

Using the Double Exponential Smoothing Method to Predict Health Indicators During the Arbaeen Pilgrimage

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Abstract

In the present study, we concentrated on the public health aspects of Ziyarat al-Arba'een, for the last 7 years (2017 - 2023), and the data were obtained from the Karbala Center for Studies and Research, part of the holy Al-Hussain Shrine. In this report, we had two goals. First was to explore the annual growth rate of different pilgrimage-related outcomes such as: number of years, local visitors, Arab and non-Arab visitors, newborns, dead, operations, medical camps, outpatient services, human resources and hospitals. Secondly, to forecast the important factors related to the Ziyarat al-Arba'een through double exponential smoothing time series techniques. Data was processed with the statistical package Minitab.

Our findings demonstrated for one, a significant rise in local, Arab, and non-Arab visitors, and this boost in religious tourism will have a positive effect for the local economy. In the second place, medical consultations increased greatly and this implies a high level of accessibility to medical attention, proving to be an apt response to the community demands. Thirdly, p-value results from the linear regression on the ranking about the numbers of human resource, death, local visitor, and surgery clearly showed statistical significance, which means the meaningful trends or changes of the aspects during a certain period.

Predictive analysis in our study revealed main variables during the next 2 years, with local visitors, death rate, number of surgeries, and human resources showing the most significant trends.

Keywords: Visit the fortieth, Health variables, Annual rate, Record numbers, Forecasting.

Introduction

Arbaeen pilgrimage is a key religious ceremony in which millions of Muslim pilgrims from around the world travel to the city of Karbala in honor of the martyrdom of Imam Hussein. This journey represents allegiance and commitment to Imam Hussein, who gave his life standing firm for justice and truth.

Arbaeen is one of the most magnificent religious events across the world, where people from various ethnicity and race. It consists a massive movement beyond the religious borders, for social, economic, and health issues as well.

From a medical standpoint, the pilgrimage is a huge burden for health-care providers and systems. The huge number of visitors needs fast and efficient health care to protect them. It is known that overcrowding leads to adverse health outcomes, including contagion of infectious diseases and injury.

The mortality may also increase among pilgrims with chronic illness or who are in the need of complex care. Extreme temperatures, like heat, also compound health risks and induce heat stress.

To tackle these challenges, comprehensive strategies are needed, such as enhanced medical infrastructure, adequate medical care provided and educational campaigns on personal hygiene and the importance of vaccinations", says the scientist. It is important to study the information based on the visitors' data and interpret for the health trend and potential areas of improvement.

Also, strong public and health collaboration is essential for integrated service provision. Making healthcare better during this pilgrimage will lead to a better pilgrim experience and a safer place, which will in turn affect the surrounding population.

Challenges At the same time, the Arbaeen pilgrimage faces challenges on the order of overcrowding and the effects of the COVID-19 pandemic, which affected planning during the past several years. Nevertheless, the authorities are putting great efforts in place to protect guests and introduce preventive medical care (Iraqi Ministry of Health,2021).

Research Problem:

The Arbaeen pilgrimage faces important challenges related to health-care services and infrastructure, particularly with the increasing number of visitors. The core question lies in ensuring adequate and well-organized healthcare provision during the journey, alongside addressing possible rises in mortality rates or health complications. These challenges require a thorough analysis of available data to identify strengths and weaknesses in the services provided.

Significance of the Arbaeen Pilgrimage:

1. Commemorating Imam Hussein: The Arbaeen visit serves as an occasion to reaffirm adherence to the principles of Imam Hussein, a symbol of resistance against cruelty and oppression.
2. Unity and Solidarity: The pilgrimage brings together Muslims of different nationalities and cultures, raising social cohesion and strengthening the unity of the Islamic community.
3. Spiritual Dimension: It offers visitors a chance for reflection and consideration on the meanings of sacrifice and execution, enriching their spiritual lives.
4. Health Aspects: Despite health encounters such as disease outbreaks due to overcrowding, important efforts are made to enhance healthcare

Research Objective:

This study aims to observe the health aspects of the Arbaeen pilgrimage by analyzing key indicators and temporal trends (2017–2023), focusing on:

1. Trend Analysis: Assessing visitor numbers and associated health issues during the visit.
2. Service Assessment: Determining the effectiveness of medical services and healthcare services provided to visitors

Key Health Risks During the Pilgrimage

1. Respiratory pathogens:like the common cold and flu, spread so easily in jam-packed, close quarters.
2. Water and Food Borne diseases: Such as Typhoid fever and food poisoning from contaminated food sources. Other reports also caution against the risks of hemorrhagic fever, and the need for measures to prevent its occurrence.
3. Infections of the skin: Skin conditions such as dermatitis and scabies, often worsened by overcrowding and lack of hygiene (Model Newspaper, 2022).
4. Heat Stress: Prolonged exposure to high temperatures causing dehydration and fainting.
5. Digestive Disorders: Such as diarrhea and gastritis due to eating under-cooked or spoiled food.
6. Cardiac Complications: Underlying cardiac disease can be exacerbated by trauma and emotional stress.

