Avrupa Bilim ve Teknoloji Dergisi
Sayı 54, S. 32-45, Aralık 2024

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 54, pp. 32-45, December 2024

Research Article

ANN Analysis and ODE Model of Selected Factors Affecting Mental Health Problems of Children in Turkey

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(First received 22 March 2024 and in final form 14 April 2024)

(**DOI:** 10.5281/zenodo.14176042)

ATIF/REFERENCE: Hızlısoy, S., Arslan, R. S., Çökük, G. Ö. & Daşbaşı, B. (2024). ANN Analysis and ODE Model of Selected Factors Affecting Mental Health Problems of Children in Turkey. *Avrupa Bilim ve Teknoloji Dergisi*, (54), 32-45.

Abstract

In this study, the effects of selected variables on mental health problems in children were examined by using data obtained from Turkish Statistical Institute (TSI). A suitable environment for ANN analysis has been created by augmenting the data with minimum error by linear ordinary differential equation (ODE) system. The augmented data was analyzed through ANN and activation functions were expressed mathematically. Therefore, the effects of some pre-selected factors affecting mental health problems in children have been presented mathematically. Additionally, predictions were made regarding the variables used. The results of the study were supported by graphics.

Keywords: ANN Analysis, Activation Function, Mathematical Modeling.

Türkiye'deki Çocukların Ruh Sağlığı Sorunlarını Etkileyen Seçilmiş Faktörlerin YSA Analizi ve ODE Modeli

Öz

Bu çalışmada TÜİK' den elde edilen veriler kullanılarak seçilen değişkenlerin çocuklarda ruh sağlığı sorunlarına etkisi incelenmiştir. Lineer ODE sistemi vasıtasıyla minimum hata ile veriler artırılarak YSA analizi için uygun ortam oluşturulmuştur. Artan veriler YSA aracılığıyla analiz edilmiş ve aktivasyon fonksiyonları matematiksel olarak ifade edilmiştir. Böylece çocuklarda ruh sağlığı sorunlarını etkileyen önceden seçilmiş bazı faktörlerin etkileri matematiksel olarak ortaya konmuştur. Ayrıca kullanılan değişkenlere ilişkin tahminlerde bulunulmuştur. Araştırmanın sonuçları grafiklerle desteklenmiştir.

Anahtar Kelimeler: YSA Analizi, Aktivasyon Fonksiyonu, Matematiksel Modelleme.

1. Introduction

There is no clear reason why children develop mental health problems, but certain factors, such as exposure to traumatic experiences, can cause serious problems such as stress, depression, anxiety, self-harm or eating disorders. These traumatic experiences can be said to be being bullied, loss of a loved one, parents' divorce, domestic violence, bad habits of their parents.

It has been shown that disruption or damage to the structure of the family, which is one of the basic building blocks of society, can affect the mental health of children. As children have difficulty adapting to the stressful transitions caused by divorce, deteriorations in their physical and psychological health may occur. Some children may experience physical reactions such as stomach, head, and chest pains under stress (Uzun, 2013).

So what are the psychological effects of divorce on children's mental health? Since divorce is a process that has psychological, social and legal consequences, it has a significant impact on the sociological and psychological development of the child. Researchers have shown in their studies that there are significant differences between the children of divorced and non-divorced parents, and that children do not accept divorce and prefer a bad marriage to divorce. They also suggested that children of divorced parents, regardless of age, gender and culture, may develop anxiety due to reasons such as the change in the lifestyle the child is used to, the disruption of the family structure and one of the parents leaving home, and accordingly, they may show symptoms of lack of self-confidence or depression. Compared to other children; it has also been observed that depression and anxiety rates are higher in children of divorced parents.

Smoking is a harmful habit that is triggered by various reasons, especially psychological and social reasons. While harmful habits such as smoking cause both material and moral harm to people who use them, they also leave various psychological, physical and social effects depending on the amount and duration of use (Yıldız & Kavaklı, 1994). In fact, these effects are not limited to the user but extend to the entire family system and society in general (Kuppens, 2020). Numerous studies spanning decades have documented that children of tobacco-using parents are more likely to develop a variety of emotional, behavioural, physical, cognitive, academic and social problems in the short and long term (Barnard & McKeganey, 2004), (Straussner & Fewell, 2011). In fact, it is associated that cognitive deficits and problematic behaviours such as attention deficit, impulsivity, anxiety and behavioural problems seen in childhood may be due to changes in the structure and function of the fetal brain due to the mother's smoking during pregnancy (Yang, 2013).

Postnatal parental attitudes and behaviours are also associated with some mental health problems that can be observed in childhood, adolescence and even adulthood. Parents' harmful habits such as tobacco and cigarettes can disrupt family relationships and lead children to chronic stress, substance abuse, depression and even suicide (Reynales-Shigematsu et al., 2024).

Also, some studies have shown that exposure to tobacco in the family setting (i.e., parent or other family member smoking) is associated with greater externalizing behaviours such as aggressive and antisocial behaviour in childhood, general conduct problems, and disruptive behaviour disorders, including emotional and behavioural problems (Steeger, 2019).

Another harmful habit, like smoking, is alcohol use. Alcohol use harms the user not only physically but also in their family, business and social life and economic situation. When studies are examined, it has been observed that even small amounts of alcohol can affect the central nervous system. In fact, it has been known for years that alcohol consumed during pregnancy causes permanent damage to the fetus, such as permanent brain damage and growth delay (Christoffersen & Soothill, 2003). Again, in children of families who use alcohol; it has been stated that they are relatively more likely to have learning difficulties than other children due to hyperactivity disorder, depression, anxiety, attention deficit, and significant perceptual delays. When looking at the more devastating consequences, it has been observed that children with alcoholic parents generally have lower self-confidence, thus face personality disorders and mental health problems, and have lower academic success. In addition, it was observed that the risk of harming themselves and those around them, aggression, and attempting suicide was higher in these children than in the children in the control group (Erdim, 2019).

