*International Research Journal of Innovations in Engineering and Technology (IRJIET)*

**ISSN (online): 2581-3048**

**Volume 5, Issue 3, pp 347-353, March-2021**

https://doi.org/10.47001/IRJIET/2021.503059

# Forecasting Daily Covid-19 Deaths in Italy Using Artificial Neural Networks

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***Abstract* - In this research paper, the ANN approach was applied to analyze daily COVID-19 deaths in Italy. The employed daily data covers the period to 1 January 2020 to 31 December 2020 and the out-of-sample period ranges over the period to 1January 2021 to 31 May 2021. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting daily COVID-19 cases in Italy. The applied ANN (12, 12, 1) model projections indicate thatCOVID-19 mortality in the country will generally range between 200 and 700 deaths per day over the out-of-sample period. Therefore the Italian government is encouraged to continue applying WHO guidelines on prevention and control of COVID-19 including vaccination in order to achieve herd immunity.**

***Keywords:*** ANN, Forecasting, COVID-19.

## I. INTRODUCTION

The COVID-19 pandemic had its origin in Wuhan City in China in December 2019 (Wang et al, 2020; Wang et al, 2020; Read et al, 2020; Wang, 2020; Tang et al, 2020; CDC, 2020).The pandemic spread rapidly all over the whole world in an astonishing manner and was characterized by high morbidity and mortality (Onder et al, 2020; Guan et al, 2020; John Hopkins University, 2020). Italy is among the European countries which were most affected by the pandemic (Scortichini et al, 2020). The first case of COVID-19 in Italy was detected on the 20$^{th}$ February 2020 in the province of Lodi and rapidly spread across the entire country (Department of Civil Protection, 2020). The Italian government responded well to the pandemic by implementing measures such as social distancing, travel restrictions, closure of non-essential businesses and industries ( Italian government, 2020). The Italian continues to face immense pressure from the increased demand for ICU admissions and medical drugs like oxygen for ICU patients (Fagiuoli et al, 2020; Grasselli et al, 2020 ) and is still witnessing COVID-19 deaths on a daily basis (Department of Civil protection, 2020).In this paper we aim to model and forecast daily COVID-19 mortality in Italy using the artificial neural network approach. The ANN (12, 12, 1) multilayer perceptron was applied. The model is composed of 3 layers of neurons (Nyoni et al, 2020; Zhao et al, 2020; Arora et al, 2020; Yan et al, 2018; Kolter & Koltun, 2018; Kaushik & Sahi, 2018; Paswan et al, 2018; Ruder, 2017; Fojnica et al, 2016; Quazi et al, 2015; Raghupathi & Raghupathi, 2015; Schmidhuber, 2014;Gomes et al, 2011; Yan et al, 2006;Ozkan et al, 2003; Zhang, 2003; Kishan, 1997; Patterson, 1995), where 12, 12, 1 represent the input, hidden and output layer neurons. The results of the study are expected to reveal the future trends of COVID-19 mortality and facilitate the assessment of the impact of the COVID-19 prevention and control measures including vaccination.

## II. METHODOLOGY

The study applies the Artificial Neural Network (ANN) approach which is usually celebrated for its capability to learn from any data-set and consequently describe then online or and interaction effects with great accuracy. Arguably, explicit guidelines exist for the determination of the ANN structure hence the study applies the popular ANN (12, 12, 1) model based on the hyperbolic tangent activation function.

### Data Issues

This study is based on daily deaths of COVID-19 in Italy for the period 1 January – 31 December 2020.The out-of-sample forecast covers the period January 2021 – May 2021. All the data employed in this paper was gathered from the World Bank.

## III. FINDINGS OF THE STUDY

### ANN Model Summary

 

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**Table 1: ANN model summary**

| | |
|---|---|
| Variable | E |
| Observations | 354 (After Adjusting Endpoints) |
| Neural Network Architecture: | |
| Input Layer Neurons | 12 |
| Hidden Layer Neurons | 12 |
| Output Layer Neurons | 1 |
| Activation Function | Hyperbolic Tangent Function |
| Back Propagation Learning: | |
| Learning Rate | 0.005 |
| Momentum | 0.05 |
| Criteria: | |
| Error | 0.076819 |
| MSE | 1909.800457 |
| MAE | 27.859910 |

