Research Article

Estimating Mobile Contactless Payment Systems Usage in Turkey Using Grey Prediction Model

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(First received January 5, 2020 and in final form March 21, 2023)

Reference: Estimating Mobile Contactless Payment Systems Usage in Turkey Using Grey Prediction Model. The European Journal of Research and Development,3(1), 86-96.

Abstract

Technological developments brought about by digitalization have made several innovations in many areas from economy to social life a part of our lives. The most important of these innovations was the electronicization of trade. Electronic commerce forced payment systems to change and differentiated them. The rapid development of the technology of mobile devices and the rapid spread of use also shaped the change in payment systems. Today we are talking about mobile payment systems. The change in payment systems also caused changes in physical credit cards, and contactless payment systems with credit cards became widespread. Mobile contactless payment systems have also started to be used through applications downloaded to mobile devices without the need for a physical credit card. After the convenience of contactless payment with credit card, many banks started to offer their customers the convenience of contactless payment by mobile phone.

In this study, the demand for the use of mobile contactless payment systems in Turkey was estimated using the grey prediction model for the coming years. In determining demand forecast, the grey prediction model, which is included in the grey system theory, which was first presented by Deng in 1982, was used. It is a model that is used to make high-precision predictions based on a small number of data and has achieved successful results in many areas. In this study, some of the data were used for estimation and some for analysis of estimation results. In this study, high sharpness results were obtained.

Keywords: *Grey system theory, grey prediction model, mobile contactless payment systems*

1. Introduction

Today, mobile phone users prefer data services and applications based on them beyond traditional voice and messaging. They intensively use applications that will facilitate their daily lives, and the share of e-commerce and financial services among these applications is large and increasing. It has become increasingly preferable thanks to the ability to make payments through phone applications, facilitate the lives of users, provide time benefits, and the trust of buyers and sellers in these systems.

In the document dated 2012 prepared by the EU commission, mobile payment; "Payment data and payment order is a payment accepted, transmitted or confirmed over a mobile phone or device. This definition covers the purchase of online or offline services and digital or physical goods." is defined as [1].

It is possible to say that there are basically two methods for mobile payments. These are Close Mobile Payments and Mobile Remote Payment. Today, the distinction between mobile payments and e-payments is becoming increasingly blurred. The volume of payments via mobile phones is currently the fastest growing of all payment methods.

Finland has been a country with many firsts in terms of mobile payments. The first mobile payment was made in 1997 at the Coca-Cola vending machine at Helsinki Airport in Finland. Thirsty passengers paid for their drinks via SMS sent from their mobile phones. The first mobile banking service was launched by Finnish Merita Bank in the same year, via SMS.The first commercial digital content upload to mobile phones was also carried out in Finland. The action taken; it was downloading ringtones from Radiolinja [2]. The mobile payment system in the banking sector in our country was first introduced in 2012 by İşbank (QR Code payment system) [3].

As of today, mobile payment systems have become popular and their use by consumers is increasing. This study focuses on the future of contactless mobile payment systems in Turkey.

2. Materials and Methods

In this study, the situation of mobile contactless payment in Turkey in the following years was tried to be estimated by using the Grey Prediction Model.

2.1. Grey System Theory and Grey Prediction Method

The grey system theory developed by Ju Long Deng in 1982; In research in the field of condition analysis, forecasting and decision making, it focuses on uncertainty and lack of information to analyze and understand systems [4]. Grey system theory, which is an interdisciplinary approach, is an alternative method for quantifying uncertainty. The basic idea in its emergence is to predict the behavior of uncertain systems, which cannot be overcome by stochastic or fuzzy methods, with the help of a limited number of data.

Probability and statistics, fuzzy mathematics and grey system theory are the most common methods and theories used in studies for non-deterministic systems. Despite dealing with different types of uncertainties, the common point of these theories is that they have the power to draw meaningful conclusions in the presence of incomplete information and uncertainty. Unlike fuzzy mathematics, objects examined with grey system theory have distinctive extension and non-obvious internality characteristics [5]. For example, the range of 20 to 25 million in the expression "It is estimated that there will be between 20 and 25 million students in Turkey in 2030" is a grey concept whose true value is not known, but whose limits are well known.

The main feature that distinguishes the grey prediction method, which is one of the main fields of work of grey system theory, from traditional prediction methods is that it needs a limited number of data to predict the behavior of uncertain systems. Traditional forecasting methods such as time series require large amounts of historical data and known statistical distributions to make accurate assessments. Unlike traditional prediction methods, the main feature of the grey prediction method is that it does not need strict assumptions about the data set and can be successfully applied in the analysis of systems with limited data.

