636	0,407	0,344	0,533	7
P10	1,000	0,636	0,393	0,559	0,344	0,556	6

CONCLUSIONS AND RECOMMENDATIONS

Gray systems theory has grown with its ability to produce solutions to practical problems in the world and to give successful results in the conditions of incomplete information and small sample. In order to understand the motivations for the introduction and development of this theory, it would be useful to understand the scientific, social and economic conjuncture in the country (China) where it was developed. The gray relational analysis method is used to investigate the qualitative and quantitative relationships between abstract and complex sequences and to determine their dynamic properties from the development process. One of the main strengths of gray relational analysis methodologically is that it can benefit from relatively small datasets, does not have to comply with certain statistical laws, and does not require strict compliance with simple or linear relationships between observable variables (Liu, 2010; Javed and Liu, 2019).

In this study, the differences in housing preferences with the Covid-19 pandemic were examined with the gray relational analysis method. The most important factor in the preference of this method was that the gray relational analysis method was effective in small and incomplete data, and the inability to include all the criteria determined for housing preferences within the scope of the study and the fact that it was studied with a certain amount of criteria.

With this method, two separate rankings were made according to the criteria being of equal weight and having different values among the options. In the first one, the data are values without any weight assignment for the criteria (that is, the weights of all criteria are considered equal to each other). According to these the options were ranked, with the preference with the highest value in the first place. In this case, preference 7 takes the first place, preference 4 takes the second place and preference 6 takes the third place. Preference 8 is in last place. According to this ranking, it is seen that villa type houses are in the first three preferences. The most important reason for this is the fear caused by the Covid-19 pandemic in people and the desire to live away from the city. At this point, since the use of common areas has decreased in terms of social life, villa-type houses with their own green area and large square meters come to the fore. In the second one, preference 7 takes the first place, preference 4 takes the second place, preference 5 takes the third place. Preference 1 took the last place. At this stage, since the weights were taken into account, the price balance was also taken into account, and detached type houses, which were lower in price in terms of certain features (The detached houses offered as a preference in this study have features such as not being included in the site, being a single storey, and security problems) compared to villa type houses, were also included in the top three. As can be seen, apartments are at the bottom of the preference list. As a result, with the Covid-19 pandemic, it has been seen that individuals who want to live away from the city center and in nature prefer houses according to their budgets. Here, the main point for the family who wants to buy a house is a quiet life away from people. According to the budget of the preferers, the features of the house increase and the price increases. The importance of health has been understood in the Covid -19 process and people have turned to live their lives far from the virus and more comfortably. Therefore, instead of investing more, it is seen that they invest their current budget in a large and independent house, and it is clear that villa type and detached houses are preferred according to the apartment. It is known that families with favorable economic conditions make a rapid transition to villa type houses.

This study showed that the Covid-19 outbreak suddenly reversed the trend of living in the city center, which is attractive for many individuals and families, and revealed the importance of the characteristics of the housing. In future studies, in addition to the gray relational analysis method in housing preferences or similar issues, productivity and performance measurement can be performed between preferences with methods such as analytical hierarchy method, TOPSIS, data envelopment analysis.

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