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Infant Mortality in Iraq and Iran: A Comparative and Predictive Study

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ABSTRACT

Infant mortality is one of the most important indicators of the A country's health status and socio-economic development. Classified as the death of an infant before his or her first birthday, the rate of infant mortality is an indicator of whether a society has sufficient healthcare, nutrition, sanitation, and maternal services. The research presents comparative predictive analysis for Iraqi and Iranian infant mortality rates (IMR) during the period 2025–2032 with the help of exponential grey mod. These findings demonstrate a high effectiveness of the proposed aforementioned application with achieved mean absolute percentage error (MAPE) values of 0.795% and 0.907% for Iraq and Iran, respectively, which correspond to accuracy rates of 99.20% and 99.09%, both as both Iraq and Iran's MAPE values in the "Highly accurate." Corresponding precision values also classifies the decisions in "Highly accurate" ($P \geq 99.0\%$). A historical comparison showed a significant difference in infant mortality when comparing Iraq (mean = 27.37) with Iran (mean = 15.57) with $P = 0.000$. Projections for 2025–2032 also indicate a difference between the two nations, as a country average IMR in Iraq will be 18.32, and, it accounts for 8.41 for Iran, with statistical significance ($P = 0.000$). It also forecasts falls in the number of births, with Iraq's dropping from 20.13 in 2025 to 16.61 in 2032, and Iran's from 9.63 to 7.28. These results validate that the exponential grey mod model offers a superior forecasting model that has great stability and performance for these two countries (Iraq and Iran) to supply decision makers with high-quality forecasts.

Index Terms: Time Series, Exponential Grey Model, Infant Mortality

1. INTRODUCTION

Infant mortality is one of the most important indicators of the health status and socio-economic development of a country. Classified as the death of an infant before his or her first birthday, rate of infant mortality or infant mortality rate (IMR) is an indicator of whether a society has sufficient healthcare, nutrition, sanitation, and maternal services [1].

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Declining of IMR is still a priority in public health policies worldwide, as well as an indicator in the UNGH's sustainable development goals (SDGs) Especial goal concerning the agenda to have health lives and to promote well-being at all ages [2]. While there has been some advance in much of the world, infant mortality remains a considerable public health problem, especially in developing and middle-income countries.

Iraq and Iran are neighboring countries in the Middle East that have a lot of common roots, including cultural, religious, and some geographical similarities, while yet having differences in political stability, economic prosperity, healthcare system structure and quality, and public health. Such differences have greatly influenced the path of childhood mortality in both countries in the last decades. Iran made a significant progress

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toward reduction of IMR by continual investment in health care, family planning and maternal services [3]. However, Iraq has experienced serious difficulties during the past decades of prolonged wars, political instability, and displacement that undermine the health for people [4].

The consequence of this is that the IMRs in Iraq were/are disproportionally higher compared with those in Iran.

Knowing the trends and forecasts of infant mortality in these two countries is critical for planning health interventions, allocation of resources, and strategic plans. Historical analysis helps us understand the macro socioeconomic and health system factors which have shaped declines in mortality, but it is equally important to project future trends to anticipate challenges and to design forward-looking policies. Time series forecasting models provide a powerful method for predicting future health outcomes from current data trends in such a setting [5].

This work uses the exponential grey model EXGM (1,1) which is one of the forecasting models of the grey system theory. This, however, limits the application of the grey model to systems affected by uncertainty, scarcity or insufficiency of data; and in the face of incomplete information or knowledge, which is often the case with health data in developing countries [6], [7]. Differing from classical models based on big data and extensive real information, the grey model can perform well with limited samples, which is particularly suitable for demography and public health analysis on account of the unattainable complete longitudinal data.

The first objective of this paper is the comparison of the history trends of infant mortality in Iraq and Iran between 2004 and 2024, and the second objective is to the prediction of IMR in both two countries from 2025 to 2032 based on forecasting by EXGM (1,1) model. Through the use of comparative analysis and predictive MODELING, this research aims to provide useful medico-sociological information about the health of Iraq and Iran, to identify its disparities, and to illustrate the suitability of Grey forecasting in health planning.