*Residual Analysis for the Applied Model*

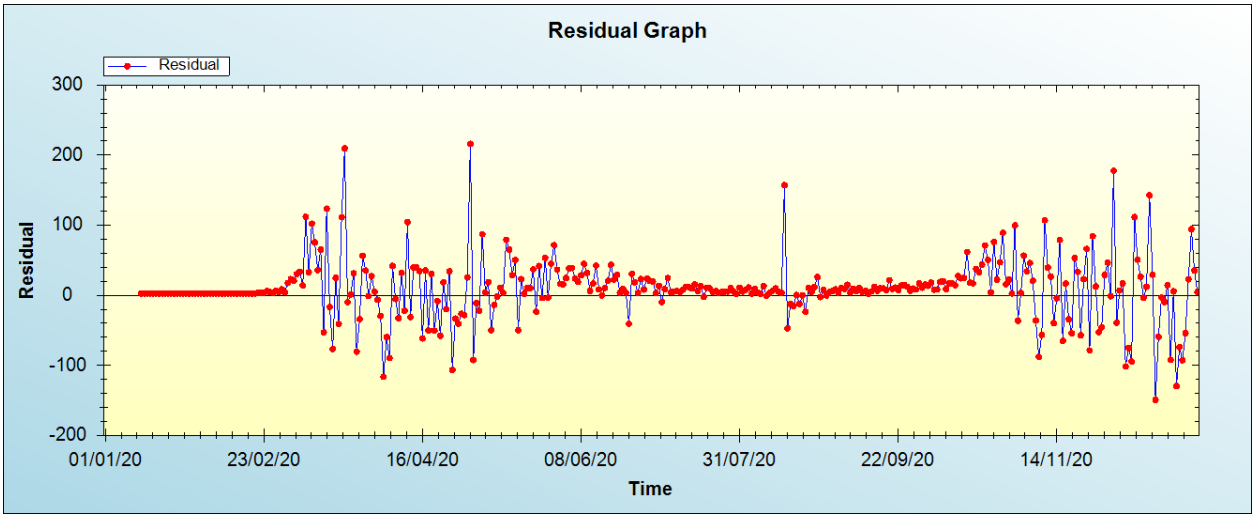


**Figure 1: Residual analysis**

*In-sample Forecast for E*

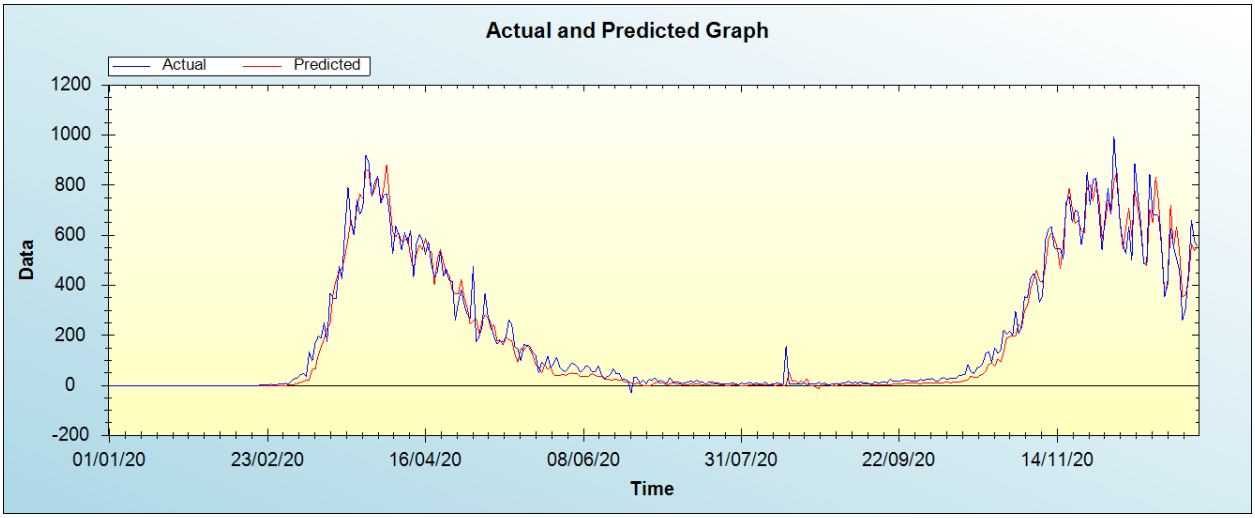


**Figure 2: In-sample forecast for the E series**

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*Out-of-Sample Forecast for E: Actual and Forecasted Graph*