The grey prediction method has been developed to make predictions about the future with the help of the grey model GM(1,1) using the available data. GM(1,1) is a time series forecasting model that contains a set of differentiable equations. The GM(1,1) notation is used to express the grey model with first-order differentiable equations with a single variable.

It is observed that the grey prediction model is frequently used in all fields in the literature. Hsu (2003), examined the precision of the grey prediction model applied to demand and sales-based samples in the global integrated circuit (IC) industry. Empirical results have shown that GM is more suitable for short-term forecasts than medium and long-term forecasts [6]. Lin & Yang (2003) applied grey prediction model from grey theory to accurately predict the output value of Taiwan's opto-electronics industry from 2000 to 2005. The findings provided a valuable reference to the government in the preparation of relevant policies for the opto-electronics industry and to companies in the preparation of relevant policies for their products [7]. Lin & Yang (2004), applied the grey prediction model of grey theory to accurately predict the output value of Taiwan's IC industry from 2000 to 2005. The results showed that the grey prediction model has a high prediction accuracy [8].

In their study, Trivedi & Singh (2005) tried to model the rainfall-runoff process by using the grey system theory, which is a relatively new approach in hydrology. Low values of various error indices and high values of correlation indices confirmed the model's ability to predict storm runoff with reasonable accuracy for the study area [9].

A grey prediction model based on grey theory can be adapted to predict energy consumption as it can be built for at least four data points or uncertainty data. However, in some cases, a grey prediction model may introduce large forecasting errors. To minimize such errors, Lee & Tong (2011) developed an advanced grey prediction model that combines residual modification with genetic programming sign prediction and compared it with a real Chinese energy consumption situation to demonstrate the effectiveness of the proposed prediction model [10].

In their study, Mohammadi et al. (2011), firstly, the original predictive values of road traffic accidents were obtained separately with the GM(1,1) model, Verhulst model and DGM(2,1) model. The results of these models to predict road traffic accidents showed that the prediction accuracy of GM(1,1) is higher than the Verhulst model and DGM(2,1) model, and then GM(1,1) used to predict road traffic accident in Fars province[11]. Mao & Sun (2011), created a new effective prediction model (Grey-Markov model) due to the fact that fire accidents have both randomness and fluctuation [12].

In their study based on grey theory and differential evolution (DE) algorithm, Zhao et al. (2012) developed a high-precision hybrid model DE-GM(1,1) to estimate the annual net income per capita of rural households in China[13].

In their study, Zhang et al., (2012) aimed to predict product demand values for cold chain logistics in China from 2010 to 2015 using GM (1,1) [14]. Tsai et al., (2013) applied the the grey prediction model from grey theory to accurately forecast Taiwanese telecommunication demand from 2004 to 2007 [15].

In their study, Shen & Lu (2014) built an electricity demand forecasting model for Jiangsu province based on the grey system theory and validated it using data from 1997 to 2012 [16]. Hamzacebi & Es (2014) predicted total electric energy demand of Turkey for the 2013-2025 period by using an optimized grey modeling (1,1) [17].

The grey prediction method consists of the basic steps described in detail below [5].

Step-1: Let X(0) be the raw time series sequence with a single variable valence n magnitude that forms the time series.

$X(0) = (x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(n))$; $n \geq 4$ (1)

X(1) is constructed using the first-order aggregate production operator.

$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), \; (i = 1,2,3, \ldots \ldots, n)$ (2)

$X(1) = (x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \ldots, x^{(1)}(n))$; $n \geq 4$ (3)

Step-2: Determination of Coefficients: $x^{(0)}(k) + a x^{(1)}(k) = b$ represents the original form of the model G(1,1). k is the time points; a is the coefficient of improvement; b represents the driver coefficient.

$Z^{(1)}$ is generated using the first-order mean value generation operator.

