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SEASONAL PATTERN FOR UNDER–FIVE CHILDREN MORTALITY IN EGYPT

A. M. Elabbasy[1], H. E. Semary[2*]

[1]Head of the Department of Biostatistics and Population, Institute of Statistical Studies and Research, Cairo University, Egypt.
[2]Department of Statistics and Insurance, Faculty of Commerce, Zagazig University, Egypt.

[*]Corresponding Author: hatem.semary@yahoo.com

ABSTRACT

This paper's main motivation is to examine the seasonal pattern of overall mortality of children whose ages are below five years in Egypt. We used the data of vital statistics for births and deaths, which have been collected by the Central Agency for Public Mobilization and Statistics (CAPMAS) from January 2002 to December 2010 in Egypt. Seasonal effects on under–five and infant mortality were measured by several different statistical models such as the classic multiple regression model (CMR), Poisson regression model (PR), generalized additive models (GAM) and neural network models (NNM). During the study period, all children below 5 years in the study population and at the aggregate level all cases of deaths of whom have been recorded. There were significant seasonal variations of under–five mortality. The mortality risk was significantly high in January and August compared with other months. This paper demonstrates that overall mortality of children under–five of age in Egypt has a seasonal pattern. Generally during the months of January and August of each year during the period of study, the death rate for the under–five children increases. This evidence, which was obtained here, may help officials to intervene to reduce the mortality rate among the under–five children in Egypt. The neural networks and the generalized additive models are the optimal alternative methods to estimate the parameters with less bias for detecting seasonality of child mortality data.

Keywords: Under–five mortality, MDGs, Seasonal, Generalized additive models (GAM), Neural network models (NNM), Poisson regression model (PR).

1. INTRODCUTION

Despite the significant decline in the mortality rate among children less than five years during the past decade (Morris, Black, & Bryce, 2003) however, this rate has an increasing pattern in a considerable number of developing countries, especially the African countries where decline is very slowly. Estimates indicate that, more than five million under–five deaths are recorded in Africa each year, which nearly equal half of the world's under–five deaths. This is evidence that child mortality is either increasing or not to decline as much as expected in many African countries (Garenne & Gakusi, 2006), raises such a serious concern regarding the continent's capacity needed to achieve the MDGs related to child health.

In reality, however, there are less than two years to reach 2015 to assess what has been achieved from the Millennium Development Goals; most of African countries are likely to fail to meet their goals related to child mortality if they do not address the worsening health conditions. Therefore, there is a need to better understand the factors associated with this high rate of mortality (Maurice, Benedict, Jacques, Eliya, & Yazoume, 2010).

However, studying childhood mortality is often faces many challenges due to the lack of the appropriate data, but the vital statistics data which provided by CAPMAS and DHS provides a great opportunity to study the determinants of under–five mortality. Using such data, various scholars have documented the effect on childhood mortality is influenced by several factors including individual, household and community and environmental

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characteristics (Ayaga & Zuberi, 2003), (Amouzou & Hill, 2004), (Ndugwa & Zulu, 2008)

While a considerable number of studies examined the determinants of mortality within different seasons, few of those studies examined the seasonal patterns of childhood mortality (Ye, Zulu, Mutisya, Orindi, Emina, & Kyobutungi, 2009b). The importance of seasonality on child's survival is clearly shown in the conceptual framework proposed by Mosley and Chen (1984) which suggests that child survival chances are due to operation of biological, social economic and environmental forces. In this framework, seasonal factors are grouped together with climate, rainfall and temperature under the ecological setting of community level factors. These ecological factors not affect only the availability of food, but also to influence mother's attention for their children, especially during rainy seasons when quality of water and sanitation conditions becomes compromised (Mosley & Chen, 1984).