1.1. Global Trends

World Bank statistics also show a great reduction in global infant mortality in recent decades. In 1990, the world's IMR was approximately 63 deaths/1,000 live births, in 2020 this had decreased to 28 deaths/1,000 live births [8]. However, in spite of the progress achieved, sub-Saharan Africa is still the region with the highest IMR, and countries such as Nigeria, Chad, and Somalia continue to record rates much higher than 100 deaths/1,000 live births [9].

According to the latest data, IMR in Iraq is approximately 25.8 deaths/1,000 live births. That number comes from sources such as the World Bank and the United Nations. IMR is a key measure of a country's general health and welfare systems, environment, and social relationships. The differences can be attributed to various factors, including access to health care, sanitation, nutrition, and political instability – all of which are present to varied degrees in Iraq. Iran's rate of infant mortality has decreased markedly in the past decades, testified to improvement of health care and public health outreach programs. Current Vital Statistics: As of the most recent information available IMR: Based on the World Bank (2024), the infant mortality rate in Iran is 12.7 deaths/1,000 live births. The World Health Organization (WHO) estimate is also in light with this decreasing trend over the years as better healthcare systems in the country improved particularly maternal and child health services [10].

1.2. Key Determinants of Infant Mortality

1.2.1. Healthcare access and quality

The availability of quality healthcare is arguably the most direct influence on infant mortality, as it determines access to essential services such as prenatal care, skilled birth attendance, and timely medical intervention. Antenatal care, skilled attendance at birth and postnatal care can substantially reduce the risk of infant death. The WHO (2016) has forwarded that interventions including skilled birth attendance and timely intra-partum and pregnancy-associated complication management are crucial in minimizing under-5 deaths. The absence of trained health personals, and health facilities present in the weak or non-availability health systems of some countries cause preventable death among newborns in such countries [11].

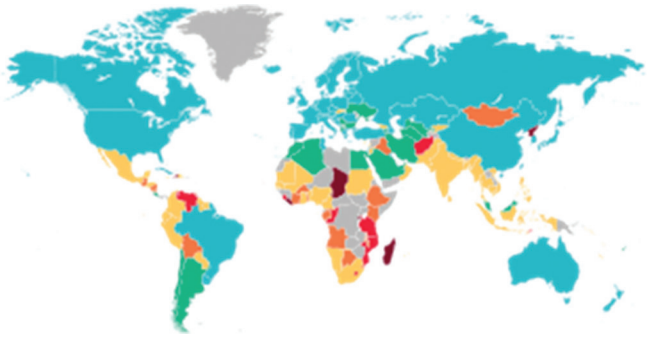
1.2.2. Socioeconomic factors

Infant survival is linked to socioeconomic status. Poverty, malnutrition, low living standards, and other factors related to those dimensions raise the probability of dying in the 1st month of life due to low birth weight, infections, and impaired immune functions [12]. Impoverished mothers, especially in low-income countries, may not have the money to pay for medical attention during pregnancy, quality prenatal care, or enough food for their babies. In addition, lower levels of maternal educational attainment have been associated with an elevated risk of infant mortality, as well-educated mothers are more likely to have access to healthcare and practices conducive to ensuring infant health [13].

1.2.3. Nutrition and maternal health

The nutrition of the mothers is vital for the well-being of the mother and the infant. Maternal malnutrition during pregnancy leads to low birth weight, which is a leading risk factor for infant mortality [14]. Poor maternal nutrition, especially in developing regions, is a risk factor responsible for high rates of preterm birth and infection, the two main causes of infant death. In addition, maternal health issues such as anemia, hypertension, or infection can complicate pregnancy and raise infant mortality risk [15].

Percentage of population suffering from hunger, [16].



<2,5%
2,5–5,0%
5,0–14,9%
15,0–24,9%
25,0–34,9%
>35,0%
No data.

1.2.4. Infections and environmental factors

Infections, especially, respiratory infections, diarrhea, and neonatal sepsis are one of the major causes of infant mortality around the world [11]. Insufficient sanitation, unclean drinking water, and poor vaccination coverage help to spread preventable illnesses [17]. Rural and impoverished communities without basic sanitation and clean water experience high levels of malnutrition and infection, adding to the risk to infant health [18].