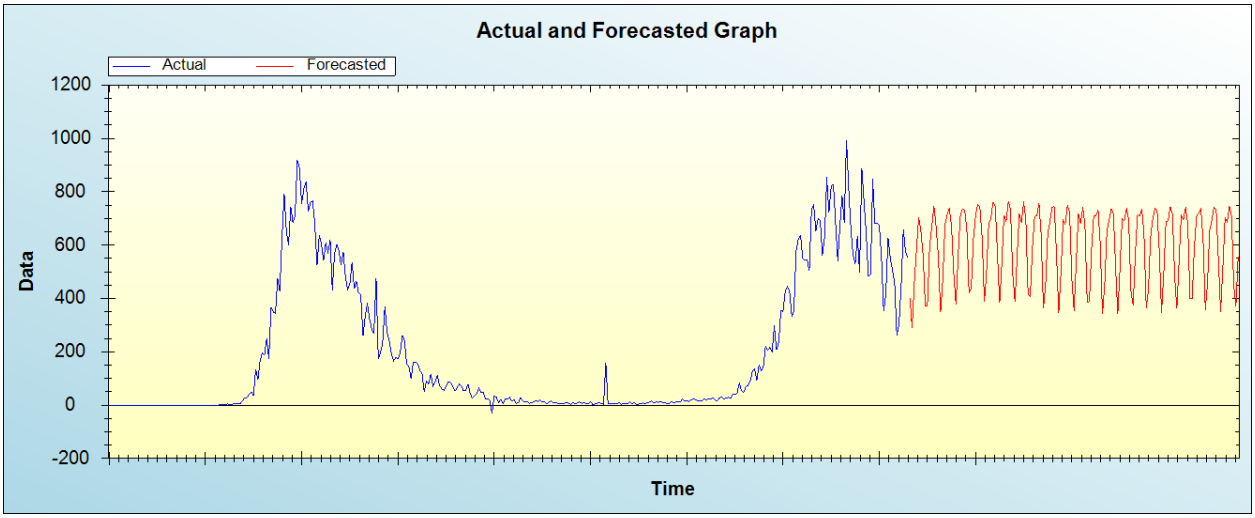


**Figure 3: Out-of-sample forecast for E: actual and forecasted graph**

*Out-of-Sample Forecast for E: Forecasts only*

**Table 3: Tabulated out-of-sample forecasts**

| Dates | Forecasts |
|---|---|
| 01/01/21 | 401.9114 |
| 02/01/21 | 290.0611 |
| 03/01/21 | 456.0070 |
| 04/01/21 | 579.9369 |
| 05/01/21 | 702.9323 |
| 06/01/21 | 654.3372 |
| 07/01/21 | 563.3034 |
| 08/01/21 | 372.2717 |
| 09/01/21 | 372.1381 |
| 10/01/21 | 592.4333 |
| 11/01/21 | 668.2142 |
| 12/01/21 | 745.3207 |
| 13/01/21 | 665.9272 |
| 14/01/21 | 557.0512 |
| 15/01/21 | 349.8313 |
| 16/01/21 | 470.2759 |
| 17/01/21 | 673.8333 |
| 18/01/21 | 713.7498 |
| 19/01/21 | 737.5803 |
| 20/01/21 | 673.1419 |
| 21/01/21 | 495.4743 |
| 22/01/21 | 377.7639 |
| 23/01/21 | 551.5134 |
| 24/01/21 | 707.2731 |
| 25/01/21 | 735.1988 |
| 26/01/21 | 731.6098 |
| 27/01/21 | 662.4063 |
| 28/01/21 | 421.6906 |
| 29/01/21 | 435.5676 |
| 30/01/21 | 621.3292 |
| 31/01/21 | 709.2738 |
| 01/02/21 | 753.6727 |
| 02/02/21 | 740.1149 |

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| | |
|---|---|
| 03/02/21 | 626.7498 |
| 04/02/21 | 388.3197 |
| 05/02/21 | 494.4316 |
| 06/02/21 | 679.2330 |
| 07/02/21 | 699.7256 |
| 08/02/21 | 762.3124 |
| 09/02/21 | 745.6691 |
| 10/02/21 | 567.8735 |
| 11/02/21 | 382.7481 |
| 12/02/21 | 533.0647 |
| 13/02/21 | 711.3414 |
| 14/02/21 | 687.0600 |
| 15/02/21 | 762.7952 |
| 16/02/21 | 733.6013 |
| 17/02/21 | 488.5032 |
| 18/02/21 | 388.8429 |
| 19/02/21 | 558.5124 |
| 20/02/21 | 718.1753 |
| 21/02/21 | 684.6126 |
| 22/02/21 | 761.7384 |
| 23/02/21 | 695.2602 |
| 24/02/21 | 412.8452 |
| 25/02/21 | 408.6073 |
| 26/02/21 | 591.9694 |
| 27/02/21 | 707.1088 |
| 28/02/21 | 709.5049 |
| 01/03/21 | 756.2002 |
| 02/03/21 | 635.5252 |
| 03/03/21 | 364.0600 |
| 04/03/21 | 448.2712 |
| 05/03/21 | 644.0226 |
| 06/03/21 | 688.4154 |
| 07/03/21 | 741.6338 |
| 08/03/21 | 744.2659 |
| 09/03/21 | 562.7518 |
| 10/03/21 | 346.9858 |
| 11/03/21 | 496.8611 |
| 12/03/21 | 695.1816 |
| 13/03/21 | 677.1745 |
| 14/03/21 | 749.1273 |
| 15/03/21 | 721.4944 |
| 16/03/21 | 471.2986 |
| 17/03/21 | 354.6603 |
| 18/03/21 | 535.8748 |
| 19/03/21 | 716.9259 |
| 20/03/21 | 680.6743 |
| 21/03/21 | 741.5819 |
| 22/03/21 | 674.5228 |
| 23/03/21 | 383.7447 |
| 24/03/21 | 389.0193 |
| 25/03/21 | 582.7686 |
| 26/03/21 | 708.4096 |
| 27/03/21 | 709.8880 |
| 28/03/21 | 731.4292 |
| 29/03/21 | 604.0417 |
| 30/03/21 | 341.6501 |
| 31/03/21 | 451.5456 |
| 01/04/21 | 649.3588 |