$z^{(1)}(k) = 0{,}5x^{(1)}(k) + 0{,}5x^{(1)}(k-1)$ (4)

$Z^{(1)} = (z^{(1)}(1), z^{(1)}(2), z^{(1)}(3), \ldots, z^{(1)}(n))$ (5)

The basic form of the G(1,1) model is written as $x^{(0)}(k)+az^{(1)}(k)=b$ in which the $Z^{(1)}$ series is used. The least squares method is used in estimating the a and b parameters. If the equation is written in matrix form, Y=Bã equality can be obtained. Here, Y, B and ã represent the matrices.

$$B = \begin{bmatrix} -z^{(1)}(2) & \cdots & 1 \\ \vdots & \ddots & \vdots \\ -z^{(1)}(n) & \cdots & 1 \end{bmatrix} \quad (6)$$

$$Y = \begin{bmatrix} x^{(0)}(2) \\ \cdot \\ \cdot \\ \cdot \\ x^{(0)}(n) \end{bmatrix} \quad (7)$$

$$ã = \begin{bmatrix} a \\ b \end{bmatrix} \quad (8)$$

In order to obtain the vector ã, the following operations must be performed in order.

$$Y=Bã \quad (9)$$

$$B^TY=B^TBã \quad (10)$$

$$ã=(B^TB)^{-1}B^TY \quad (11)$$

Step-3: Obtaining the GE equation.

The prediction model is obtained by solving the differential equation 12.

$$\frac{dx^{(1)}(k)}{dk} + ax^{(1)}(k) = b \quad (12)$$

$$X^{(t)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-ak} + \frac{b}{a} \quad (13)$$

The last Grey Model to be used for prediction calculated as;

$$X^{(t)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-ak}(1-e^{a}) \quad (14)$$

Forecasting is performed using the prediction model.

Step-4: Determining the margin of error of the forecast model and testing whether the model can be used to generate future forecast values.

To test the performance of the grey prediction model, Deng (1986) proposed two determinants of accuracy and error rate (P and C values).

The prediction error for any k elements of the original data set is denoted by $\varepsilon^{(0)}(k)$ and is calculated as follows.

$$\varepsilon^{(0)}(k) = x^{(0)}(k) - X^{(0)}(k) \text{ , k=1,2,3,.....n} \quad (15)$$

The error rate for any k elements of the original data set is denoted by $\delta^{(0)}(k)$ and is calculated as follows:

$$\delta^{(0)}(k) = \left(\frac{x^{(0)}(k) - X^{(0)}(k)}{x^{(0)}(k)}\right) * 100\% \text{ , k=1,2, 3,.....n} \quad (16)$$

The accuracy of the prediction model is determined by the parameter P defined below.

$$P = \frac{\sum_{k=2}^{n}(1-|\delta^{(0)}(k)|)}{n-1} \quad (17)$$

The error mean of the predicted data and the mean of error squares are represented by symbols ξ and S_1 respectively, and are calculated as follows:

$$\xi = \frac{\sum_{k=1}^{n} \varepsilon^{(0)}(k)}{n} \tag{18}$$

$$S_1 = \sqrt{\frac{\sum_{k=1}^{n} (\varepsilon^{(0)}(k) - \xi)^2}{n}} \tag{19}$$

The mean of the observed data and the mean of squares of error are represented by symbols m and S_2, respectively, and are calculated as follows:

$$m = \frac{\sum_{k=1}^{n} x^{(0)}(k)}{n} \tag{20}$$

$$S_2 = \sqrt{\frac{\sum_{k=1}^{n} (x^{(0)}(k) - m)^2}{n}} \tag{21}$$

The parameter value that gives the error rate of the prediction model is denoted by C and is calculated with the help of the following formula:

$$C = \frac{S_1}{S_2} \tag{22}$$

The lower the error rate, the higher the performance of the prediction model will be. The classification of the prediction models according to the values of the P and C parameters, which are the two decisive criteria for the prediction model, is shown in the Table 1 below.

Table 1: The classification of the prediction models

CLASSIFICATION	PARAMETERS	
	P	C
GOOD	>0.95	<0.35
SUFFICIENT	>0.80	<0.50
BOUNDARY	>0.70	<0.65
INSUFFICIENT	≤0.70	≥0.65

Step-5: If the test result is positive, generate the forecast values for the next period using the prediction model.

3. Application

As of today, the popularity of the mobile payment system and the increase in its acceptance by consumers have directed many authors and academics to research/study on this subject. In this study, the situation of Mobile Contactless Payment in Turkey in the future quarterly periods was tried to be estimated by using the Grey Prediction Model.

The following table lists the quarterly data of Mobile Contactless Payment data received from the Interbank Card Center [18].