The effect of season is also seen in the prevalence of diseases such as diarrhea, gastrointestinal and respiratory diseases. For instance, the seasonal pattern of death resulted from such diseases had been observed in the 20th century, whereby peak of respiratory system diseases has been observed during Winter (Apostolidou, Katsouyanni, Touloumi, Kalpoyannis, Constantopoulos, & Trichopoulos, 1994), (Madrigal, 1994), (Mackenbach, Kunst, & Looman, 1992). Recently, increasing in malaria incidence and mortality has been shown to occur during or after the rainy season in West Africa (Hammer, Some, Muller, Kynast-Wolf, Kouyate, & Becher, 2006). Moreover, diarrhea diseases are likely to be more spread during rainy and cold seasons.

Studying seasonality of childhood mortality will help officials, decision–makers and policy makers to implement appropriate interventions to reduce the rate of child mortality and to devote efforts in high–risky seasons (Kandala, Magadi, & Madise, 2006). Using the vital statistics data which provided by CAPMAS, this paper explores to what extent childhood mortality among children in Egypt is seasonal.

2. METHODS

2.1 Study Site:

Central Agency for Public Mobilization and Statistics (CAPMAS) in Egypt which was established in 1964 upon a presidential decree No. 2915 (http://www.capmas.gov.eg, 2013) is the official organ of the statistics in Egypt; in addition, it is responsible for collection, processing, analysis and dissemination of statistical data and census data.

Most of Egyptian land populated not to exceed the water level of sea level; Egypt also features widely coastal beaches on both the Red and the Mediterranean Sea. The climate of Egypt is mainly affected by its location at the north–eastern part of Africa where it is subject to the dry weather of the largest desert in the world. Egypt's latitudinal position, between 22^o and 32^o N places it firmly in the sub–tropical dry belt. However, the presence of the Mediterranean Sea at the northern borders of Egypt should ameliorate the weather conditions. Egypt's climate can be precisely described as a contest between the hot, dry air masses over the Sahara and the cooler, damper maritime air masses at the north carried by eastward moving depressions. Throughout most of the year the hot, dry tropical continental air masses dominate, however during the winter period air masses of both tropical and polar maritime origin make brief incursions into Egypt from the north, frequently bringing rain with them.

The climate of a country is mostly described in terms of variables (in average) such as temperature, humidity, and precipitation. However, using this approach is subject to the negative impact of overlooking significant fluctuations of vital important factors such as agricultural activity. Given its latitudinal position, it is not surprising that Egypt's mean annual temperatures are high and register between 20 and 25 ^{o} C. Moreover Major variations occur between summer and winter temperature, as well as between coastal and interior locations.

There are one rainy and three dry seasons. The main rainy season goes from mid–December to mid–March and it is cold and rainy. The second season is from mid–March to mid–June. The third season goes from mid–June to mid–September and it is hot and dry. The last season is starting from mid–June to mid–December and it is cold and dry.

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2.2 Study Population:

The data used in this study was collected for the years 2000 to 2010 and was extracted from the CAPMAS database. All children aged less than 5 years were included in the study. The study included all children born in the study area and those who in–migrated into the study area as long as they were within the age limits.

Key demographic events (birth, death, migratory movements) are regularly recorded for all residents in households through CAPMAS. These data are collected every month by offices of CAPMAS. Through this system births and deaths that occurred in our study population were recorded. The data quality control procedures include refresher trainings that are usually conducted before the start of a new data collection cycle and regular spot–checks that are done by field supervisors.

3. ANALYSIS

3.1 Description of the Time Series Under Study:

Using the following data for table (1), this represents the monthly time series of under–five and infant mortality in Egypt during the period 2002–2010:

Table (1): The Under–Five and Infant Mortality in Egypt from 2002 to 2010;

Y \ M	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	8770	6733	7124	7119	8997	7464	9082	8741	7320	7775	7566	7815
2003	7955	7064	7002	6701	7189	7789	8257	8714	7735	7199	7402	6684
2004	7561	7044	7011	6450	6836	7095	7330	7691	7055	7256	7199	7014
2005	7878	6200	6480	6498	6891	6952	7583	7973	7336	6992	7311	7330
2006	7716	6739	6729	6726	7079	7384	7629	8494	7319	7136	7111	7270
2007	7537	6248	6603	6718	6709	6691	7806	7531	6983	7231	6604	7117
2008	7500	6488	6696	5985	6619	7174	7445	7555	7350	7253	6844	6975
2009	8028	6732	7476	6837	6878	7295	8211	7690	7327	7268	6902	7723
2010	8532	6912	6428	6496	7325	7679	7687	8437	7381	7212	6973	7359

Source: Central Agency for Public Mobilization and Statistics, Egypt.

