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TRAFFIC ACCIDENT FORECASTS FOR RURAL HIGHWAYS

تنبوءات حوادث المرور على الطرق الخلوية

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خلاصة _ ان الهدف من هذا البحث هو اختبار نماذج التسلسل الزمنى المبنية على أساس منهاج بوكس وجينكنز . تم تطبيق هذا المنهاج على أربعة طرق خلوية بجمهورية مصر العربية تشمل :

- طريق القاهرة _ الاسكندرية الزراعى .
- طريق القاهرة _ الاسكندرية الصحراوى .
- طريق القاهرة _ السويس الصحراوى .
- طريق القاهرة _ الاسماعيلية .

بتطبيق المنهاج لقد تم الحصول على عدة نماذج لكل طريق والتى من بينها تم اختيار أحسن نموذج لكل طريق على حدة . ولقد قيمت النماذج الأربعة المختارة من حيث قدرتها على التنبوء مستقبلا كما تم مقارنة نتائجها بنتائج نماذج أخرى حيث أعطت نتائج أفضل مما يدل على أن منهاج بوكس وجينكنز من الممكن استخدامه للتنبوء بحوادث الطرق بدقة مقبولة . وترجع أهمية التنبوء بحوادث الطرق الى أن الهيئات المسئولة مثل ادارات المرور وشركات التأمين ... الخ يمكنها استخدام هذه المعلومات المستقبلية فى معرفة حجم الخسارة الناتجة اذا لم يحدث أى اصلاحات فى الطرق لتفادى الحوادث .

ABSTRACT- The Purpose of this paper is to develop and test time series models fo predicting short term traffic accidents. These models are based on the Box-Jenkins techniqu The used data are the monthly numbers of traffic accidents on four rural highways in Egypt. The developed models were evaluated and the forecasting ability was checked for each model. The obtained results indicate that time series technique can be used effectively to develop short term accident forecasts.

INTRODUCTION

Causes of traffic accidents are numerous. They can be related to many factors, such as driver, vehicle, road geometric design, and others. Prediction of the number of accidents that is likely to occur in the future is of great use to concerned authorties (i.e. Traffic Police Department (s), General Authority for Road and Bridges, Insurance Companies, ... etc). Accident forecasts these authorities in estimating the costs associated with the accidents if improvements would not be undertaken in the future. If any improvements are suggested, then cost-benefit analysis can be performed to estimate the savings obtained through these improvements. Because of the diversity of the factors contributing to accident occurrence, the future number of accidents is difficult to predict. Such prediction should incorporate the whole set of explanatory variables which increase the complexity of the process. Using regression technique in estimating or predicting number of accidents has encountered with many problems. An examplé is the multicollinearity problem that limits the use of regression technique in such these situations in which the explanatory variables may be highly correlated. Another problem remains in the data collection difficulty for each accident which requires a high amount of time, effort, and costs. Even in such situations, the models may perform poor results because of the difficulties in obtaining reliable data. Given this, the feature for simple and realistic models which do not require a lot of data is increasing. One of the simple techniques that has been previously applied in transportation is the time series technique developed by Box and Jenkins (1976). For example, Nihan and Holmesland (1980) utilised the technique to forecast average weekday volume traffic. Another use of the technique was to forecast spot speed data (1985). The technique showed to be useful in these applications. Therefore, the purpose of this paper is to extend the technique to traffic accident forecasts. In such cases of traffic accident analysis, it is recommended that the collected data include the monthly numbers of accidents and the traffic volume on each road. These data provide a general measure in obtaining the percentage of accidents corresponding to each traffic volume. However, the second type of data (traffic volume) was not available. Therefore, the only available and used data in this research are the monthly numbers of traffic accidents. The rural roads considered in the analysis are :

1- Cairo - Alexandria Agricultural Road (CAAR)
2- Cairo - Alexandria Desert Road (CADR)
3- Cairo - Suez Road (CSR)
4- Cairo - Ismailia Road (CIR)

The following sections include models specification, calibration, evaluation, and finally conclusions.