Table 2: Mobile Contactless Payment Data

Period	Number of Transactions	Transaction Amount (Million TL)
2020Q1	1.184.133	58,54
2020Q2	2.005.219	140,35
2020Q3	3.423.199	225,38
2020Q4	3.668.903	248,52
2021Q1	3.870.280	292,44
2021Q2	4.572.341	364,94
2021Q3	6.118.134	494,02
2021Q4	6.216.362	573,69
2022Q1	6.460.090	707,33

In the application, firstly $X^{(0)}$ time series were created. (Separate calculations were made for Transaction Amount and Transaction Number).

$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \ldots, x^{(0)}(n))$; $n \geq 4$

$X^{(0)}$ =(1184133, 2005219, 3423199, 3668903, 3870280, 4572341, 6118134, 6216362, 6460090)

As a second step, $X^{(1)}$ is constructed using the first-order aggregate production operator.

$X^{(1)}$ = (1184133, 3189352, 6612551, 10281454, 14151734,18724075, 24842209, 31058571, 37518661)

Then, using the first-order mean value generation operator, $Z^{(1)}$ was generated.

$z^{(1)}(k)=0,5x^{(1)}(k)+0,5x^{(1)}(k-1)$

$Z^{(1)} = (z^{(1)}(2), z^{(1)}(3), \ldots, z^{(1)}(n))$

$Z^{(1)}$ =(2186743, 4900952, 8447003, 12216594, 16437905, 21783142, 27950390, 34288616)

Then B and Y matrices were created by calculating the equation $\tilde{a}=(B^TB)^{-1}B^TY$ the vector $\tilde{a}$ is obtained. Estimated values were calculated with the formula:

$$X^{(t)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a}\right] e^{-ak}(1 - e^{a})$$

In the next step, it was tested whether the model could be used for prediction. P and C values were calculated for this test.

For the Number of Transactions;;

- P: 0,902915645 > 0,80 Sufficient
- C:0,236872673 < 0,35 Good

For Transaction Amount:

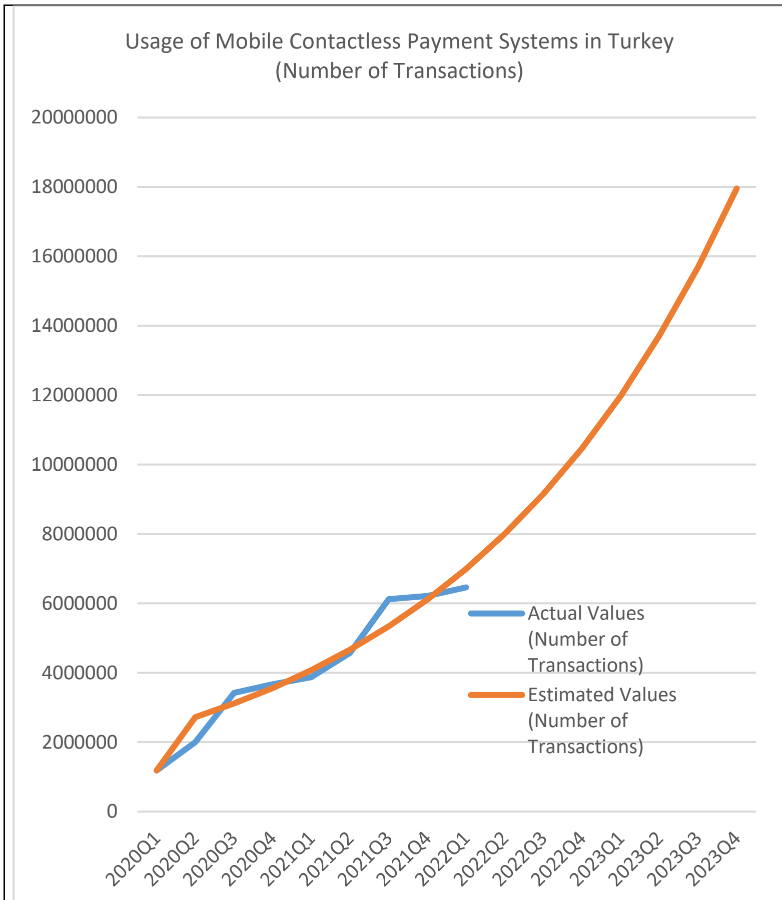
- P: 0,948883845 >0,80 Sufficient
- C: 0,07935459 < 0,35 Good

The test results were positive, so the forecast values for the next period were generated using the prediction model.

3. Results

Actual and estimated values based on the number of transactions regarding the use of mobile contactless payment systems in Turkey are shown in Table 3 and the related chart.