By examining this data we illustrate the following; Data variable is the child monthly mortality, number of observations is 108 months starting at 1/2002 and finishing at 12/2010, sampling interval equal one month and finally the length of seasonality equal 2.

Through the analysis of the study data according to figures (1) and (2); we note the presence of a seasonal effect of under–five mortality which culminates in the summer during the months of August and July, and winter during the month of January. The seasonal effect is decline during the month of April.

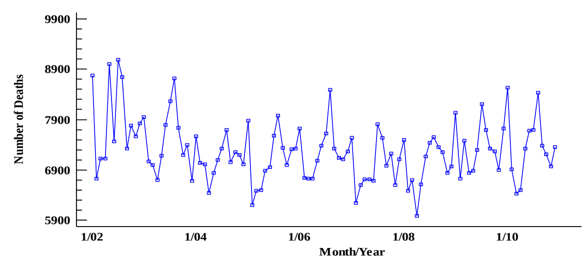

Figure (1): Time Series Plot for Monthly Under–Five and Infant Mortality in Egypt from 2002 to 2010;

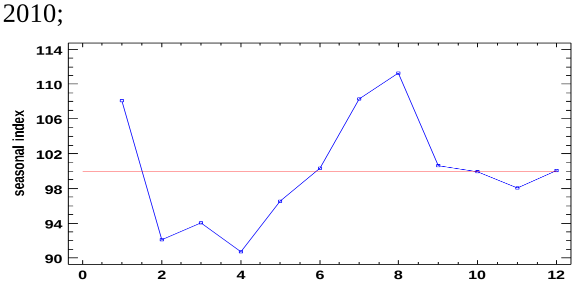

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Figure (2): Seasonal Index for Monthly Under–Five and Infant Mortality in Egypt from 2002 to 2010;

The following table (2) shows values of estimated autocorrelations between values of monthly mortality at various lags. The lag *k* autocorrelation coefficient measures the correlation between values of monthly mortality at time *t* and time *t–k*. Also shown are 95.0% probability limits around 0. If the probability limits at a particular lag do not contain the estimated coefficient, there is a statistically significant correlation at that lag of 95.0 %confidence level. In this case, 3 of the 24 autocorrelation coefficients are statistically significant; consequently, it is possible to imply that the time series may not be completely random (white noise).

Table (2): Estimated Autocorrelations for Monthly Mortality;

Lag	Autocorrelation	Std. Error	Lower 95.0% Prob. Limit	Upper 95.0% Prob. Limit
1	0.339411	0.096225	-0.188598	0.188598
2	0.161834	0.106736	-0.209199	0.209199
3	-0.048042	0.108984	-0.213606	0.213606
4	-0.0563504	0.10918	-0.21399	0.21399
5	0.0454947	0.109449	-0.214517	0.214517
6	0.117585	0.109624	-0.21486	0.21486
7	0.124232	0.110786	-0.217137	0.217137
8	-0.0874527	0.112068	-0.21965	0.21965
9	-0.114411	0.112698	-0.220885	0.220885
10	0.0521758	0.113769	-0.222983	0.222983
11	0.210758	0.11399	-0.223417	0.223417
12	0.507154	0.117543	-0.23038	0.23038
13	0.243627	0.136306	-0.267156	0.267156
14	0.0875684	0.14028	-0.274945	0.274945
15	-0.0882308	0.140785	-0.275935	0.275935
16	-0.155493	0.141297	-0.276937	0.276937

The autocorrelation coefficients can be plot through the following figure (3);