Poverty is generally expressed as the fact that opportunities such as food, clothing and shelter fall behind the general level of the society. Family poverty is one of the increasing public health problems affecting children and young people around the world. Because family poverty brings with it many negative consequences such as cognitive, emotional, behavioral and health problems, and is undoubtedly an important risk factor for children in the family in terms of lifelong health (Adjei et al., 2024). Childhood years are the most important period for physical and spiritual development, therefore, depending on the severity and duration of childhood poverty, children's health is affected physically and psychologically in different ways. This problem may cause these children to experience socio-emotional problems such as early death, lower academic success, depression, social withdrawal, and low self-confidence, as well as physical problems, when they become adults (Günaydın, 2021).

Nowadays, scientists try to clarify almost everything in mathematical terms. In this way, we can better discover the events around us and find solutions to technical problems connected to them. This process and way of thinking, in which events are stated in mathematical terms, is called mathematical modeling. Mathematical modeling takes many different forms. Some of these may be called dynamical systems, statistical models, differential equations or game theoretic models (Daşbaşı, 2023). Considering differential equations, they are widely used in almost every field of science. Some of them are: Economics (Tsoularis, 2021), Finance and

Accounting (Liu et al., 2022), Behavioral Sciences (Helbing et al., 2000), (Verdière et al., 2015), Mechanics (Soare et al., 2007), Electromagnetics (Bondeson et al., 2012), Neural Network (Chen et al., 2018), Image Encryption (Javeed & Shah, 2020), Chemistry (Mincheva & Roussel, 2007), (Daşbaşı & Daşbaşı, 2017), (Joshi et al., 2023), Biology (Mustapha et al., 2023), Medicine (Atede et al., 2023), etc.

In this study, the effects of the followings:

- Rate of Households with the Habit of Using Alcoholic Beverages (%),
- Child Addiction Rate (0-14 Years) (%),
- Proportion of Children in Serious Financial Deprivation (%),
- Crude Divorce Rate and
- Proportion of Households with the Habit of Using Cigarettes or Tobacco (%)

on mental health problems (%), which have an important place among the Selected Health Problems in Children, were mathematically investigated by using the data obtained from TSI.

In the second section of this study, the literature review is given. In the third section, the ODE and ANN-based methodology structure, dataset details, and data augmentation approach are explained. In the next section, ANN and ODE system performance results are comparatively given and discussed. In the last section, a general evaluation of the study was made.

2. Literature Review

The influence of the household from past to present on the subsequent behaviour of the children in the home is examined. Mental health problems in children have both hereditary and environmental factors related to upbringing. In existing studies, it is seen that factors such as alcohol and tobacco use, financial deprivation or separation of parents are generally evaluated separately and their effects are examined. In the studies conducted, the effects of all these factors on child mental health are examined.

Regarding the impact of divorce on children's mental health, Tolan (2023) (Tolan, 2023) stated in this study that in families where parents divorce, all members of the family are deeply affected psychologically, and the children are the ones most affected by this situation. In this study, he examined the effects of divorce on the child according to age variable; He discussed his study in four sections: infancy, pre-school, school period and adolescence.

Aktas and Bulut (2022) (Aktaş, 2022) presented different ideas in their study that the mental health of children in divorced families is negatively affected and they face many psychological, emotional and social difficulties. It has been stated that children have various problems with their parents who have or cannot get custody, and if the mother has custody, the mother will experience difficulties due to financial and psychological problems after the process, and the separation from the father will cause the child to feel deficient in many aspects, which will affect their entire life in the future.

In one of the studies conducted on the effect of smoking within the family on the psychology of the children living in that family, Steeger et al. (2020) (Steeger, 2019) examined whether there was a connection between parental smoking and young people's externalizing behaviours (i.e. opposition and behavioral problems), both simultaneously and one year later. The data to be used in the study were taken from The SSDP Intergenerational Project, and both concurrent and lagged analyzes were examined in 325 families with teenagers (ages 6-19). In simultaneous analyses, it was predicted that the relationship between parental smoking and the child's externalizing behaviours was at high levels, while in lagged analyses it was predicted that parental smoking did not affect externalizing behaviours.

Brook et al. (2007) (Brook, 2008) stated in their study that the mental health of children exposed to environmental tobacco smoke (ETS), which is an important public health problem, is negatively affected by the increased risk of both internalizing symptoms and externalizing behaviours.

In a study aiming to investigate whether parental alcohol use has an impact on children in their developmental age, Christoffersen and Soothill (2003) (Christoffersen, 2003) used data from 84,765 children born in Denmark in 1966. Results showed that parental alcohol use can cause a variety of long-term consequences for children ages 15-27, including increased mortality and self-destructive behaviour (e.g., attempted suicide or drug addiction). In fact, it has been claimed that mothers' alcohol use increases all the mentioned negativities to higher levels.

In another study, Raitasalo et al. (2019) (Raitasalo et al., 2019), using a dataset containing children born in Finland in 1997 and their biological parents, examined whether parental alcohol use was associated with mental health problems in children.
This study compared the number of mental and behavioural disorders in children of parents without alcohol problems, children of parents with less serious alcohol problems, and children of parents with serious alcohol problems. It was concluded that regardless of the level, both mother's alcohol use and father's alcohol use are associated with increased mental and behavioural disorders in children.

While many studies claim that family members' smoking and alcohol consumption even before birth has negative effects on children's mental health; In their study, Easey and Sharp (2021) (Easey & Sharp, 2021) argued that in order to reach definitive and strong conclusions, the sample size should be increased and more studies should be conducted using different methods.

One of the most important factors thought to affect children's mental health is the family's financial inadequacy, that is, poverty.In the study conducted by Yoshikawa et al. (2012) (Yoshikawa et al., 2012) examined the issue under 4 main headings and identified strategies to reduce family poverty and its negative effects on children's mental, emotional and behavioral health, and explained the results of these strategies.