In addition, environmental assaults such as pollution and climate change are being more widely appreciated as child health hazards. Increasing temperatures and poor air quality – especially in urban areas – have been associated with increased rates of respiratory infections and associated infant mortality [19].

1.2.5. Infections and environmental factors

Infectious diseases and adverse environmental conditions, including poor sanitation and unsafe water, substantially increase infant mortality risk in low-resource settings [20], [21].

1.3. The Target of this Study

The main objective of this research is to examine and predict IMRs in Iraq and Iran from 2025 to 2032 by exploiting the exponential grey model EXGM (1,1). This article attempts to attain three objectives: first, to analyze and compare the historical pattern and trend of IMR in the two countries through 2004 to 2024; second, to develop the forecasting model for IMR in future time based on the existing data; and third, to compare the population projections of IMR in both Iraq and Iran of projection period under study through 2025–2032, with maximum possible accuracy.

2. MATERIALS AND METHODS

Statistical forecasting is an essential element of data analysis, particularly in the case of public health indicators like infant mortality. In this work, the exponential grey model EXGM (1,1), which is a commonly-used grey-forecasting model, is used for prediction of future values on the patterns of past data. The EXGM (1,1) model is specially designed for small, incomplete or uncertain data sets, so it is applied to IMRs. Historical IMR data for Iraq and Iran from 2004 to 2024 were accessed from Macrotrends.net. The data set is available at this link: https://www.macrotrends.net/global-metrics/countries/IRQ/Iraq/birth-rate. The IMRs for the interval 2025–2032 were forecasted by adopting the exponential grey model, the EXGM (1,1). This model was fitted to each country's data independently to have computationally feasible forecasts.

2.1. Forecasting Model

Exponential grey model EXGM (1,1). The new grey appearance estimation model EXGM (1,1) is proposed. It applies to exponentially growing raw data sequences, and to the case of grey action as a function of time. In contrast to the classical GM (1,1) where the grey action is regarded as constant.

2.2. Evaluate Precision of Forecasting Models

2.2.1. Mean absolute percentage error (MAPE)

A number of statistical measures/test are utilized to check the validity and efficiency of the proposed model, on such measure is MAPE. Assessing the reliability and performance of the forecasting approach used in this study. The forecasting accuracy level can be classified into four grades based on the MAPE of each model as indicated in Table 1:

TABLE 1: Categorizing the grade of predicting accuracy depends on MAPE

Grade level	Highly accurate	Good	Reasonable	Inaccurate
MAPE	<10%	10% - 20%	20% - 50%	>50%

MAPE: Mean absolute percentage error

TABLE 2: Categorizing the grade of predicting accuracy depends on Precision rate (p)

Precision rank	Highly accurate	Good	Reasonable	Inaccurate
Precision rate (p)	p ≥ 99.0%	p ≥ 95.0%	p ≥ 90.0%	p ≥ 90.0%

MAPE: Mean absolute percentage error

TABLE 3: The infant mortality rates in Iraq and Iran

Years	Infant mortality rates		Years	Infant mortality rates	
	Iraq	Iran		Iraq	Iran
2004	33.94	23.68	2014	27.62	14.69
2005	33.39	22.54	2015	26.74	14.23
2006	32.83	21.41	2016	25.86	13.76
2007	32.28	20.27	2017	24.98	13.29
2008	31.73	19.13	2018	24.11	12.82
2009	31.08	18.34	2019	23.51	12.36
2010	30.43	17.55	2020	22.92	11.89
2011	29.79	16.75	2021	22.32	11.43
2012	29.14	15.96	2023	21.73	10.96
2013	28.49	15.16	2024	21.14	10.5

Per 1000 live births

TABLE 4: Compare the infant mortality rates between Iraq and Iran between 2004 and 2024

Countries	*N*	Mean	SD	*t*-test	*P*-value
Iraq	21	27.3662	4.36255	9.057	0.000
Iran	21	15.5652	4.07710		

SD: Standard deviation

Grade level highly accurate good reasonable inaccurate MAPE <10% 10–20% 20–50% >50%. A lower MAPE indicates higher precision in the forecasting model. Typically, a MAPE below 10% signifies an accurate model, while a MAPE between 10% and 20% denotes a good model with acceptable accuracy.

2.2.2. Precision rate (p)

Precision rate, which measures the level of the closeness of the statement of forecast quantity and the actual value.