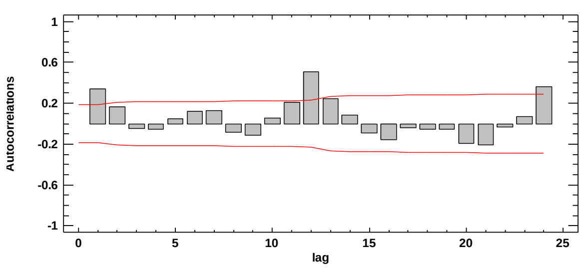

Figure (3): Estimated Autocorrelation for Monthly Mortality;

3.2 Traditional Models:

At the stage of examination and diagnosis the models we study the suitability of the models for analysis the series of under–five mortality in Egypt. Models have been identified, its parameters were estimated, its efficiency was examined and its suitability was determined according to ACI criterion (Akaike Information Criteria) using *STATGRAPHICS package*. According to this, the best model is "ARIMA (0, 1, 1) x (1, 1, 2)12" as shown in table (3).

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Table (3): Statistical Criteria Used for Comparison between the Estimated Periods for the Generated Models;

Model	RMSE	MAE	MAPE	ME	MPE	AIC	HQC	SBIC
(A)	448.504	319.501	4.34331	-6.64549	-0.245415	12.4155	12.5263	12.6887
(B)	450.809	319.657	4.34389	0.21952	-0.150782	12.4443	12.5651	12.7423
(C)	414.492	283.721	3.81467	0.221878	-0.266222	12.2763	12.3972	12.5743
(D)	396.154	273.907	3.68962	0.386144	-0.241336	12.2043	12.3353	12.5272
(E)	333.623	237.165	3.21995	0.396307	-0.171569	11.8793	12.0203	12.227
(F)	395.878	272.638	3.66784	9.3613	-0.118629	12.203	12.3339	12.5258
(G)	392.814	270.974	3.64682	9.24427	-0.116943	12.1874	12.3183	12.5103
(H)	390.623	270.927	3.71001	-4.94832	-0.213183	12.1577	12.2785	12.4557
(I)	345.427	241.864	3.29382	-24.5158	-0.495119	11.9118	12.0326	12.2098
(J)	352.732	247.653	3.37439	-12.8506	-0.313001	11.9536	12.0745	12.2517
(K)	353.374	248.785	3.38727	1.07766	-0.130713	11.9758	12.1067	12.2986
(L)	359.057	253.587	3.45471	-7.22659	-0.232185	11.9892	12.11	12.2872
(M)	317.064	249.745	3.47126	-4.50312	-0.223863	11.5738	11.604	11.6483
(N)	293.74	231.28	3.20077	19.3506	0.164701	11.4395	11.4797	11.5388
(O)	294.332	230.908	3.19797	-12.9686	-0.283454	11.462	11.5124	11.5862
(P)	292.753	222.65	3.07804	18.3404	0.155471	11.4698	11.5302	11.6188
(Q)	295.897	231.49	3.20411	19.2589	0.163296	11.4726	11.523	11.5968
(R)	296.235	226.835	3.14915	5.54861	-0.0303105	11.4749	11.5252	11.5991

Where,

(A) Random walk.

(B) Random walk with drift = –6.87034

(C) Constant mean = 7286.31

(D) Linear trend = 9904.26–3.85845 t

(E) Quadratic trend =

$$= 114459 - 312.705\hat{t} + 0.227595\hat{t}^2$$

(F) Exponential trend $= e^{(9.23494\ +\ -0.000504851\ t)}$

(G) S–curve trend $e^{(8.52728\ +\ 247.206/t)}$

(H) Simple moving average of 2 terms.