In another study, Yiğit and Sümeyye (2018) (Yiğit & Sümeyye, 2018) stated that family poverty may affect not only health as a child but also health as an adult in the future. In addition, while explaining the necessity of a common international definition of the concept of poverty, it was explained that in families with medium or high income levels, the needs of the child are neglected and they are left deprived of certain opportunities such as health, access to social services, and full participation as active individuals in society.

In a study examining the effects of poverty on children and mothers, Wen and Goh (2023) (Wen & Goh, 2023) tried to determine whether economic difficulties have an effect on the relationship between family resilience and stress factors and mental health severity. To this end, the moderating effect of family resilience on the relationship between the course of family resilience and symptoms of depression and anxiety in children was investigated in 511 low-income mother-child dyads living in Singapore. In the results of working; the effect of family resilience on the relationship between economic hardship and maternal and children's mental health was not found.

3. Methodology

Within the scope of this study, data on mental health problems in children between 2010-2019 obtained from the Turkish Statistical Institute were analysed and the features affecting these problems were examined with an artificial neural network model. 5 features were given as input to the model and the artificial neural network model was used to estimate the percentage of children with mental health problems. The pre-processing processes, training, testing stages and analysis processes of the proposed model are as shown in Figure 1.

The first stage of the model is to edit and complete the missing data obtained from TSI. When the data is analysed, it is seen that each input parameter contains data from different years. Therefore, the years 2010, 2012, 2014, 2016 and 2019, in which all variables existed in the same year, were taken into account. Since data were insufficient for ANN analysis, these data were increased by modeling the variables by the general linear ordinary differential equation system. Using this system, the missing data for each input was completed and data forecasting was carried out until 2040 for the future. Thus, a data set covering the years 2010-2040 was obtained.

In the second stage of the designed system, it was aimed to predict the percentage of mental health problems in children by using the dataset obtained as the output of the ODE system. For this purpose, a unique Artificial Neural Network model was designed. A total of 100 data were divided into training, testing and validation and used in the training and testing processes of the ANN model. Thus, the process of revealing the model that predicts the percentage of mental health problems in children with the lowest error rate was carried out by comparative analysis.

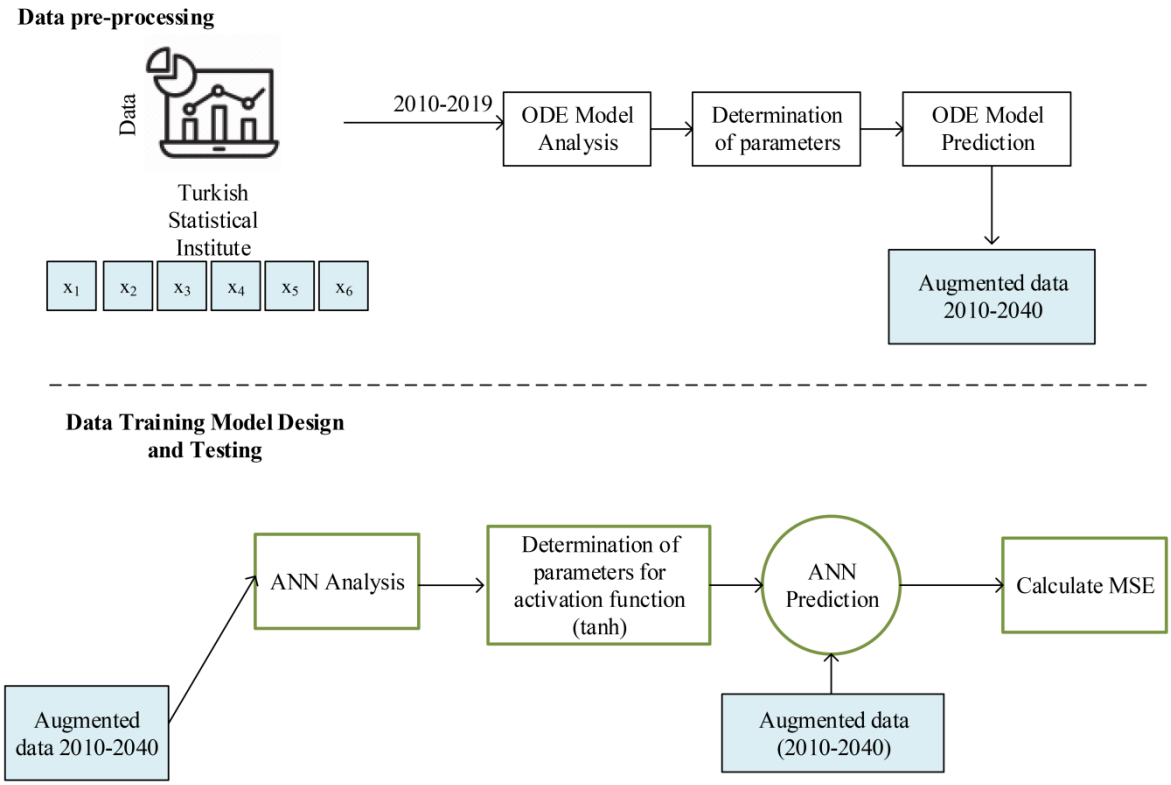

Figure 1. Methodology Diagram of Analysis

3.1. Dataset

The data analysing the problems affecting the percentage of children with mental health problems in Turkey are as shown in Table 1. The number of households with alcoholic beverage habits, child dependency ratio, the proportion of children in severe material deprivation, crude divorce rate and the proportion of households with smoking or tobacco habits are considered. For each input value, data for different years are provided by TSI. In this study, the common years for all features belong to five different years as shown in Table 1. This data was used the parameter determination in the ODE system and the data up to 2040 was augmented as shown in the next section.