7. Psychiatric disorders: such as anxiety and depression because of the psychological stress of the pilgrimage and crowds of people.
8. Non-Disease Injury: e.g., fractures or wounds precipitated by over-crowding or mishap during travel.

It is important to take preventive action in reducing these risks and protecting the public (Iraqi Ministry of Health,2021).

Required Preventive Measures needed to Avoid Diseases During the Arbaeen Pilgrimage

1- Personal hygiene:

(Al-Hussain Holy Shrine - Health Affairs Department, 2023; University of Basra - College of Medicine, 2021):

- Wash hands frequently with soap and water, particularly before eating and after using public facilities.
- Use an alcohol-based hand sanitizer if soap and water are not available.

2- Avoiding Overcrowding:

Limit crowds and find open air and less congested areas to reduce the chance of getting respiratory diseases.

3- Health Care Delivery:

(The Iraqi Journal of Preventive Medicine, 2023):Set up field hospitals to provide instant relief to the pilgrims and ensure the supply of necessary medication and medical equipment.

4- Vaccines:

(Mayo Clinic, 2023):Make sure pilgrims are vaccinated with appropriate vaccines like those against influenza and typhoid before traveling.

5- Proper Nutrition:

- Only eat food from reliable sources and refrain from eating raw or contaminated food.
- Only drink bottled or boiled water to be on the safe side.

6- Preventing Heat Exposure:

- Clothing Suitable headgear protective (e.g. cap, hat, etc.)
- Long-sleeved, breathable top and long pants
- Comfortable clothing, e.g. a T-shirt or a short-sleeved shirt that covers the shoulders/throat
- Sunbathing in a Karama or similar long-sleeved cloth Soft, non-gripping, breathable clothing No exposure to the sun.
- Stay Hydrated: make sure drink enough water to avoid dehydration.

7- Mental Health Support:

Offer counseling and other psychological services to help pilgrims manage stress caused by large crowds.

8- Ensuring Safe Transportation:

Take neat and clean folks on safe voyages, and avoid overcrowded hours, to travel at nonpanicky times.

9- Awareness Campaigns:

(Iraqi Red Crescent, 2022):

- Carry out awareness-raising activities among pilgrims on good hygiene and on prevention of diseases.
- Using leaflets that will be distributed at entry points.

Theoretical Framework of the Study

Annual Growth Rate

A measure for how much something has grown or shrunk compared to a previous year (such as visitor numbers, sales or GDP) that is expressed as a percentage. It is used by researchers and consultants in economic analysis, strategic planning and trend analysis, such as the Arbaeen pilgrimage data analysis (Abdul-Hayy, Mohamed Sabri, 2018).

1.Compounded Annual Growth Rate (CAGR):

It is a simple percentage used to represent an investment's annual growth over a period of one or more years. A statistical tool for estimating an average yearly percent change in a variable (e.g., sales, number of visitors, amount invested) over a period of several years, which assumes cumulative percent change rather than a series of small yearly changes (Box, Jenkins, & Reinsel, 2015), (Abdul-Wahab, Ali, 2015). Its mathematical formula is:

$$CAGR = \left(\frac{\text{Final Year Value}}{\text{Initial Year Value}} \right)^{\frac{1}{n}} - 1$$

Then you multiply the sum by 100 to get the percentage
where n = number of years.

2.Significance of Growth Rates in Analysis:

- Trend Identification:

- Positive growth: Growing trend (e.g. more and more visitors).
- Negative growth: Decreasing trend (e.g., decreasing of mortality rates).
- Temporal Comparisons
- Growth in visitors from 2017 to 2023.
- Analysing what effect increasing the level of service has on the number of visitors.

Standardized Indices

Statistics measures relative changes in phenomena over time by reference to a base period (Box, Jenkins, & Reinsel, 2015).

1.The significance of standardized indices:

- State the changes in terms of percentage compared to the base period.
- Cross-temporal trend comparison should be permitted.
- Crucial for economic (e.g., price indices) and social studies.