(I) Simple exponential smoothing with alpha = 0.1997

(J) Brown's linear exp. smoothing with alpha= 0.1213

(K) Holt's linear exp. smoothing with $\alpha = 0.179$ and $\beta = 0.1848$

(L) Brown's quadratic exp. smoothing with $\alpha = 0.0924$

(M) Winter's exp. smoothing with $\alpha = 0.1984$, $\beta = 0.0308$ and $\Gamma = 0.197$

(N) ARIMA (0, 1, 1) x (1, 1, 2)12

(O) ARIMA (1, 0, 1) x (1, 1, 2)12

(P) ARIMA (2, 1, 1) x (1, 1, 2)12

(Q) ARIMA (1, 1, 1) x (1, 1, 2)12

(R) ARIMA (2, 1, 0) x (1, 1, 2)12

Table (3) compares the results of different models fitted to the data. It is possible to notice that, the model with the lowest value of (AIC) is the model N "ARIMA (0, 1, 1) x (1, 1, 2)12", which has been used to generate the forecasts. Time sequence plot for the best model can be plot through the figure (4);

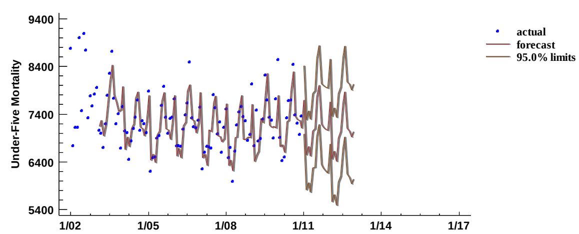

Figure (4): Time Sequence Plot for Under–Five and Infant Mortality; "ARIMA (0, 1, 1) × (1, 1, 2)12"

Table (4) summarizes the results of five tests run on the residuals in order to determine the adequacy of each model. OK means that the model successfully passed the test, One * means that it fails at the 95% level of confidence, Two *'s means that the model failed at the 99% level of confidence, while three *'s means that it failed at the 99.9% level of confidence. The currently selected model is model N, which passes 5 tests. Since no tests are statistically significant at the 95% or higher confidence level, the current model is probably adequate for the data.

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Table (4): Statistical Criteria Used for Comparison between the Estimated Periods for the Generated Models;

Model	*RMSE*	*RUN*	*RUNM*	*AUTO*	*MEAN*	*VAR*
(A)	448.5	OK	*	**	OK	*
(B)	450.8	OK	*	**	OK	*
(C)	414.5	OK	**	***	**	**
(D)	396.2	OK	*	***	OK	OK
(E)	333.6	OK	OK	**	OK	OK
(F)	395.9	OK	OK	***	OK	OK
(G)	392.8	OK	*	***	OK	OK
(H)	390.6	OK	OK	**	OK	OK
(I)	345.4	OK	OK	OK	OK	OK
(J)	352.7	OK	OK	OK	OK	OK
(K)	353.4	OK	OK	OK	OK	OK
(L)	359.6	OK	OK	OK	OK	OK
(M)	317.1	OK	OK	OK	OK	OK
(N)	293.7	OK	OK	OK	OK	OK
(O)	294.3	OK	OK	OK	OK	OK
(P)	292.8	OK	OK	OK	OK	OK
(Q)	295.9	OK	OK	OK	OK	OK
(R)	296.2	OK	OK	OK	OK	OK

Where,

RMSE = Root Mean Squared Error.

RUNS = Test for excessive runs up and down.

RUNM = Test for excessive runs above and below median.

AUTO = Box-Pierce test for excessive autocorrelation.

MEAN = Test for difference in mean 1st half to 2nd half.

VAR = Test for difference in variance 1st half to 2nd half.

OK = not significant ($\rho \geq 0.5$).

***** = marginally significant ($0.01 < \rho \leq 0.5$).

****** = significant ($0.001 < \rho \leq 0.01$).

******* = highly significant ($\rho \leq 0.001$).

3.3 Poisson Regression:

In order to examine the seasonal impact on the risk of childhood death during the period of study, a Poisson regression model for overall under–five years of age and infant mortality was fitted using *STATGRAPHICS package* (Table 5).