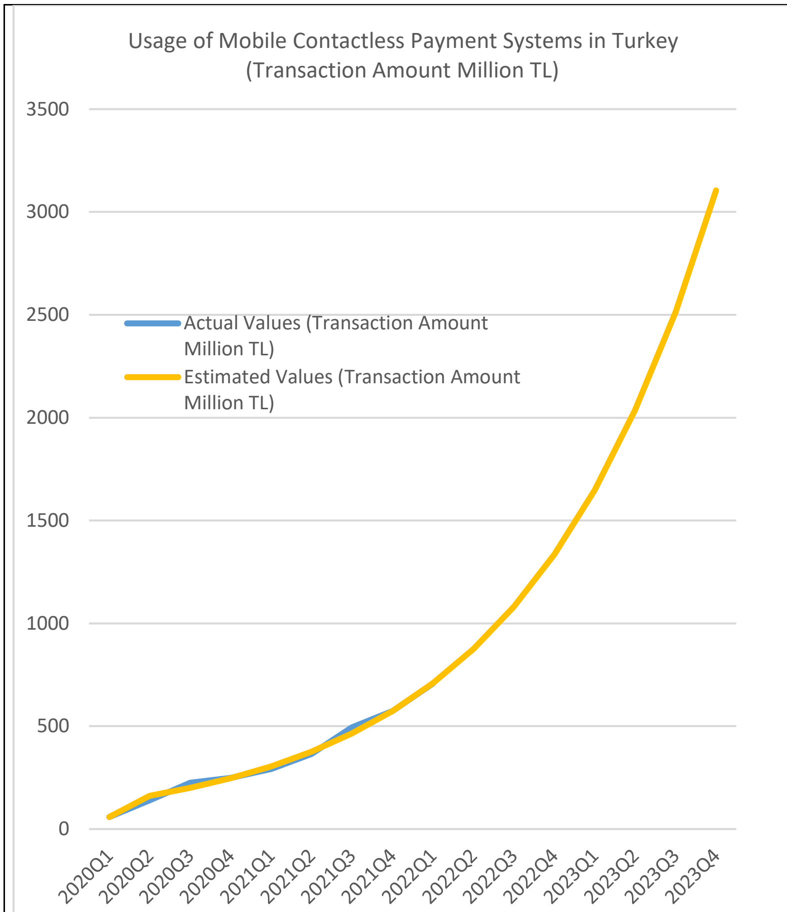
Table 3: Usage of Mobile Contactless Payment Systems in Turkey 2020-2023 (Number of Transactions)



Period	Actual Values (Number of Transactions)	Estimated Values (Number of Transactions)
2020Q1	1184133	1184133
2020Q2	2005219	2720405
2020Q3	3423199	3112960
2020Q4	3668903	3562160
2021Q1	3870280	4076180
2021Q2	4572341	4664374
2021Q3	6118134	5337444
2021Q4	6216362	6107638
2022Q1	6460090	6988971
2022Q2		7997480
2022Q3		9151518
2022Q4		10472084
2023Q1		11983207
2023Q2		13712386
2023Q3		15691085
2023Q4		17955311

Actual and estimated values based on the transaction amount for the use of mobile contactless payment systems in Turkey are shown in Table 4 and the related chart.

Table 4: Usage of Mobile Contactless Payment Systems in Turkey 2020-2023 (Transactions Amount)



Period	Actual Values (Transaction Amount Million TL)	Estimated Values (Transaction Amount Million TL)
2020Q1	58,54	58,54
2020Q2	140,35	161,87
2020Q3	225,38	199,89
2020Q4	248,52	246,84
2021Q1	292,44	304,83
2021Q2	364,94	376,44
2021Q3	494,02	464,86
2021Q4	573,69	574,07
2022Q1	707,33	708,92
2022Q2		875,45
2022Q3		1081,10
2022Q4		1335,05
2023Q1		1648,67
2023Q2		2035,95
2023Q3		2514,21
2023Q4		3104,82

4. Discussion and Conclusion

In this study, the demand for the use of mobile contactless payment systems in Turkey was estimated using the grey forecasting model for the future quarterly periods.
It was seen that the Grey Forecasting model created was sufficient for the prediction of the future years, and it was sufficient with the tests (P and C values).
Estimates were made for the number and amounts of Contactless mobile payment transactions for the coming quarters. It is estimated that in the last quarter of 2023, the number of transactions will be 17.955.310 and the transaction amount will reach 3.104.822.586 TL. As can be seen, the volume is increasing rapidly.
These figures are important in terms of planning the investments of the stakeholders who play a role in the realization of mobile payments.

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