Table 1. Some TSI Data for children for years 2010-2019

Year	Percentage of Households with the Habit of Using Alcoholic Beverages (%)	Child Dependency Rate (0-14 Years) (%)	Proportion of Children in Severe Financial Deprivation (%)	Crude divorce rate	Percentage of Households with the Habit of Using Cigarettes or Tobacco (%)	Mental health problems (Selected Health Problems in Children (%))
t	$x_1(t)$	$x_2(t)$	$x_3(t)$	$x_4(t)$	$x_5(t)$	$x_6(t)$
2010	2.7	38.1	71.8	1.62	36	1.9
2012	2.9	36.9	65.4	1.64	34.9	2.4
2014	2.4	35.8	42.2	1.7	31.9	2.1
2016	2.4	34.9	38.4	1.59	31.2	1.3
2019	2.7	34.1	32.3	1.9	29.1	1.1

3.2. Data Augmentation with ODE Model

Within the scope of this study, data belonging to five different years were subjected to augmentation process between 2010 and 2040. Augmentation process was carried out with the designed linear ODE system. In this section, the details of the ODE system are presented. Let t denote the time parameter and the independent variable. The proposed general linear system is in system (1).

Also, the definitions of the dependent variables used in the system (1) are given in Table 2.

$$\begin{aligned}
\frac{dx_1(t)}{dt} &= \theta_1 + \theta_2 x_1 + \theta_3 x_2 + \theta_4 x_3 + \theta_5 x_4 + \theta_6 x_5 + \theta_7 x_6,\\
\frac{dx_2(t)}{dt} &= \theta_8 + \theta_9 x_1 + \theta_{10} x_2 + \theta_{11} x_3 + \theta_{12} x_4 + \theta_{13} x_5 + \theta_{14} x_6,\\
\frac{dx_3(t)}{dt} &= \theta_{15} + \theta_{16} x_1 + \theta_{17} x_2 + \theta_{18} x_3 + \theta_{19} x_4 + \theta_{20} x_5 + \theta_{21} x_6,\\
\frac{dx_4(t)}{dt} &= \theta_{22} + \theta_{23} x_1 + \theta_{24} x_2 + \theta_{25} x_3 + \theta_{26} x_4 + \theta_{27} x_5 + \theta_{28} x_6,\\
\frac{dx_5(t)}{dt} &= \theta_{29} + \theta_{30} x_1 + \theta_{31} x_2 + \theta_{32} x_3 + \theta_{33} x_4 + \theta_{34} x_5 + \theta_{35} x_6,\\
\frac{dx_6(t)}{dt} &= \theta_{36} + \theta_{37} x_1 + \theta_{38} x_2 + \theta_{39} x_3 + \theta_{40} x_4 + \theta_{41} x_5 + \theta_{42} x_6,\\
x_1(t_0) &= x_{1_0}, x_2(t_0) = x_{2_0}, x_3(t_0) = x_{3_0}, x_4(t_0) = x_{4_0}, x_5(t_0) = x_{5_0}, x_6(t_0) = x_{6_0}
\end{aligned} \tag{1}$$

The ODE model in (1) was solved with the Matlab R2023a program rungekutta45, and then the parameter values closest to the values in Table 1 (giving the minimum error) were found by using the lsqcurvefit function (Mathworks, 2024) (Işık & Daşbaşı, 2023). In this context, the graphical results of the used approach are in Figure 2. Thus, the parameters θ_i for $i = 1,2,\ldots,42$ obtained are given in Table 3.

Table 2. Dependent variables in system (1)

Variables	**Definition**
$\boldsymbol{x_1(t)}$	Percentage of Households with the Habit of Using Alcoholic Beverages at time t (%)
$\boldsymbol{x_2(t)}$	Child Dependency Rate at time t (0-14 Years) (%)
$\boldsymbol{x_3(t)}$	Proportion of Children in Severe Material Deprivation at time t (%)
$\boldsymbol{x_4(t)}$	Crude divorce rate at time t
$\boldsymbol{x_5(t)}$	Percentage of Households with the Habit of Using Cigarettes or Tobacco at time t (%)
$\boldsymbol{x_6(t)}$	Rate of Mental Health Problems in Children at time t (%)

Table 3. Rate Constants of the system (1)

$\boldsymbol{\theta_1 = -0.17151}$	$\boldsymbol{\theta_2 = -2.31348}$	$\boldsymbol{\theta_3 = 1.20780}$
$\boldsymbol{\theta_4 = 0.10672}$	$\theta_5 = -0.39003$	$\theta_6 = -1.34231$
$\boldsymbol{\theta_7 = 0.95128}$	$\theta_8 = -0.03630$	$\theta_9 = -2.81927$
$\boldsymbol{\theta_{10} = 1.30169}$	$\theta_{11} = 0.09910$	$\theta_{12} = -0.66537$
$\boldsymbol{\theta_{13} = -1.41865}$	$\theta_{14} = 1.30767$	$\theta_{15} = 0.35596$
$\boldsymbol{\theta_{16} = 1.10642}$	$\theta_{17} = 4.95710$	$\theta_{18} = 0.58079$
$\boldsymbol{\theta_{19} = 1.79007}$	$\theta_{20} = -6.53310$	$\theta_{21} = -2.88155$
$\boldsymbol{\theta_{22} = -0.01216}$	$\theta_{23} = -1.65863$	$\theta_{24} = 0.38020$
$\boldsymbol{\theta_{25} = 0.04712}$	$\theta_{26} = -0.17444$	$\theta_{27} = -0.32712$
$\boldsymbol{\theta_{28} = -0.36359}$	$\theta_{29} = 0.03340$	$\theta_{30} = 4.48183$
$\boldsymbol{\theta_{31} = -1.08278}$	$\theta_{32} = -0.07873$	$\theta_{33} = 0.87790$