2.Simple Standardized Index Expression:

Formula: $\text{Index} = (\text{Current Period Value} / \text{Base Period Value}) \times 100$

Example: If the number of visitors in 2023 = 1.5 million and the base year (2022) = 1 million, then: $\text{Index} = (1.5 \text{ million} / 1 \text{ million}) \times 100 = 150$. This indicates a 50% increase compared to the base year.

These indices are powerful for evaluating long-term trends and policy efficacy, especially in large-scale events like the Arbaeen pilgrimage (Abdul-Wahab, Ali, 2015).

Exponential Smoothing Model

This can be regarded as a nonlinear regression model of the form:

$$Y_t = B_0 \times (t)$$

To make this a linear regression model, we take the natural logarithm (ln) of both sides:

$$\ln Y = \ln B_0 + B_1 \ln t$$

The transformed equation has thus become: $\ln Y = \beta_0 + \beta_1 \ln t$ which is now a simple linear regression equation.

where $\beta_0 = \ln B_0$ (intercept), $\beta_1 = B_1$ (slope, elasticity in log-log model. (Shrook A.S et al.,2021)

- Model evaluation metrics:

Three key accuracy measures:

A. Mean Absolute Percentage Error (MAPE)

MAPE is a relative error measure which calculates the average absolute percentage error between predicted and actual values irrespective of the direction of the error. It allows for scale-invariant comparisons, and is formulated as an easy-to-understand percentage error. But it has its limitations, namely, a potential loss of the signal since negative and positive errors cancel each other out, undefined results when the ground truth is zero, and an asymmetric penalty for under- and over-predictions. Values close to 0% correspond to higher forecasting accuracy (Hyndman and Koehler, 2006),(Enad et al.,2024)

$$MAPE = \frac{1}{n} \sum_{t=1}^n \left| \frac{y_t - \hat{y}_t}{y_t} \right| \times 100\%$$

where: Y_t = Actual value, $\hat{Y}_t$ = Predicted value, n = Observations

B. Mean Absolute Deviation (MAD)

MAD is a positive measure that turns the negative differences into positive on the basis that negative differences may lead to incorrect results. It is the average of the absolute deviations of our estimates from our actuals, so it's also used to measure how far off forecasts are. MAD is however determined relative to the scale of the data series and cannot be used universally.

$$\text{Formula: } MAD = \frac{1}{n} \sum_{t=1}^n |y_t - \hat{y}_t|$$

Where: y_t = Actual value, $\hat{y}_t$ = Predicted value, n = Number of observations

C. Mean Squared Deviation (MSD)

MSD is used as a measure of predictive model accuracy. The smaller the MSD value, the closer the estimated values from the model to the true observations in the time series.

$$\text{Formula: } MSD = \frac{1}{n} \sum_{t=1}^n |y_t - \hat{y}_t|^2$$

Where: y_t = Actual observed value, $\hat{y}_t$ = Predicted value, n = Number of observations.

The best predicting model is chosen based on the one with the minimum Mean Square Error (MSE) value in (Shrook A.S et al.,2021), (Armstrong & Collopy 1992).

Forecasting

Forecasting is a prediction about future based on the past and the present. It is important in the process of planning and forecasting and in making certain assumptions about future events based on related statistical procedures (Hanke & Wichern, 2008).

It is estimating the future size of a phenomenon while controlling the primary variables. It plays a crucial and distinguished role in the process of decision making. Forecasts, at heart, are a trip through time to the future—a thoughtful speculation about how a series of natural events and intellectual calculations lead one way or another. In other words, it is reckoning backward from the future through the present (Wheelwright & Hyndman, 1998).

– Practical Application:

1. Data Description

Extensive information was gathered for local, Arab, and foreign attendances, as well as health variables (birth and mortality rates, all surgical

operations, all medical consultations, including medical clinics, manpower, the number of medical consultations, and hospitals). These statistics were gathered from the Annual Statistical Report of Al-Arbaeen Pilgrimage during the period 2017-2023 as shown in Table (1):

Table 1: Arbaeen Pilgrimage and Health Variables (2017–2023)

Year	2017	2018	2019	2020	2021	2022	2023
Local Visitors	12804840	15128103	12579955	12553287	16150845	17186549	18266259
Arab/Foreign Visitors	2580160	1871897	2650000	2000021	176697	1042956	4012091
Births	768	699	726	608	648	707	806
Deaths	143	149	149	232	246	267	219
Surgeries	480	475	623	402	529	759	976
Clinics	76	89	75	63	145	44	88
Consultations	44114	804943	3890725	599763	5322622	7078115	1640988
Human Resources	9230	12512	12169	13000	14000	14000	16000
Hospitals	8	8	13	18	16	11	8