MODELS SPECIFICATION

As previously mentioned, the models used in this research are based on time series technique developed by Box and Jenkins (1976). The Auto Regressive Integrated Moving Average (ARIMA) method was used. The multiplicative model as a (p, d, q) x (P, D, Q) s was used to incorporate seasonal and nonseasonal operators. Using STATGRAPHICS package (1985), the used model form is as follows :

$$W_t = \frac{\Theta(B)\,\Theta_s(B)}{\phi(B)\,\phi_s(B)}\,a_t$$

where :

W_t = the original data or a difference of that data

$\Theta(B)$ = the nonseasonal moving-average operator

$= 1 - \Theta_1 B - \Theta_2 B^2 - \ldots\ldots - \Theta_q B^q$

B = the backwards operator

q = order of the nonseasonal moving-average term

$\Theta_s(B)$ = the seasonal moving-average operator

$= 1 - \Theta_1 B^s - \Theta_2 B^{2s} - \ldots\ldots - \Theta_Q B^{Qs}$

Q = order of the seasonal moving-average term

$\phi(B)$ = the nonseasonal autoregressive operator

$= 1 - \phi_1 B - \phi_2 B^2 - \ldots\ldots - \phi_p B^p$

p = order of the nonseasonal autoregressive term

$\phi_s(B)$ = the seasonal autoregressive operator

$= 1 - \phi_1 B^s - \phi_2 B^{2s} - \ldots\ldots - \phi_p B^{ps}$

a_t = the random error.

t = time index

p = order of the seasonal autoregressive term

d = order of nonseasonal differencing

D = order of seasonal differencing

MODELS CALIBRATION

The data obtained from Public Traffic Police Department included the monthly numbers of traffic accidents for each road for the years 1983 to 1986 as seen in the appendices 1 to 4 . In other words, 48 observations were considered for each road. These data were divided into two sets.

The first set included 42 observations for use in model calibration whereas the last 6 observations were kept for use in diagnostic checking. Using different values for the order of seasonal and non-seasonal autoregressive and moving average, different models were obtained. Out of these, the best model was chosen for each road. The summary of the estimates of the best model for each road is shown in Table I while Figure 1 shows the estimated autocorrelations for each road. It can be noticed that for CAAR and CSR, only one autocorrelation differs significantly from zero. In the case of CADR, two autocorrelations showed to differ from zero while in the case of CIR, all the autocorrelation values proved to be nonsignificantly different from zero .

Partial autocorrelation plots for all roads are seen in Figure 2. It can be noticed that only one partial autocorrelation fall out the two-sigma bounds is the case of CAAR, CADR, and CSR. In the case of CIR, all the values of partial correlation fall within the bounds.

MODELS EVALUATION

Two criteria were chosen in evaluating the models. These are :

1- Checking Forecasting Ability :

As was already mentioned, a set of data including the last observations (these represent the second half of 1986) was kept for use in evaluation. Therefore, the developed time series models were used to forecast the monthly numbers of accidents for the second half of 1986. The estimated and observed values can be seen in Figure 3. As can be noticed, all the observed values fall in the range of estimated values obtained using models except only for CADR in which 2 of the 6 observations fall outside the range. Examination of the data led to the identification of a high increase in the number of accidents within these two months than ever before. It leads to investigate the reasons of the high number of accident within the mentioned period. This shows that beside using time series technique in forecasting, it can be used in identification that may occur in the future.

2- Comparative Evaluation :

The comparative evaluation was made by using least squares method to develop linear, multiplicative, and exponential models for each road. The forms of the models are as follows :

Linear model : $N = a + bt$

Multiplicative model : $N = at^b$

Exponential model : $N = e^{(a + bt)}$

where :

N = number of accidents,

t = time in months, and

a and b are coefficients to be determined from regression.

Using the number of accidents as the dependent variable and the time as the independent variable for each road, the summary of the results obtained can be seen in Table 2. In this table, the residual sum of squares (RSS), R-square, and F ratio are presented for each road. Comparison of RSS obtained from time series models with those obtained using other models, as seen in Table I, indicated the following :

1- In the case of CAAR, the RSS obtained using time series technique represents 91 % of that obtained from the exponential model which is the best in the group of least squares models .

2- In the case of CADR, the RSS obtained from time series equals to 46 % of the linear model which is the best model in the group in this case.

3- In the case of CSR, the RSS value showed to be 64 % of that obtained using the linear model.

4- In the case of CIR, the obtained RSS value represents 42 % of that obtained using the linear form which performed better than the multiplicative and the expontential forms.

Closing, this shows that time series technique performs better results than the linear, multiplicative, and exponential forms.