$\boldsymbol{\theta_{34} = 0.96334}$	$\theta_{35} = -1.31798$	$\theta_{36} = 0.35264$
$\boldsymbol{\theta_{37} = -0.77666}$	$\theta_{38} = -0.17648$	$\theta_{39} = 0.03588$
$\boldsymbol{\theta_{40} = 1.07308}$	$\theta_{41} = 0.19407$	$\theta_{42} = -1.04774$

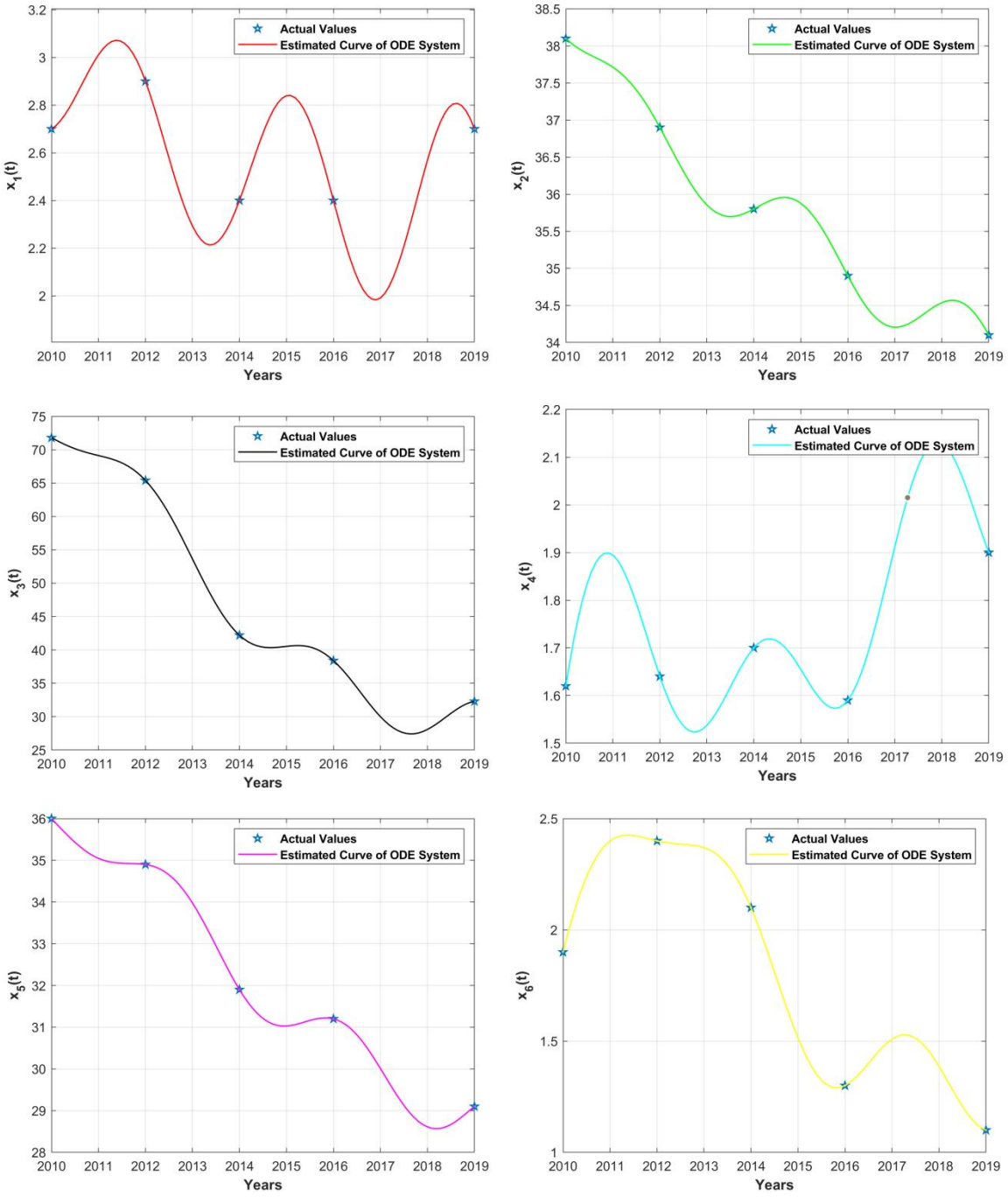

Figure 2. Plot of prediction curves versus actual results of the ODE model

If the parameter values obtained by lsqcurvefit function, method is rewritten in the suggested ODE model in (1), then we have the system in (2).

$$\begin{aligned}
\frac{dx_1(t)}{dt} &= -0.17151 - 2.31348x_1 + 1.20780x_2 + 0.10672x_3 - 0.39003x_4 - 1.34231x_5 + 0.95128x_6;\\
\frac{dx_2(t)}{dt} &= -0.03630 - 2.81927x_1 + 1.30169x_2 + 0.09910x_3 - 0.66537x_4 - 1.41865x_5 + 1.30767x_6;\\
\frac{dx_3(t)}{dt} &= 0.35596 + 1.10642x_1 + 4.95710x_2 + 0.58079x_3 + 1.79007x_4 - 6.53310x_5 - 2.88155x_6;\\
\frac{dx_4(t)}{dt} &= -0.01216 - 1.65863x_1 + 0.38020x_2 + 0.04712x_3 - 0.17444x_4 - 0.32712x_5 - 0.36359\,x_6;\\
\frac{dx_5(t)}{dt} &= 0.03340 + 4.48183x_1 - 1.08278x_2 - 0.07873x_3 + 0.87790x_4 + 0.96334x_5 - 1.31798x_6;\\
\frac{dx_6(t)}{dt} &= 0.35264 - 0.77666x_1 - 0.17648x_2 + 0.03588x_3 + 1.07308x_4 + 0.19407x_5 - 1.0477x_6;
\end{aligned} \tag{2}$$

Thanks to the ODE system detailed in this section, the missing data and the data until 2040 were estimated and a sample part of the final dataset obtained as a result of the estimation was as shown in Table 4.