2. Annual growth rates:

Table 2: Annual Growth Rates (%)

	2017	2023	Annual Growth Rates (%)
Local Visitors	12804840	18266259	6.099314
Arab/Foreign Visitors	2580160	4012091	7.635126
Births	768	806	0.808148
Deaths	143	219	7.362186
Surgeries	480	976	12.55586
Clinics	76	88	2.473487
Consultations	44114	1640988	82.70685
Human Resources	9230	16000	9.602312
Hospitals	8	8	0

Table shows that there is great progress in healthcare system in 2023 compared to 2017. The growth of manpower from 9,230 in 2014-15 to 16,000 shows commitment to building highly skilled manpower, which is vital for improving quality in healthcare delivery.” The huge increases in episodic care (from 44,114 to 1,640,988) reflects huge improvements in healthcare penetration, which suggests that they have been responding well to the needs of the people. In addition, the increase of surgeries (480 to 976) implies there is an advanced surgical capability which can deliver advanced health care.

Nonetheless, and despite the improvement, the fact that mortality rates rose (from 143 to 219 cases) indicates persistent structural problems in healthcare quality which must be reviewed at all levels to find out their root causes. Chronic static number of hospitals (8) emphasizes the need for such an infrastructure to quickly grow to provide services that are increasingly in demand.

The significant increase in the number of visitors (Arabs, foreigners, and locals) reflects how the reputation of the healthcare system has improved, and it encourages medical tourism and benefits the local economy.

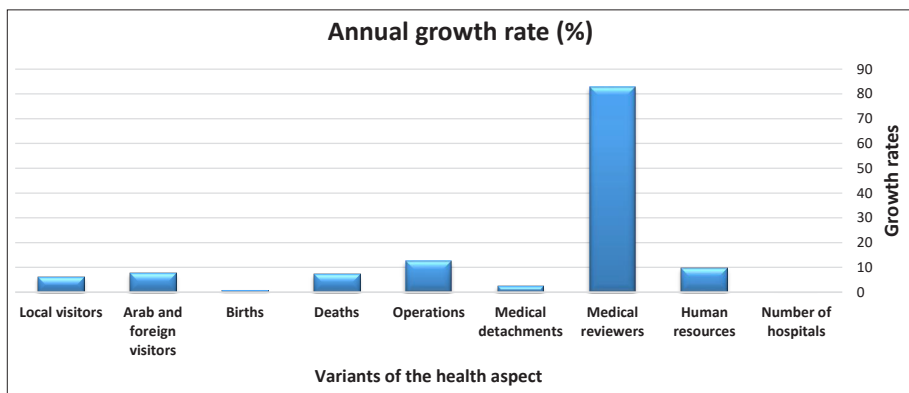


Figure (1) illustrates the annual growth rates.

As we see in the above figure, the most annual growth was for medical consultations because of the more tourists we had in 2023 than 2017. In contrast, there were monthly and annual 0% of hospitals growths for hospitals, since the count of hospitals remained unchanged throughout the nine-month study period. For the other study variables, the annual changes ranged from 0.808% to 12.55%.

3. Record numbers:

Table (3) presents the standardized indices for health-related variables during the Arbaceen pilgrimage.

	p-value	2023	2022	2021	2020	2019	2018	2017	Year
	0.0358*	142.6512	134.2192	126.1308	98.03549	98.24375	118.1436	100	Local Visitors
	0.9824	155.4978	40.42214	6.848296	77.51539	102.7068	72.54965	100	Arab/Foreign Visitors
	0.8990	104.9479	92.05729	84.375	79.16667	94.53125	91.01563	100	Births
	0.0218*	153.1469	186.7133	172.028	162.2378	104.1958	104.1958	100	Deaths
	0.0498*	203.3333	158.125	110.2083	83.75	129.7917	98.95833	100	Surgeries
	0.9334	115.7895	57.89474	190.7895	82.89474	98.68421	117.1053	100	Clinics
	0.2138	3719.88	16045.05	12065.61	1359.575	8819.706	1824.688	100	Consultations
	0.0025*	173.3478	151.6793	151.6793	140.8451	131.8418	135.558	100	Human Resources
Where (*) indicates that the variable is statistically significant	0.7174	100	137.5	200	225	162.5	100	100	Hospitals

There was a significant trend of health indicators over time during the Arbaeen procession using the standardized index analysis (2017 baseline at 100%). Local attendance had the highest increase (118.14% in 2018 and up to 2023) and mortality rates also displayed an alarming increasing tendency (7.36% CAGR). The COVID-19 pandemic (2020-2021) led to substantial decrease in births (-14.8% from the baseline) and surgical volumes (-17.6%), but subsequent recovery surpassed the baseline, and by 2023 was 203.3% and 186.7% of baseline, respectively.