CONCLUSIONS

The results obtained indicate that time series models based on the Box-Jenkins technique can be used effectively in traffic accident forecasts. The advantages of the technique remain in its simplicity and usage of data which are not expensive to collect. The data can be obtained easaily from Traffic Police Department (s) with no costs. Although complex forecasting models which incorporate many and different explanatory variables can be developed, there is a trade-off between the accuracy gained and the higher costs involved in these models.

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Table 1 : Summary of fitted models based on time series technique

Road / Estimate of	CAAR	CADR	CASR	CIR
AR* (1)	- 0.604	- 0.335	- 0.648	- 0.737
AR (2)	- 0.479	- 0.727	- 0.465	- 0.525
AR (3)	- 0.320	- 0.668	0.165	- 0.435
AR (4)	- 0.264	- 0.367	- 0.141	-0.087
AR (5)	- 0.311	- 0.389	- 0.197	- 1.020
AR (6)	- 0.069	- 0.920	- 0.326	- 0.489
AR (7)	- 0.140	- 0.469	- 0.573	- 0.492
AR (8)	- 0.344	- 0.778	- 0.555	0.152
AR (9)	- 0.320	- 0.186	- 0.189	0.408
MA**(1)	- 0.716	0.405	- 0.225	0.773
MA (2)	- 0.372	- 1.084	- 0.550	0.383
MA (3)	0.684	- 0.003	- 0.936	- 0.027
MA (4)	0.041	- 0.307	- 0.613	- 0.432
MA (5)	- 0.828	- 0.100	- 0.169	- 1.565
MA (6)	0.719	- 0.253	- 0.011	0.519
MA (7)	- 0.044	- 0.029	- 0.146	- 0.018
MA (8)	- 0.203	- 0.352	- 0.104	0.509
MA (9)	- 0.131	0.634	- 0.107	0.304
RSS$^+$ (1)	1645.78	745.58	140.96	144.79
RSS (1) / RSS° (2)	91 %	46 %	64 %	42 %

Notes :

* AR : Nonseasonal Auto Regressive

** MA : Non seasonal Moving Average

+ RSS (1) : Residual sum of squares of developed time series models

° RSS (2) : Residual sum of squares of the best developed regression model

Table 2 : Summary of Fitted Models Based on Least Squares Method .

Road	Model Type	a	b	R^2	F-ratio	RSS (2)
CAAR	Linear (1)	53.122	-0.61	0.400	26.410	3481.520
	Multiplicative (2)	17416.800	-0.216	0.290	16.260	4108.500
	Exponential (3)	4.005	-0.017	0.360	22.380	1816.200
CADR	Linear (1)	10.866	0.238	0.180	8.590	1622.440
	Multiplicative (2)	177.280	0.149	0.070	3.000	2.13×10^9
	Exponential (3)	2.346	0.015	0.140	6.350	4.50×10^8
CSR	Linear (1)	9.573	-0.132	0.330	19.420	220.870
	Multiplicative (2)	341.100	-0.261	0.200	10.110	2.94×10^8
	Exponential (3)	2.331	-0.025	0.350	21.760	7.40×10^6
CIR	Linear (1)	7.878	0.016	0.004	0.180	341.560
	Multiplicative (2)	90.200	0.027	0.003	0.130	10.2×10^6
	Exponential (3)	2.038	-0.0003	0.000	0.003	10.8×10^6