Table 4. Augmenting the Data in Table 1 to the Years 2010-2040 with ODE

t	$x_1(t)$	$x_2(t)$	$x_3(t)$	$x_4(t)$	$x_5(t)$	$x_6(t)$
2010	2.7	38.1	71.8	1.62	36	1.9
2010.3	2.7648	37.9521	70.7199	1.7798	35.6444	2.1264
2010.6	2.871	37.8496	69.8772	1.8734	35.3266	2.2881
2010.9	2.9829	37.7492	69.2853	1.8989	35.0964	2.3826
2011.2	3.0589	37.6074	68.7561	1.8648	34.9707	2.4212
2011.5	3.0655	37.3953	67.9663	1.7893	34.9268	2.4234
2011.8	2.9855	37.1037	66.6044	1.695	34.9191	2.4094
2012.1	2.8298	36.7561	64.4168	1.6069	34.8726	2.3948
…	…	…	…	…	…	…
2038.2	0.42	25.9135	8.9561	1.776	23.7085	1.3536
2038.5	0.5923	26.2457	3.5952	2.0772	22.3206	1.5404
2038.8	1.1374	26.9384	1.2863	2.3115	20.978	1.5456
2039.1	1.9117	27.7832	2.7933	2.4079	20.0452	1.3608
2039.4	2.7018	28.5212	7.8254	2.3319	19.7835	1.0314
2039.7	3.282	28.9148	15.0808	2.0969	20.2728	0.6452
2040	3.4775	28.8148	22.5724	1.762	21.3827	0.31

3.3. Design of ANN Prediction Model and Results

The main purpose of artificial neural network models is to capture distinguishing points between input features, to identify and distinguish patterns, and to generate predictive insights and thus generate solutions to real-life problems (Aydın et al., 2021) (Taşyürek & Çelik, 2020). This versatile structure and their superior ability to handle complex relationships between data make them a tool for finding solutions to different problems ANN is used in many different fields in different studies (Arslan & Taşyürek, 2022) (Arslan, 2023) (Arslan & Barışçı, 2018), (Hızlısoy & Tüfekci, 2021), (Daşbaşı et al., 2019).

The ANN model proposed in this study, the schematic of which is given in Figure 3, was used to predict the percentage of mental health problems in children using five different input parameters. The choice of activation functions is critical in the design of the network and is applied to the output of each neuron, making it easier to uncover and learn the complex patterns and relationships present in the data. It also ensures that the network maintains its nonlinearity. The layers of the network, the number of nodes in the layers, the activation function selected in each layer directly affect the overall performance of the model. The structure proposed in this study is the network with the highest performance as a result of the tests.

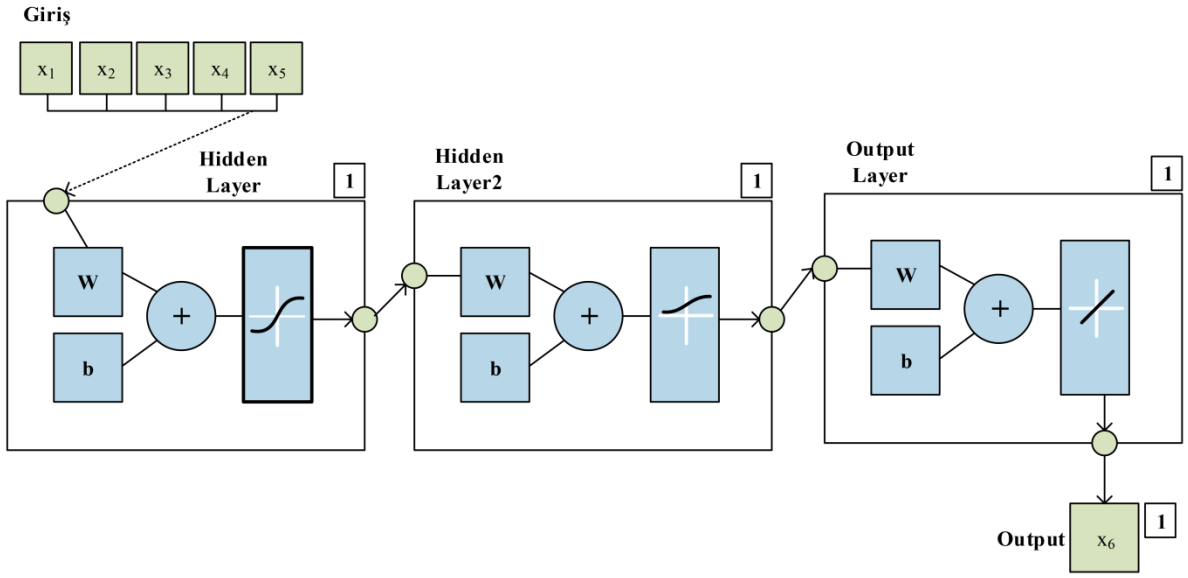

Figure 3. Structure of the used ANN Model

In this structure, the variable $x_6(t)$ was estimated using the other five inputs. For the estimation, training and testing processes were carried out using the data obtained with the ODE system between 2010 and 2040. No normalisation was made in the data and the whole process was carried out with the original data.

Transfer functions as hyperbolic tangent and sigmoid is used as the activation function. The mathematical expressions of these nonlinear functions are

$$g(z) = \frac{1}{1+e^{-z}} \text{ and } \frac{dg(z)}{dz} = g(z)\big(1-g(z)\big) \text{ for Logistic (Sigmoid),}$$
$$g(z) = \frac{e^{z}-e^{-z}}{e^{z}+e^{-z}} \text{ and } \frac{dg(z)}{dz} = \big(1-g^{2}(z)\big) \text{ for Hyperbolic Tangent.} \quad (3)$$

Additionally, their related graphs are shown in Figure 4.