Precision rank highly accurate good reasonable inaccurate. Precision rate (p) $P \geq 99.0\%$ $P \geq 95.0\%$ $P \geq 90.0\%$ $P \leq 90.0\%$. Table 2 shows a higher precision rate indicates greater precision in the forecasting model. Typically, a precision rate greater than 99% signifies an accurate model, while a precision rate between 98.0% and 95.0% suggests a good model with acceptable accuracy.

2.3. Application

The present paper also intends to investigate the time series structure of the IMRs in Iraq and Iran publicly announced during the period 2004: 1–2024: 12. The study also examines the use of the EXGM (1,1) model to predict the IMRs in Iraq and Iran from 2025 to 2032, using an historical series from 2004 to 2024 as a reference for model calibration and forecasting.

Table 3 illustrates the trends in IMRs in Iraq and Iran from 2004 to 2024. The data show a consistent decline in both countries, reflecting gradual improvements in healthcare systems, maternal and child health services, and living standards. In Iraq, the IMR decreased from 33.94 to 1,000 live births in 2004–21.14 in 2024, marking a reduction of approximately 37.7%. In contrast, Iran's rate fell more sharply from 23.68 to 10.5 during the same period, a decline of about 55.7%. Despite steady progress in Iraq, its rates remain higher than Iran's throughout the entire period, highlighting a persistent gap likely linked to differences in healthcare access, socio-economic conditions, and public health stability. These findings suggest that although both countries have improved, additional targeted efforts are needed in Iraq to accelerate progress and reduce infant mortality further, particularly by strengthening healthcare infrastructure, expanding maternal services, and addressing socio-economic challenges.

Table 4 presents a comparison of Infant Mortality Rates (IMRs) between Iraq and Iran over the period 2004–2024, with 21 observations recorded for each country. Findings indicate that Iraq had a higher mean IMR of 27.37 deaths/1,000 live births (standard deviation [SD] = 4.36) than Iran 15.57 (SD = 4.08). An independent samples *t*-test calculated whether this mean difference was significant. The result of the test gave a $t = 9.057$ and $P = 0.000$ indicating that there was a very high difference between the two countries ($P < 0.05$). These findings demonstrate that, during the past two decades, the level of infant mortality in Iraq has been considerably higher than in Iran. The wide variation in IMRs mirrors inequities in health systems, MCH care, economic development, and public health policies. This

study emphasizes the immediate necessity for sustained and thorough health programs in Iraq for preventing infant deaths and catching up with neighboring countries, such as Iran. Key investments in primary care, maternal education, immunization, and neonatal care are needed to reduce child deaths in Iraq.

Table 5 presents comparison of actual Table 5 presents that the comparison study of actual, predicted, and PE% values of IMR of Iraq, Iran from 2004 to 2024 based on exponential grey model EXGM (1,1). Our put the empirical results show that the empirical model generates accurate forecasts for the two countries. In Iran, the MAPE is 0.90706867% indicating a precision rate of 99.09293133%. In Iraq, lower MAPE of 0.795267266% is achieved with a precision of 99.20473273%. Using universal accuracy classification tables, a MAPE of <10% and a precision rate of 99% or more would be categorized as "highly accurate." The forecast of EXGM (1,1) in Iraq is optimum with regard to the less MAPE and little higher precision ratio than Iraq, and it is classified into the "Highly Accurate" class and occupy the top by following both the Grading criterion of Tables 1 and 2. Thus, the EXGM (1,1) model is of high credibility in the prediction of infant mortality in both countries. These findings validate the eventual performance and reliability of the model in generating robust predictions. The forecasted values for the years 2025–2032 are presented in Table 6.

Table 6 indicates that the comparison between the IMF in Iraq and Iran, (2025–2032) through EXGM (1,1) IMF in Iraq and IMF in Iran forecasting IMR for economy of Iraq and Iran up to 2032 in the Table 6 gives the forecasting of IMR in Iraq and in Iran for the period T = 2025–2032, we use of EXGM (1,1). Results reveal a consistent decrease in under-5 mortality rates for the two countries in the 8 years of prediction.