Table (5): Estimated Regression Model (Maximum Likelihood);

Para-meter	Estimate	Standard Error	Estimated Rate Ratio
CONST.	8.37914	0.0389045	
M_{12}	0.0000256	0.00000258	1.00003
M_{11}	0.0000038	0.00000265	1.0
M_{10}	-0.000005	0.00000265	0.999995
M_9	-0.000015	0.00000261	0.999985
M_8	0.0000027	0.00000258	1.0
M_7	-0.000005	0.00000246	0.999995
M_6	0.0000087	0.00000240	1.00001
M_5	-0.000013	0.00000230	0.999987
M_4	-0.000016	0.00000233	0.999984
M_3	0.0000049	0.00000235	1.0
M_2	0.0000106	0.00000230	1.00001
M_1	0.0000673	0.00000217	1.00007

Where M_i, refers to the number of month.

The output shows the results of undertaking a Poisson regression model to describe the relationship between M_{13} and 12 independent variables. The equation of the fitted model is,

$$\begin{aligned} M_{13} = \exp\,(&8.37914 + 0.0000256331 M_{12} + \\ &0.00000377102 M_{11} - 0.00000520232 M_{10} - \\ &0.0000148154 M_9 + 0.00000271294 M_8 - \\ &0.00000505316 M_7 + 0.00000869037 M_6 - \\ &0.0000132383 M_5 - 0.0000163765 M_4 + \\ &0.00000488243 M_3 + 0.0000106196 M_2 + \\ &0.0000672519 M_1) \end{aligned} \qquad (1)$$

Because the *P–value* of the model in the Analysis shown in table 6 is below 0.05, consequently, there is a statistically significant relationship between the variables at the 95.0% level of confidence. In addition, the *P–value* of the residuals is less than 0.05; this indicates that the model is significantly worse than the best possible model for this data at the 95.0% level of confidence.

Table (6): Analysis of Deviance;

Source	Deviance	D.f	P-Value
Model	2444.03	12	0.0000
Residual	1929.43	107	0.0000
Total (corr.)	4373.46	119	

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Percentage of deviance explained by model = 55.8832, and Adjusted percentage = 55.2887

The overall risk of under–five deaths is significantly higher in the eight month (August) than other months, which saw the fewest deaths. The following residual analysis table shows criteria for judging the quality of the model.

Table (7): Residual Analysis;

	Estimation
n	108
MSE	9.58468E8
MAE	257.112
MAPE	3.55661
ME	-0.0187
MPE	-0.224766

3.4 Artificial Neural Networks (ANN):

In order to facilitate the process of comparing between the "artificial neural networks method" and "traditional methods"', the same data have been used, then the network training on these data using *NeuroShell Predictor* program for the design and training the neural network accordingly. The criterion used is the absence of any change in the average error which means that, the network will not learn more or the amount of additional learning may be minimal.

The statistical criteria used are the coefficient of determination R^2, the average error ME, as well as the square root of the mean square error RMSE. The inputs of the network are 12 variables (values of the previous twelve months) and only one output (the value of the first month of the next year), using *NeuroShell Predictor* program. At the beginning of process of training the neural network, R^2 was 50.32% and with gradient in training this value reached 97.8% upon completion of the training process of the data in the learning phase.

The following figures show both the "actual values versus the predicted values" and the Scatter plot respectively.

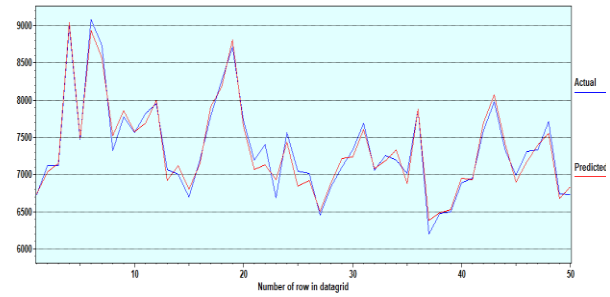

Figure (5): The Actual Values versus the Predicted Values;

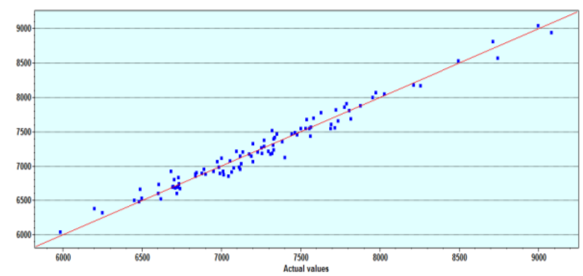

Figure (6): The Scatter Plot;

The hidden layer contains 96 neurons in the learning phase and the other statistical criterion is the average error, which measures the variation or difference between the actual outputs and the estimated outputs, which means, if the average error is at its lowest value, this means that the network properly trained 100%. When the training began, the average error is approximately equal to 308.74 and after the end of the training process this value amounted to 78.66 approx.