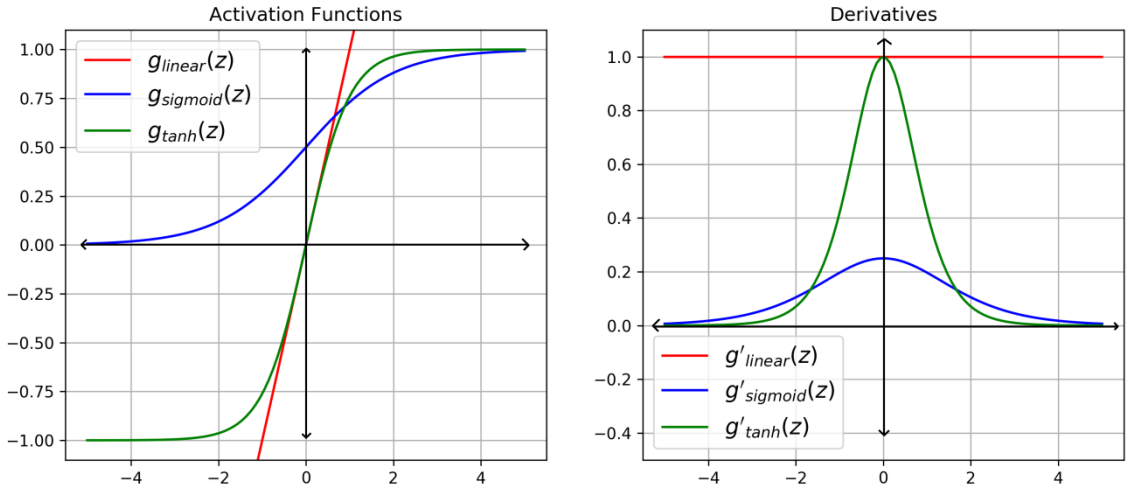

Figure 4. Some common activation functions and their derivatives

3.1.1. Parameter selection of ANN

Model parameters for the ANN analysis are shown in Table 5. Model parameter selections were determined by considering the situations in which the best results were obtained.

Table 5. Training Progress for ANN

	ANN Prediction		
	Initial Value	Stopped Value	Target Value
Epoch	0	11111	11111
Elapsed Time	-	00:00:35	-
Performance	0.69	0.00851	3e-15
Gradient	16.2	0.000445	0
Mu	0.001	0.0001	1e+10
Validation Checks	0	562	1.11e+04

3.1.2. Activation function of ANN

The resulting model with activation functions of ANN is written as in Equation (4). Therefore, we have

$$x_6(t) = b_3 + LW_2 * \text{logsig}\big(b_2 + LW * \tanh(b_1 + IW * X)\big) \quad (4)$$

where $X = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix}_{5x1}$ Thus, the obtained coefficients of Eq. (4) are given in Table 6.

Table 6. Coefficients of activation functions in (4)

Coefficients of the model (4)
$\boldsymbol{b_1 = (-3.4705)_{1x1}}$
$\boldsymbol{b_2 = (266.0157)_{1x1}}$
$\boldsymbol{b_3 = (-121.7920)_{1x1}}$
$\boldsymbol{IW = (-0.7682 \quad 0.1536 \quad 0.0636 \quad 0.7227 \quad -0.2161)_{5x1}}$
$\boldsymbol{LW = (262.2359)_{1x1}}$
$\boldsymbol{LW_2 = (124.1163)_{1x1}}$

For ANN analysis, 70 % of 100 real values for the years 2010-2040 were used for training, 15 % for validation and 15 % for testing. The graphs of the results obtained are as given in Figure 5. The lowest R-value is 0.9850 for training and the highest value is 0.9890 for test samples. This high performance value indicates the success of the model in predicting the percentage probability of mental problems in children with 5 different input values and shows that it can learn the relationship between the input and the target output. The results obtained proved that the proposed ANN model is successful for the dataset generated as the output of the ODE system. The fact that the high performance shown in the training set is maintained in the validation and test samples shows that the model can successfully generalise to previously unseen data. This also proves that the model does not suffer from overfitting problems.

4. Comparison of ANN and ODE Models and Discussion

In this section, the prediction results of the original values between 2010-2040 with ANN and ODE model are shown in Table 7. The average error value is 0.06449 for both models. This value shows that both the ODE model and the ANN model are successful in predicting mental health problems in children.

Table 7. The prediction performances of the proposed models according to the values of Table 1

Order	**Original Data $x_6(t)$**	**$x_6(t)$ according to ANN Prediction**	**$x_6(t)$ according to ODE Model**
2010	1.9000	2.3243	2.3243
2010.3	2.1264	2.3243	2.3243
2010.6	2.2881	2.3243	2.3243
2010.9	2.3826	2.3243	2.3243
2011.2	2.4212	2.3243	2.3243
2011.5	2.4234	2.3241	2.3241
2011.8	2.4094	2.3219	2.3219
2012.1	2.3948	2.3126	2.3126
2012.4	2.3863	2.2902	2.2902
2012.7	2.3815	2.2540	2.2540
…	…	…	…
2039.1	1.3608	1.3821	1.3821
2039.4	1.0314	1.0336	1.0336
2039.7	0.6452	0.6642	0.6642
2040	0.3100	0.3984	0.3984
Average MSE		0.06449	0.06449