(1) Linear Model : $N = a + bt$

(2) Multiplicative MOdel : $N = at^b$

(3) Exponential Model : $N = e^{(a + bt)}$

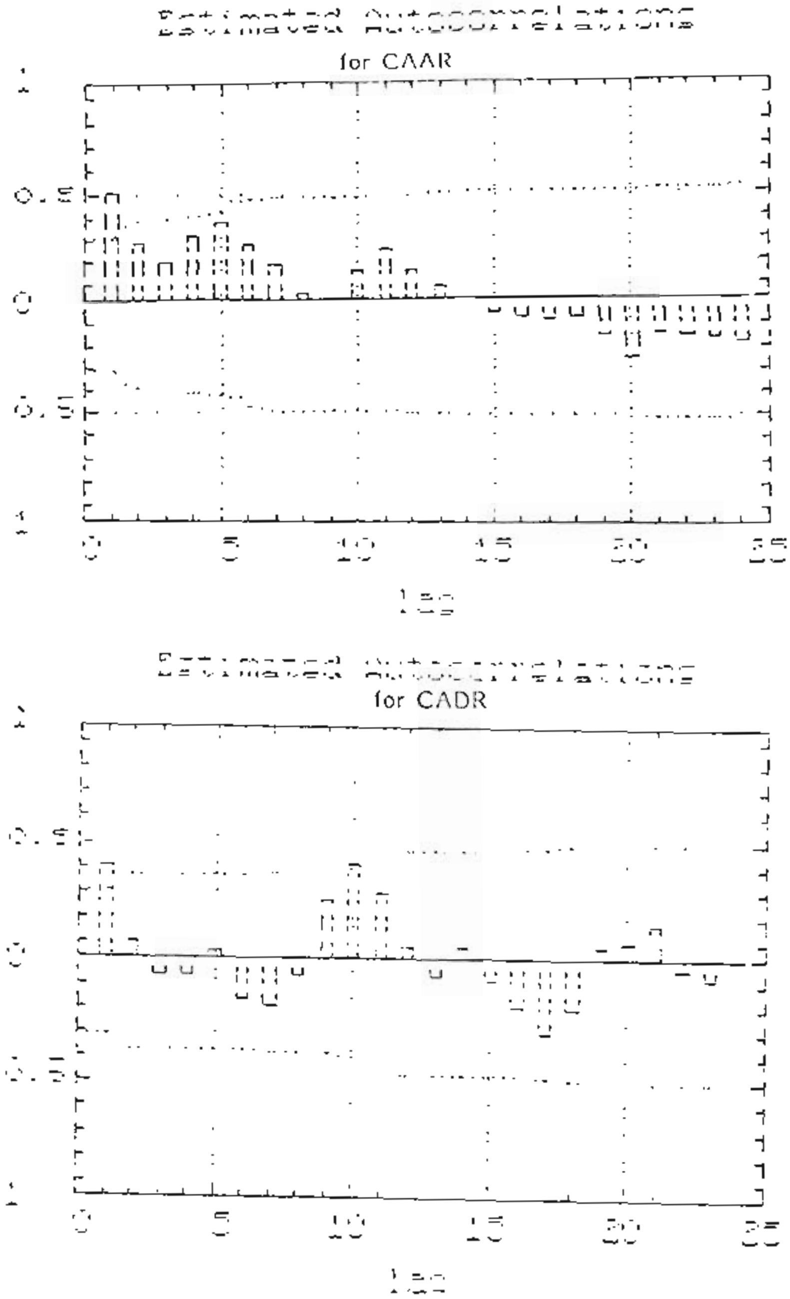
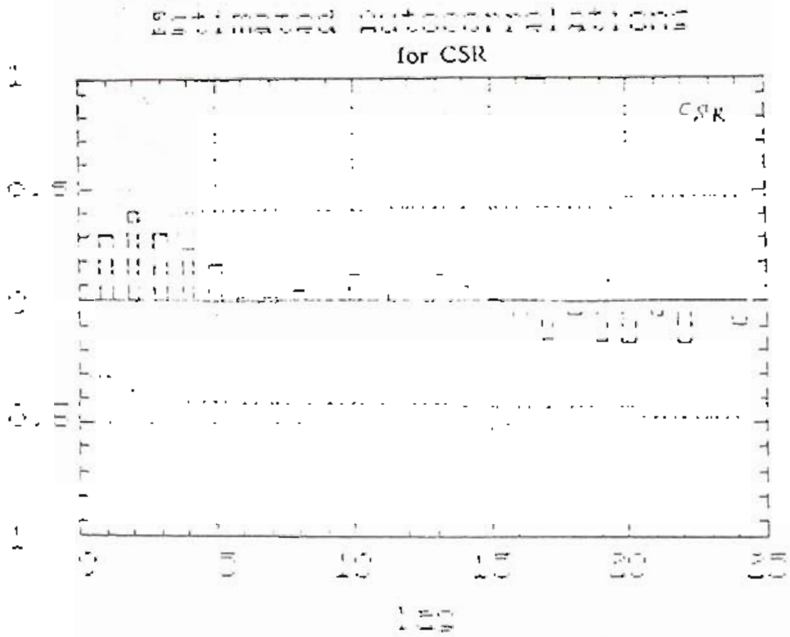