The rate of infant mortality in Iraq should drop from 20.13 deaths/1,000 live births in 2025–16.61 by 2032. This slow decline indicates ongoing progress in maternal and child health, as well as in vaccination coverage and social conditions. However, that higher IMR as compared to Iran could signal continued differences in healthcare infrastructure and socio-economic status.

We will, however, see a steeper decrease in the IMR of Iran, from 9.63 in 2025 to 7.28 in 2032. The relatively lower and progressively diminishing IMR is partly a result of the nation's historical commitment toward public health, successful family planning programs and the provision of urban health services.

TABLE 5: Predicted value and rate error value of the EXGM (1,1) model

Year	Real value		Forecast value		Percentage error (PE%)	
	Iraq	Iran	Iraq	Iran	Iraq	Iran
2004	33.94	23.68	33.94	23.68	0	0
2005	33.39	22.54	33.15895207	22.70337201	0.691967445	0.724809282
2006	32.83	21.41	33.26153384	21.06292185	1.314449707	1.621102997
2007	32.28	20.27	32.73009217	19.96115913	1.394337566	1.523635273
2008	31.73	19.13	31.9807869	19.07710135	0.790377872	0.276521937
2009	31.08	18.34	31.16629916	18.29189987	0.277667833	0.262268954
2010	30.43	17.55	30.34239284	17.561097	0.287897323	0.063230795
2011	29.79	16.75	29.52918888	16.86763082	0.875498902	0.702273551
2012	29.14	15.96	28.7337065	16.20454545	1.394281041	1.532239645
2013	28.49	15.16	27.95815547	15.56862945	1.866776156	2.695444918
2014	27.62	14.69	27.20298628	14.95807447	1.50982521	1.824877257
2015	26.74	14.23	26.46801201	14.37161289	1.017157773	0.995171395
2016	25.86	13.76	25.75282082	13.80819964	0.414459338	0.350288048
2017	24.98	13.29	25.05692734	13.26689419	0.307955726	0.173858641
2018	24.11	12.82	24.37982823	12.74681628	1.119154819	0.570855813
2019	23.51	12.36	23.72102227	12.24712878	0.897585136	0.913197539
2020	22.92	11.89	23.08001758	11.76703052	0.69815697	1.034226058
2021	22.32	11.43	22.45633403	11.3057529	0.610815535	1.087026203
2022	21.73	10.96	21.84950388	10.8625579	0.549948841	0.889070258
2023	21.14	10.5	21.25907184	10.43673656	0.56325375	0.602508944
2024	20.66	10.15	20.68459483	10.02760779	0.119045645	1.205834557
Results			MAPE (%)		0.795267266	0.90706867
			Precision rate (p)		99.20473273	99.09293133

MAPE: Mean absolute percentage error

TABLE 6: The forecasted value for infant mortality rate in Iraq and Iran

Years	2025	2026	2027	2028	2029	2030	2031	2032
Iraq	20.12564	19.58179	19.05264	18.53779	18.03685	17.54944	17.07521	16.61379
Iran	9.634517	9.256836	8.89396	8.54531	8.210327	7.888475	7.57924	7.282128

Ongoing decline in infant mortality in these countries may be attributed to improved prenatal and postnatal care, better nutrition, and improving accessibility to healthcare Iraq probably lags slightly behind Iran's achievements in these fronts.

Such projections are important for public health policy-makers and policy and program planners and help point out that continued efforts to reduce infant mortality are necessary through focused health interventions, particularly in rural and underserved areas. Knowledge of these trends can help planning of adequate interventions for the attainment of the SDGs concerning child survival and health equity.

In Table 7, we compare that the predicted infant in Table 7 displays that the compare predicted IMR in may Iraq and Iran for the period 2025–2032 using the predictions of the exponential grey model (EXGM [1,1]). The table contains estimates for 8 years for each country. Based on the fitted model, the average infant mortality rate (IMR) in Iraq is estimated at 18.32 deaths per 1,000 live births (SD = 1.23), whereas Iran is predicted to have a significantly lower mean IMR of 8.41 deaths per 1,000 live births (SD = 0.82). To test if such a difference is statistically significant, an independent samples *t*-test was performed. The *t*-test provided a $t = 18.951$ and $P = 0.000$, which is extremely less than the standard level of 0.05. This finding implies that there is a significant difference in the predicted IMRs of the two countries up to the observed period. These results reveal a huge gap between expected child health attainment of Iraq and that of Iran. Iraq is expected to suffer many more infant deaths than Iran, unless effective policy actions and healthcare interventions are implemented. The ironic prediction highlights an urgent requirement for focused investments in public health, especially in maternal and child health, to minimize infant fatalities and help Iraq approach international child survival thresholds.