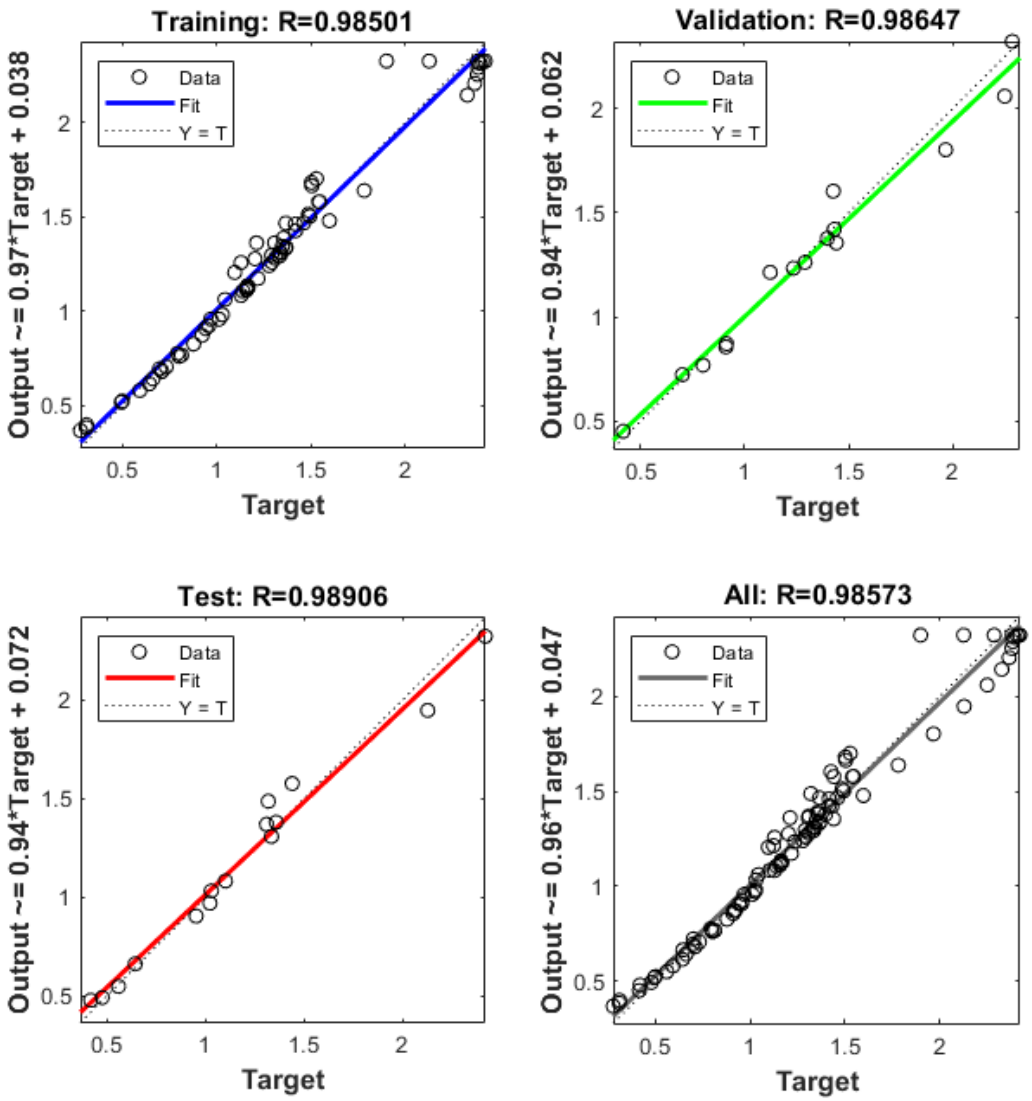

Figure 5. Graphical Representation of Analysis Results for ANN Prediction

It was in Table 2 explained that the variable x_6 represents the rate of mental health problems in children at time t (%). If the equation for the ANN activation functions in (4) is rearranged according to the coefficients in Table 6, then it is found

$$x_6(t) = -121.7920 + 124.1163\text{logsig}\begin{pmatrix} 266.0157 + \\ 262.2359\tanh(\psi) \end{pmatrix} \quad (5)$$

where $\psi = \psi(x_1, x_2, x_3, x_4, x_5)$ and

$$\psi = \begin{pmatrix} -3.4705 - 0.7682x_1 + 0.1536x_2 + \\ 0.0636x_3 + 0.7227x_4 - 0.2161x_5 \end{pmatrix} \quad (6-a)$$

$$\frac{d\psi}{dt} = \begin{pmatrix} 0.132811586 - 0.752671588x_1 + \\ 0.096138482x_2 + \\ 0.021244877x_3 - 0.004513312x_4 - \\ 0.046834656x_5 - 0.691132779x_6 \end{pmatrix} \quad (6-b)$$

Someone can calculate $x_6 > 0$ for $\psi(x_1, x_2, x_3, x_4, x_5) > \frac{1}{2}\ln\left(\frac{1-0.9993}{1+0.9993}\right) = -3.97861$.

Consider the properties of the activation functions shown in Equation (3) and Figure 4. On the variable x_6 according to equation (5), it can be said that x_1 and x_5 have a negative effect and x_2, x_3 and x_4 have a positive effect. In this study, parental divorce, severe poverty and child dependency ratio have a positive effect on mental health problems as one of the selected health problems in children in Turkey.

5. Conclusion

Within the scope of this study, the effects of five different conditions, which are thought to affect mental health in children, on health problems were examined. In the first stage, the data received from TSI was increased with minimum error between the years 2010 and 2040, using a unique ODE system. This data obtained was used in the training and testing processes of the designed ANN model. Then, the ANN output was expressed mathematically and analyzed, and the effects of 5 different situations on mental health in children were analyzed.

Two important outcomes of this study were obtained. The first of these is the linear ODE system in (2). Thanks to this system, time-dependent changes of variables $\boldsymbol{x_1 - x_6}$ can be found. Regarding this, the values of the variables have been estimated until 2040. See Table 4. Another important outcome of this study is equation in (5). This equation was obtained from the ANN structure with a very high $\boldsymbol{R^2}$ value. In this way, the approximate value of $\boldsymbol{x_6}$ variable can be estimated by the values of $\boldsymbol{x_1 - x_5}$ variables.

In the future, a model will be developed that examines other environmental elements that may affect mental health in children. Thus, it will be possible to make a comprehensive evaluation based on more environmental effects in children. Additionally, unlike this study, if real data is collected for a longer period, the same models will be repeated on real data and the results will be re-evaluated.

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