Figure 1 : Estimated Autocorrelations for CAAR and CADR



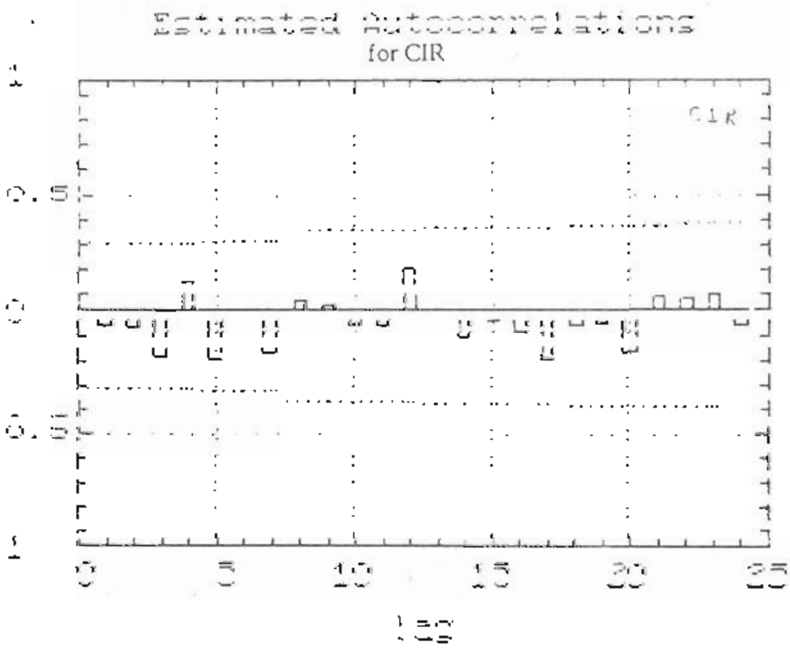


Figure 1 Cont. : Estimated Autocorrelation for CSR and CIR

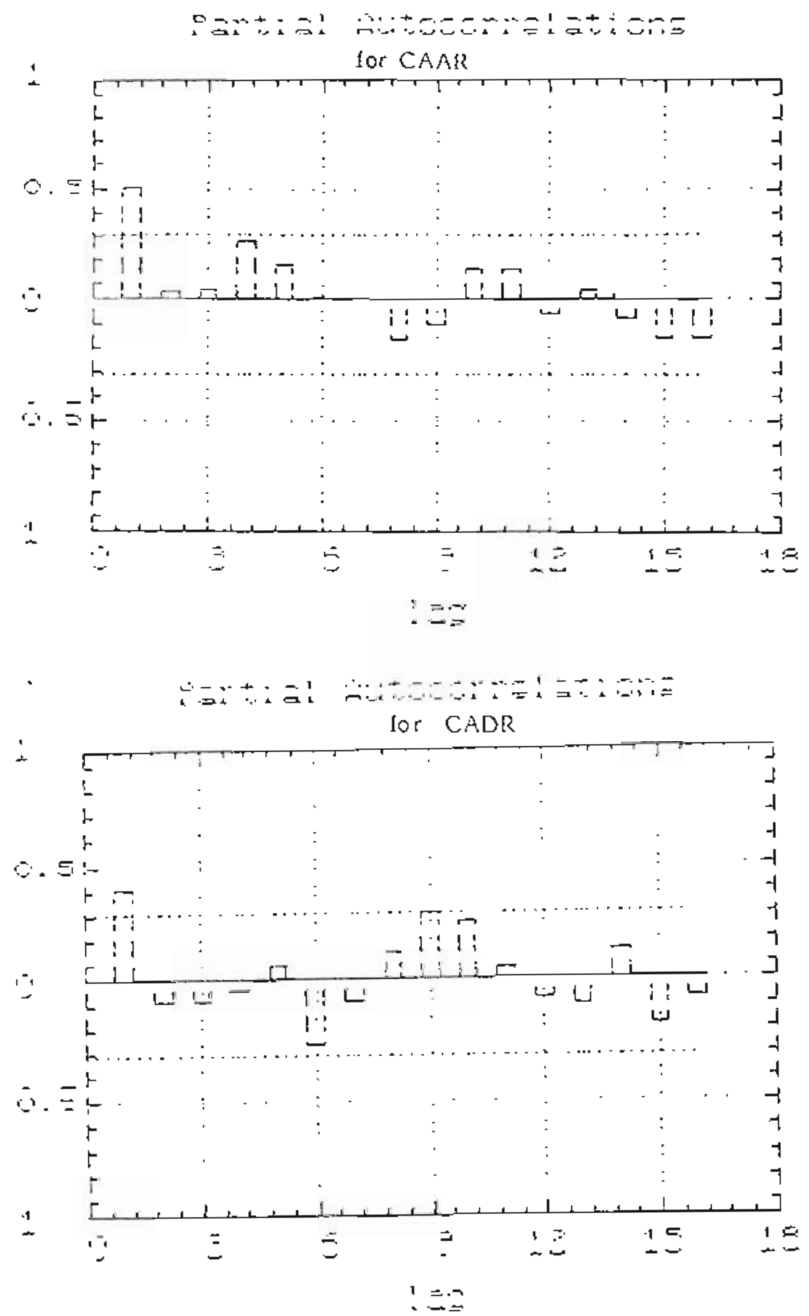
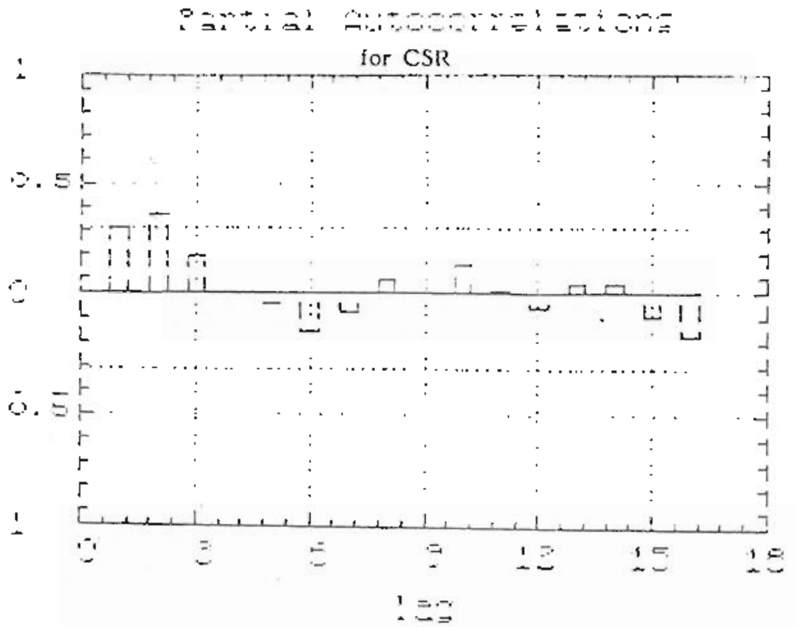