The relative importance for the independent variables can be clarified through table (8) and figure (7) respectively;

Table (8): Independent Variable Importance;

Var.	X_1	X_2	X_3	X_4	X_5	X_6
Impt.	0.173	0.079	0.046	0.062	0.012	0.014
Var.	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Impt.	0.098	0.028	0.224	0.102	0.107	0.056

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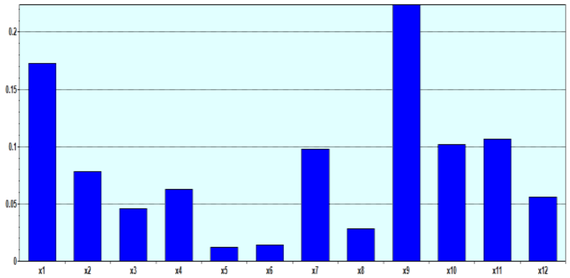

Figure (7): The Relative Importance of Inputs;

Comparing these statistical criteria conclude without doubt that the neural network actually trained well. In view of another statistical criterion which is, the square root of the mean square error (RMSE) with the continuation of the process of training the network we note that, it was continued to decline until it reached its lowest extent and settled to 98.59, which means that the neural network has already learning and training properly and well.

3.5 Generalized Additive Models (GAM):

Here we are exposed to study the generalized additive models (GAM), its stages and its characteristics, these models will be fitting using *STATISTICA package* program so as to detect the seasonality of child mortality data (He, 2004). The following table shows the results of estimating the model parameters using the approach of generalized additive models.

Table (9): Fit Summary for Under–Five and Infant Mortality in Egypt from 2002 to 2010;

	Response: V_1 , Distribution: Poisson; link function: Log					
	Var. index	D.F.	GAM. Coef.	Std. Error	Std. Score	Non-Linear P-value
Intcpt	0	1.000000	8.044154	0.040003	201.0882	0
V_2	1	6.989954	0.000036	0.000003	12.9048	0.000000
V_3	2	6.996564	0.000001	0.000003	0.2159	0.000000
V_4	3	7.000097	-0.000011	0.000003	-3.7083	0.000000
V_5	4	6.996458	0.000006	0.000003	2.2659	0.000000
V_6	5	6.999189	0.000016	0.000003	5.5916	0.000000
V_7	6	7.000188	-0.000004	0.000003	-1.5549	0.000016
V_8	7	6.998709	0.000021	0.000003	8.2405	0.058886
V_9	8	7.006445	-0.000019	0.000002	-7.6336	0.000000
V_{10}	9	7.004609	-0.000004	0.000003	-1.7519	0.000000
V_{11}	10	7.005414	0.000005	0.000003	2.0938	0.000000
V_{12}	11	7.002744	0.000009	0.000002	3.4832	0.000000
V_{13}	12	7.002167	0.000060	0.000002	25.3257	0.000000

The previous table shows the significantly of all months of the year at 5% level of significant, with the exception of the eighth month (August), suggesting the existence of the effect of seasonality on the data. The value of the coefficient of determination R^2 equals 85.48 which confirms the significantly of the model and its ability to predict. The following Table (10) shows summary of the most important results.