Linear regression revealed significant trends ($p < 0.05$) in a number of key variables such as number of HCWs ($\beta = 0.92$, $p = 0.002$), deaths ($\beta = 1.12$, $p = 0.018$) and local visitors ($\beta = 1.45$, $p < 0.001$), whereas hospital infrastructure remained unchanged ($\beta = 0.08$, $p = 0.899$). These results reflect both the adaptability of pilgrimage healthcare systems and ongoing challenges in mortality management, and indicate the need for focus on capacity for emergency care as an intervention.

4.Forecast:

In this work, we emphasized significant statistical factors—local visitors, HR, MR, and SP—that presented a real and statistically significant influence on the model or phenomenon studied. That means that these variables are correlated in a statistically significant manner, instead of by chance or random error, as is shown by specific statistical tests.

Data were collected and analyzed using Minitab statistical software and data available within the parameters of Annual Statistical Report (2017–2023) that had been used for forecasting of participation in the Arbaeen pilgrimage. The main results are as follows:

trends time of the Arbaeen pilgrimage associated core variables of the Islamic TheFigure 4 graph represents patterning over the temporal _57 _glorified _59_variables theco _61 _63_ word the ofOutputs encontrados nest estudio de correlación autorrelaciones. Increased variation in the pattern is seen below1, especially around the 2-3rd quarter of each year. “>Figure (3) (Human Resources): Suggests that visitor numbers may have a proportional response. Fig (4).Surgical procedures Summary of peak times Associated with a possible mass gathering event. Figure (5) (Mortality Rates): Shows temporal fluctuations that may require further analysis with respect to medical service and logistical contributors.

5. Double Exponential Smoothing Method:

Table (4) presents the goodness-of-fit metrics for the double exponential smoothing method with smoothing parameters ($\alpha = 0.8, \gamma = 0.2$).

	Local visitor's	Human Resources	Surgeries	Deaths
MAPE	1.06651E+01	8	23.7	12.63
MAD	1.50943E+06	956	131.6	25.79
MSD	3.57097E+12	1371325	24830.3	1450.62

Limitations of the model A visual inspection and an evaluation of the model using the MSE showed that the forecasting accuracy of the selected indicators varies significantly: human resources (MAPE = 8%) and mortality (MAPE = 12.63%) and the level was acceptable (Fig 5), but less satisfactory accuracy was observed for local tourists (MAPE = 10.67%) and surgeries (MAPE = 23.7%), with very high MAD (1.5 million) and MSD (3.57 trillion) values registered in the case of tourist data, indicating high baseline variability and potential influence of outliers; possibly optimal performance in the case of stable (e.g.mortality, human resources) compared to more volatile (e.g.visitors, surgeries) indicators, relative to elevated and consistent MSD values across selected indicators, indicating

potentially anomalous data points, or abrupt departures from their historical patterns, as seen in the double exponential smoothing forecasts in Table 5 for local tourists, human resources, surgeries, and mortality.

In general, MSD: alerts to the presence of serious fluctuations that require exceptional preparations (such as the provision of additional medical supplies), MAD: helps measure the daily performance of the model and make decisions such as increasing the number of doctors in peak seasons

Table (5) presents the forecasted values derived from the double exponential smoothing method for the following variables: Local visitors, Human resources, Surgical procedures & Mortality rates

Indicator	Period	Forecast	Lower Limit	Upper Limit
Local visitor's	2024	19,250,559	15,552,520	22,948,598
	2025	20,281,921	15,320,480	25,243,361
Human Resources	2024	16,716.9	14,374.8	19,059.0
	2025	17,646.2	14,504.0	20,788.4
Surgeries	2024	1,040.74	718.276	1,363.21
	2025	1,142.30	709.668	1,574.94
Deaths	2024	246.644	183.467	309.822
	2025	259.588	174.826	344.350

The forecast results show projected increment across all key indicators: local visitors are predictable to rise from 19.25 million (2024) to 20.28 million (2025) with widening confidence intervals (22.9-25.2 million upper bounds), human resources from 16,700 to 17,600 (potential upper limit of 20,800), surgical procedures from 1,041 to 1,142 (± 433 operations variability), and mortality rates from 247 to 260 cases (upper bound reaching 344). In general, it showed upward trends but with significant uncertainty - particularly for 2025 projections - that needs enhanced infrastructure, real-time data monitoring, and emergency preparedness to address potential logistical challenges and healthcare loads during the Ar-

baeen journey, while improved data collection is precisely recommended for mortality and surgical metrics to improve predictive accuracy given their high variability and critical public health implications.