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| | |
|---|---|
| 02/04/21 | 692.3588 |
| 03/04/21 | 736.6760 |
| 04/04/21 | 718.4295 |
| 05/04/21 | 522.2942 |
| 06/04/21 | 343.3203 |
| 07/04/21 | 516.0938 |
| 08/04/21 | 700.5573 |
| 09/04/21 | 692.2797 |
| 10/04/21 | 737.6082 |
| 11/04/21 | 693.1837 |
| 12/04/21 | 428.4531 |
| 13/04/21 | 373.6997 |
| 14/04/21 | 568.6277 |
| 15/04/21 | 712.2511 |
| 16/04/21 | 709.8733 |
| 17/04/21 | 733.3198 |
| 18/04/21 | 641.5930 |
| 19/04/21 | 363.5929 |
| 20/04/21 | 430.2877 |
| 21/04/21 | 630.6702 |
| 22/04/21 | 700.0627 |
| 23/04/21 | 736.7773 |
| 24/04/21 | 728.4049 |
| 25/04/21 | 571.5300 |
| 26/04/21 | 347.6860 |
| 27/04/21 | 494.8484 |
| 28/04/21 | 688.4815 |
| 29/04/21 | 691.3677 |
| 30/04/21 | 743.9453 |
| 01/05/21 | 715.0699 |
| 02/05/21 | 483.5364 |
| 03/05/21 | 362.4275 |
| 04/05/21 | 544.4304 |
| 05/05/21 | 713.8712 |
| 06/05/21 | 695.1574 |
| 07/05/21 | 740.9868 |
| 08/05/21 | 679.1446 |
| 09/05/21 | 398.8302 |
| 10/05/21 | 400.4642 |
| 11/05/21 | 594.5308 |
| 12/05/21 | 708.1200 |
| 13/05/21 | 719.8016 |
| 14/05/21 | 737.8574 |
| 15/05/21 | 618.6874 |
| 16/05/21 | 355.4840 |
| 17/05/21 | 458.2691 |
| 18/05/21 | 656.0546 |
| 19/05/21 | 692.8169 |
| 20/05/21 | 743.0181 |
| 21/05/21 | 730.3284 |
| 22/05/21 | 543.1680 |
| 23/05/21 | 350.8876 |
| 24/05/21 | 513.5936 |
| 25/05/21 | 702.5827 |
| 26/05/21 | 686.4225 |
| 27/05/21 | 745.1277 |
| 28/05/21 | 709.1461 |
| 29/05/21 | 451.2958 |

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https://doi.org/10.47001/IRJIET/2021.503059

| | |
|---|---|
| 30/05/21 | 370.4134 |
| 31/05/21 | 556.7020 |

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that COVID-19 mortality in the country will generally range between 200 and 700 deaths per day over the out-of-sample period.

## IV. CONCLUSION & ROCOMMENDATIONS

Forecasting COVID-19 mortality is a critical component in COVID-19 disease surveillance. This helps to detect the future path of COVID-19 mortality and facilitate the implementation of robust measures to reduce the impact of the deadly pandemic. Mortality forecasting has been done in the past by many researchers and this has helped identify vulnerable groups and factorsassociated with high mortality. In this study the ANN (12, 12, 1) model predictions suggested that COVID-19 mortality in Italy is likely to range between 200 and 700 deaths per day over the out of sample period. Therefore the government is encouraged to speed up the COVID-19 vaccination and continuous health education to improve the acceptability of the COVID-19 vaccines among its citizens.

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**Citation of this Article:**

Dr. Smartson. P. NYONI, Thabani NYONI, Tatenda. A. CHIHOHO, "Forecasting Daily Covid-19 Deaths in Italy Using Artificial Neural Networks" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 3, pp 347-353, March 2021. Article DOI https://doi.org/10.47001/IRJIET/2021.503059

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