TABLE 7: Compare the forecasting of the Infant mortality rates between Iraq and Iran between 2025 and 2032

Countries	*N*	Mean	SD	*t*-test	*P*-value
Iraq	8	18.3216	1.22889	18.951	0.000
Iran	8	8.4113	0.82316		

SD: Standard deviation

3. DISCUSSION

The results of this research contribute a better understanding of the dynamics of infant mortality in Iraq and Iran and show the effectiveness of EXGM (1,1) model through time series prediction. The higher rate of infant mortality in Iraq during 2004–2024 with a statistically significant mean difference underlines the long-lasting difficulties still present in the system of maternal and child health. These can be attributed to factors such as a lack of health care infrastructure, economic uncertainty, war, and a lack of pre and postnatal care.

The model's projections for 2025–32 suggest this gap will not only persist but could widen unless Iraq enacts major change. The predicted average IMR for Iraq, exactly more than twice as high as Iran's (18.32 vs. 8.41), is a shocking shot in the arm. In stark contrast, the below (and steadily further reducing) predicted rates for Iran shows that its healthcare policies and social programs are working well.

As from the researcher's point of view for the future evolution of the birth rate, future demographic changes are predicted in both countries. The falling birthrate, especially in Iran, could be explained by growing internet use, higher education for women, economic shifts, urbanization, and easy access to contraception. Iraq also shows slight but continuing decrease and hints at the beginning of the long-term demographic trend toward change.

Such developments have more widespread relevance for long-term population and labor force structures, and health care systems. These dynamics must be taken into account by policy makers going forward. The EXGM (1,1) model is demonstrated to be an effective tool for predicting such complex trends and can provide practical implications which can contribute for designing effective public health interventions.

4. CONCLUSION

In this study, the exponential grey model EXGM (1,1) is used to evaluate and predict the infant mortality rate in Iraq and

Iran between 2004 and 2032. The model performs very well, with small MAPE values of 0.795% and 0.907% for Iraq and Iran, respectively, implying accuracy rates higher than 99% for both countries. These results categorize the performance of the model in the "highly accurate" range and demonstrate its adequacy for robust time series predictions even with scarce data.

Statistical analysis A historical comparison covering a 20-year period (2004–2024) to compare the frequency of the events statewide between Iran and Iraq indicated a large difference in the infantile mortality rate, where the infantile mortality rate was high in Iraq rather than Iran (the average rate for infantile mortalities in Iran is 15.57 vs. 27.37 in Iraq). This difference was highly significant ($P < 0.001$), indicating pronounced differences in access to healthcare, socio-economic circumstances, and Child Welfare Services in the two countries.

In addition, predictions of 2025–2032 periods also supported the trend. A statistically significant higher IMRs in Iraq estimated with a mean of 18.32 (Iraq) compared with Iran 8.41 ($P < 0.001$) is also predicted. The birth rate is also projected to fall in both countries during the same period from 20.13 to 16.61 in Iraq and 9.63 to 7.28 in Iran.

These findings highlight the urgent requirement for Iraq to utilize such focused public health strategies and interventions. Without such work, the difference in infant mortality between Iraq and Iran is set to endure. This study illustrates the potential of predictive modeling to inform health policy and enhance child health conditions.

5. RECOMMENDATION

These data suggest that Iraq should work to develop a reform policy for health sector focusing on maternal and child health. This would include increased access to prenatal care, better neonatal care facilities, trained healthcare providers, and using updated guideline in heath setting community health education. Policymakers also need to invest in surveillance systems able to generate timely warning. Furthermore, the inclusion of successful components of Iran's health program – especially family planning and preventive health care – could bring Iraq's infant death rate down significantly. Finally, prediction models such as the exponential grey model must be institutionalized to enable regular monitoring and prediction of key indicators in health, for evidence-based decision-making.

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