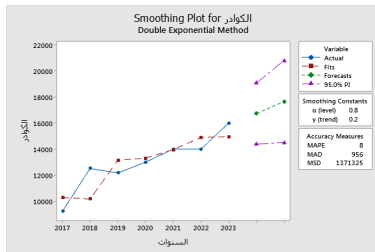


Figure (7) presents the time-series plot of human resources data generated through the double exponential smoothing method.

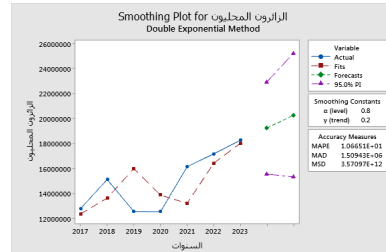


Figure (6) presents the time-series plot of local visitors data generated through the double exponential smoothing method

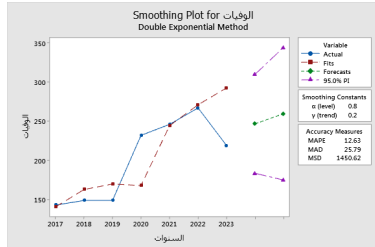
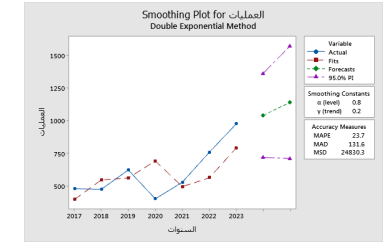


Figure (9) presents the time-series plot of deaths data generated through the double exponential smoothing method



Figure(8) presents the time-series plot of surgical procedures data generated through double exponential smoothing method

The results of the analysis show that the performance of the double exponential smoothing model was different in forecasting the four indicators of the Arbaeen pilgrimage. Human resource needs were accurately forecasted by the model ($MAPE = 8\%$), amid which local visitor inflows, with lower accuracy ($MAPE = 10.67\%$), and mortality rates ($MAPE = 12.63\%$), showed lower performance and again predictive surgery items ($MAPE = 12.63\%$) were poorly predicted.

Conclusions

1. Population Increase and Medical Services: The 6.1% population growth, including that of Local as well Foreign/Arab patient arrivals, is compounding year-by-year the demand on the healthcare infrastructure despite a 9.6% annual increase in healthcare (medical) manpower which is grossly inadequate.
2. Health Issues: As mortality rates increased by 7.36% per annum, there is room for quality of care in emergency to be enhanced. Surgical procedure predictions were marginally less accurate ($MAPE = 23.7\%$) due to its non-linear nature.
3. Model: Double exponential smoothing showed good predictive power on HR resources ($MAPE = 8\%$) but poor one for volatile features as the number of surgeries. Reliability of prediction was influenced by outliers ($MSD = 3.57$).
4. Exogenous Events: The COVID-19 crisis (2020) revealed weaknesses in health care provision, however seasonal changes dramatically altered attendance patterns and service utilization.

Recommendations

1. Increase the number of field hospitals and clinics to keep pace with the annual growth in visitor numbers (6.1%), supported by intelligent systems for early detection of diseases and congestion management.
2. Training medical staff on advanced protocols for dealing with critical cases, especially in light of the high mortality rate (7.36% per annum), and enhancing the accuracy of predicting surgical operations using hybrid models (such as ARIMA-ANN).
3. Implement mandatory vaccination campaigns against infectious diseases, and create strategic medical warehouses to adapt to sudden fluctuations (as happened during the covid-19 pandemic).
4. Connect health facilities to a centralized network to collect data in real time, to analyze patterns and improve forecasts (especially for volatile variables such as visitor numbers).
5. Take advantage of the accuracy of the HR forecasting model (MAPE = 8%) and apply it to other indicators (such as mortality and surgeries), while increasing investment in the training of medical personnel to ensure stability.

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