Figure 2 : Partial Autocorrelations for CAAR and CADR



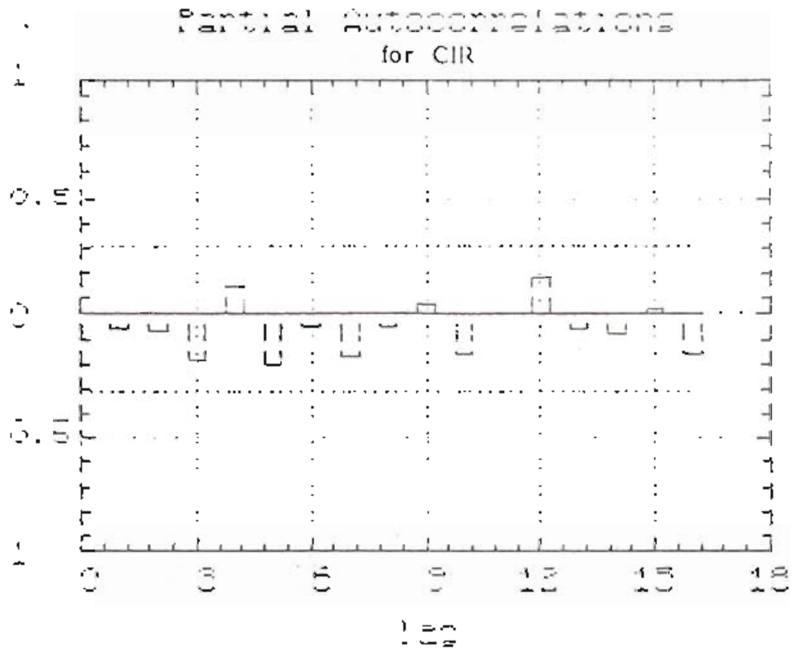
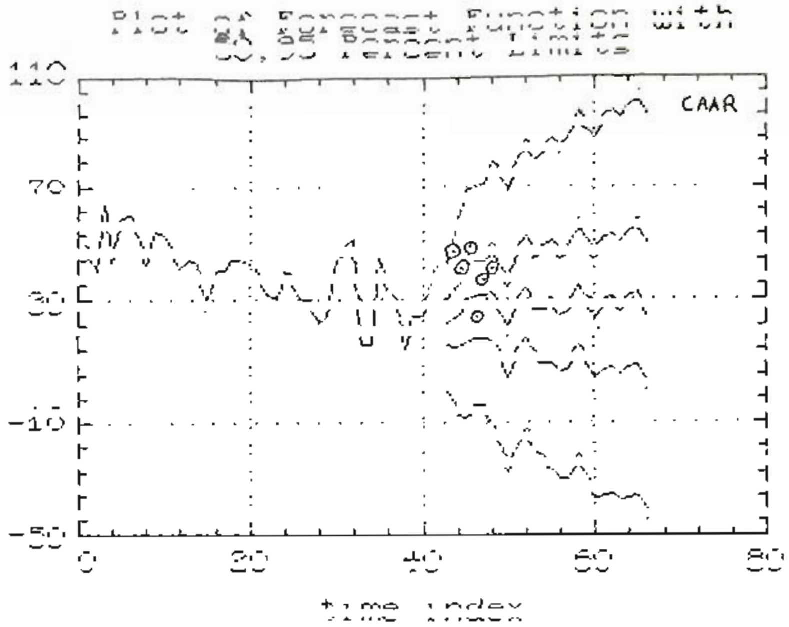