Table (10): Summary Statistics for Under–Five and Infant Mortality;

	Response: V_1, Distribution: Poisson; link function: Log						
	Final Deviance	Residual D.F.	Num. of Obs.	Outer Iter. Num.	Num. of smooth	Scale Estimate	R^2 100%
Statistic	533.9779	10.99746	96	20	62	1.0000	85.4753

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The proposed model using the generalized additive models is in the following form;

$$\begin{aligned} Y_t = & 8.044154 + 0.000036V_{2t} + \\ & 0.000001V_{3t} - 0.000011V_{4t} + \\ & 0.000006V_{5t} + 0.000016V_{6t} - \\ & 0.000004V_{7t} + 0.000021V_{8t} - \\ & 0.000019V_{9t} - 0.000004V_{10t} + \\ & 0.000005V_{11t} + 0.000009V_{12t} + \\ & 0.000060V_{13t} \end{aligned} \quad (2)$$

To ensure the suitability of the proposed model using generalized additive models, figures (8), (9) show the histogram and the normal probability figure for the proposed model. By studying these figures we note the appropriate of the estimated model for data.

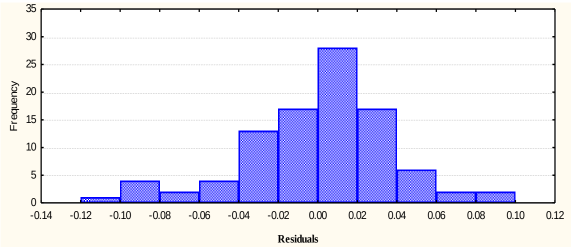

Figure (8): Histogram for Residuals;

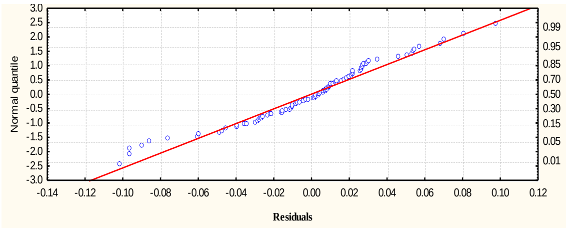

Figure (9): Normal Probability Plot for Residuals;

4. COMPARISON BETWEEN MODELS AND EVALUATION

By comparing estimates of each of traditional models, Poisson regression model, ANN and GAM to predict the numbers of under–five and infant mortality in Egypt during the period from 1/1/2002 to 31/12/2010, and to know which is more suited to fit that kind of data using the appropriate statistical criteria for measuring the ability of the model to predict and to differentiate between the previous models, the following criteria were used **(**Elabbasy**,** 2004**)**:

- (RMSE) Root Mean Square Error,
- (MAE) Mean Absolute Error,
- (MAPE) Mean Absolute Percentage Error,
- (R^2) the coefficient of determination,
- (THEIL) THEIL test,
- (TS) Trade Sign test and
- (ρ_1) the first autocorrelation.

The next table (11) presents these criteria;

Table (11): Statistical Criteria for Comparison between Different Models;

Model	RMSE	MAE	MAPE	R^2	THEIL	TS	Rho
Poisson Reg.	410.322	257.112	3.557	55.883%	0.028	-2.928	0.058
Traditional Mod.	293.740	231.280	3.201	71.140%	0.020	7.949	0.092
GAM	237.487	182.626	2.503	83.61%	0.016	0.00	0.124
ANN	98.592	78.657	1.086	97.08%	0.007	0.00	-0.109

5. CONCLUSION

i. Our study confirms that under–five and infant mortality has a seasonal pattern among children in Egypt.
ii. Children are most likely to die during the months severe cold (January), severe heat (August).
iii. Special attention should be given to address the main drivers of mortality during seasons when children are most susceptible to disease.
iv. The study calls with officials and those who prepare the annual census of the State to take special interest in the preparation of data for cohorts, because there is private link between each cohort of births and the surrounding environmental conditions.
v. Seasonality in child mortality may return to air pollution, which increases in the summer, especially in August as a result of the burning of rice straw.

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vi. The neural networks and the generalized additive models are the optimal alternative methods to estimate the parameters with less bias for detecting seasonality of child mortality data.

vii. The neural networks and the generalized additive models can be used as statistical methods in the analysis of time series widely, that is because these methods have a great ability to predict the values of demographic phenomena in the future especially in the field of child mortality.

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