Figure 2 Cont. : Partial Autocorrelations for CSR and CIR



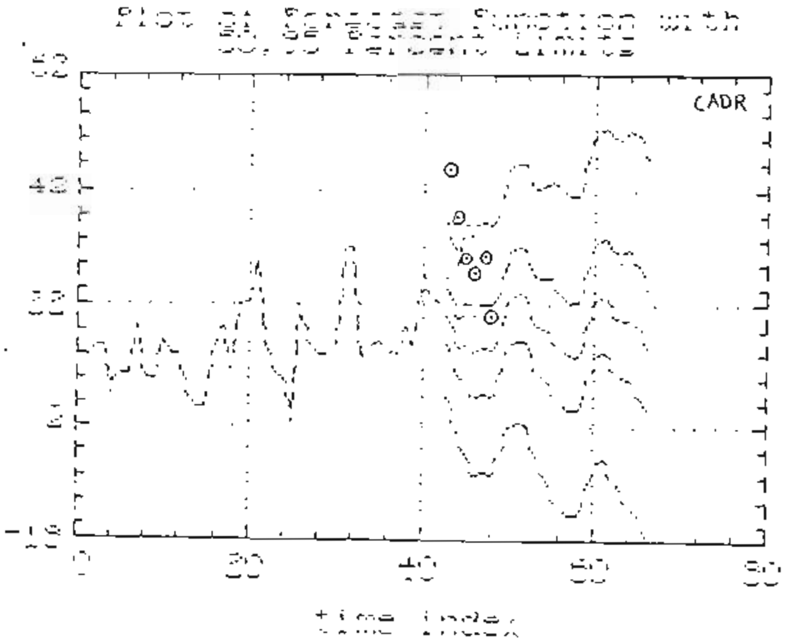
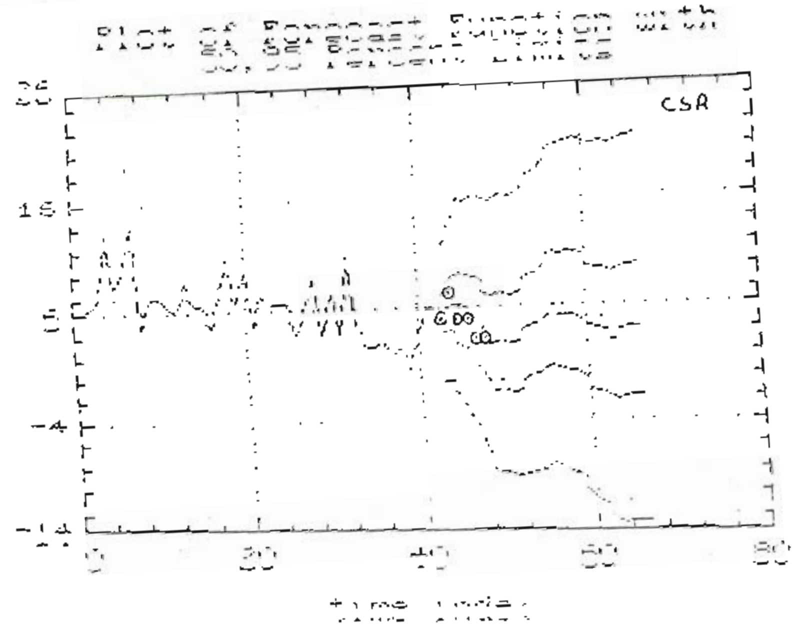


Figure 3 : Polt of Forecast Function at 50 and 95 Percent Limits with observed values for Second Half of 1986 for CAAR and CADR



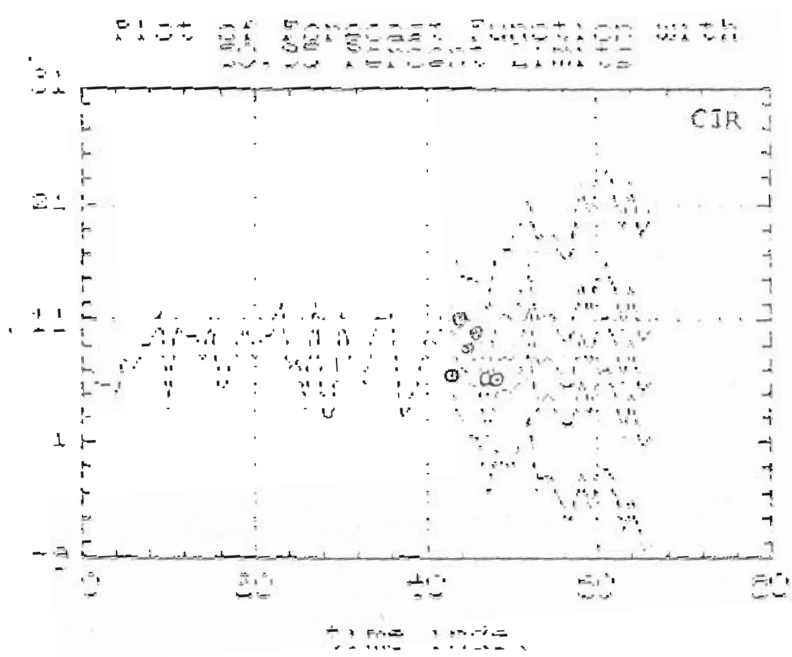


Figure 3 Cont. : Plot of Forecast Function at 50 and 95 Percent Limits With Observed values for second half of 1986 for CSR and CIR

Appendix (1)

Monthly Number of Accidents on Desert Cairo-Alexandria Road for the period 1983-1986.

Month	1983	1984	1985	1986
January	13	7	3	14
February	16	5	22	19
March	16	5	16	16
April	8	16	14	28
May	11	19	14	24
June	11	12	16	23
July	19	22	32	45
August	10	23	33	38
September	10	21	13	33
October	17	16	16	28
November	14	11	17	34
December	14	10	15	19

Appendix (2)

Monthly Number of Accidents on Agricultural Cairo-alexandria Road for the period 1983-1986.

Month	1983	1984	1985	1986
January	49	46	38	31
February	41	44	30	14
March	65	29	31	26
April	45	40	23	26
May	57	41	26	38
June	59	46	46	44
July	54	46	48	48
August	43	44	52	42
September	56	39	16	49
October	54	33	16	23
November	48	32	46	35
December	42	41	35	40

Appendix (3)

Monthly Number of Accidents on Cairo-Suez Road for the period 1983-1986

Year / Month	1983	1984	1985	1986
January	6	9	7	2
February	7	7	4	3
March	8	7	7	1
April	13	5	9	4
May	8	8	4	6
June	11	11	8	6
July	14	7	4	5
August	5	10	11	8
September	8	5	5	4
October	8	8	3	5
November	7	7	3	3
December	6	7	4	3

Appendix (4)

Monthly Number of Accidents on Cairo-Ismailia Road for the Period 1983-1986

Year / Month	1983	1984	1985	1986
Junuary	7	10	8	3
February	6	8	4	4
March	6	11	13	6
April	5	5	3	10
May	8	7	3	9
June	7	9	12	12
July	9	11	8	5
August	9	8	7	11
September	12	10	6	7
October	4	10	11	10
November	11	13	11	5
December	10	7	12	5