Problem E

Spread and Development of Metropolitan Areas

The metropolitan area which our chose is Los Angeles.

The task of our team is to create a set of quantitative support models to evaluate the various impacts of the expansion of urbanization. First, we have defined important indicators and evaluation criteria: population and GDP per capita. We use GDP and population as the main indicators. Based on the increase in cancer population, the loss caused by the metropolitan area was evaluated. Finally, the impact of urbanization on food security is considered through the annual farmland output.

1.

Considering that the number of cars in a city is related to the city's population and the disposable income of residents, the data of Los Angeles population and per capita GDP from 2106 to 2019 are linearly fitted to its impact on the number of cars, and then the corresponding year is predicted Car ownership.

DATASET:

DATE	CALOSA7POP(Thousand)	GDP per citizen	number of cars
2010/1/1	9823.246	43594	11,412,659
2011/1/1	9876.482	46470	11,433,755
2012/1/1	9935.375	49525	11,470,565
2013/1/1	9992.484	49157	11,543,124
2014/1/1	10040.072	52272	11,591,690
2015/1/1	10085.416	55578	11,671,288
2016/1/1	10105.708	57538	11,878,573
2017/1/1	10103.711	59625	12,074,796
2018/1/1	10073.906	62300	12,383,481

Form 1

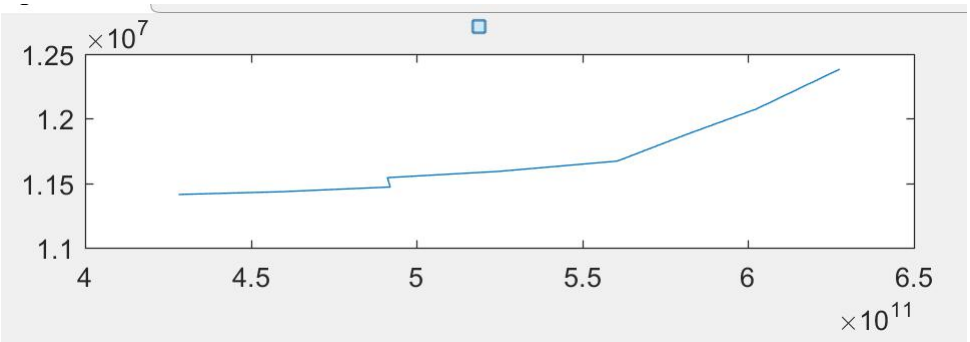

Figure 1

It can be observed through the *figure 1* that the relationship is slightly linear

The car ownership in a region is generally linearly related to the economic level of the region, so here we use the economic aggregate and car ownership to perform a linear fit by the least square method.

Define the relationship between economic aggregate and car ownership as followed:

$$y=Ax + B$$

Fitting result :

A = 4.51237444194451e-06

B = 9327571.92687742

Therefore, it is easy to know that the population growth brought about by the development of big cities and the economic aggregate growth will lead to the increase in the number of cars.

2.

The expansion of urban area and the increase of urban population will lead to increased living environment pollution of residents, such as air pollution and water pollution, and will lead to an increase in unhealthy eating rates. All of these will lead to an increase in the prevalence of chronic diseases among residents, which in turn will cause the government to increase expenditures on medical and environmental treatment and increase additional losses.

Here we use cancer expenditure to count the losses caused.

YearStart	YearEnd	LocationA	Locatior	DataSource	Topic	Question	Respons	DataValueType	DataVal
2008	2012	CA	California	Statewide central	Cancer	Invasive cancer (all sites combined), inciden		Average Annual Number	155711
2009	2013	CA	California	Statewide central	Cancer	Invasive cancer (all sites combined), inciden		Average Annual Number	156386
2010	2014	CA	California	Statewide central	Cancer	Invasive cancer (all sites combined), inciden		Average Annual Number	157155
2011	2015	CA	California	Statewide central	Cancer	Invasive cancer (all sites combined), inciden		Average Annual Number	158302
2012	2016	CA	California	Statewide central	Cancer	Invasive cancer (all sites combined), inciden		Average Annual Number	158450

Form 2

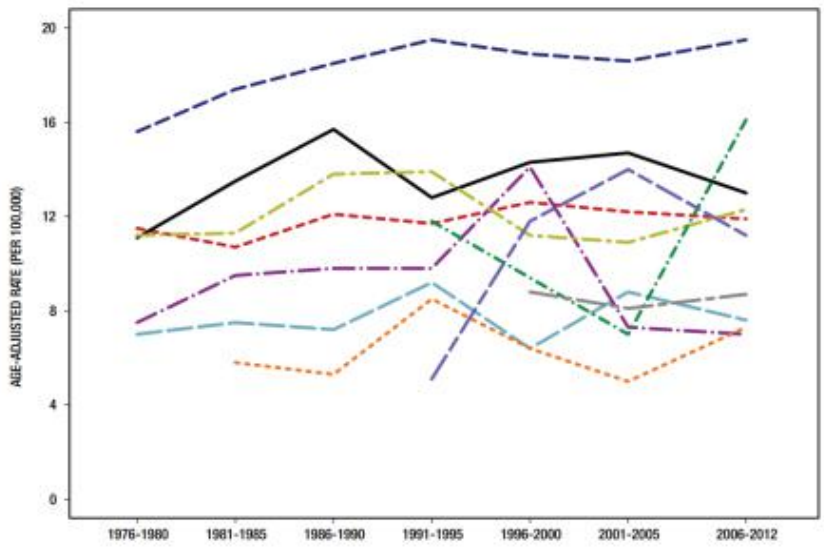

Figure 2

It shows that the proportion of cancer patients from 2008 to 2012 has increased year by year.

According to the statistical report of the U.S. Census Bureau, the average cost of cancer in the United States is $150,000.

In order to protect the privacy of residents, the CDC updates statistics on cancer every 5 years and then releases them uniformly. Therefore, there is not data about recent years.

Due to the small amount of data, it is more appropriate to adopt the GM(1,1) to estimate the loss in the short term. Forecast the growth of cancer call charges in the next five years

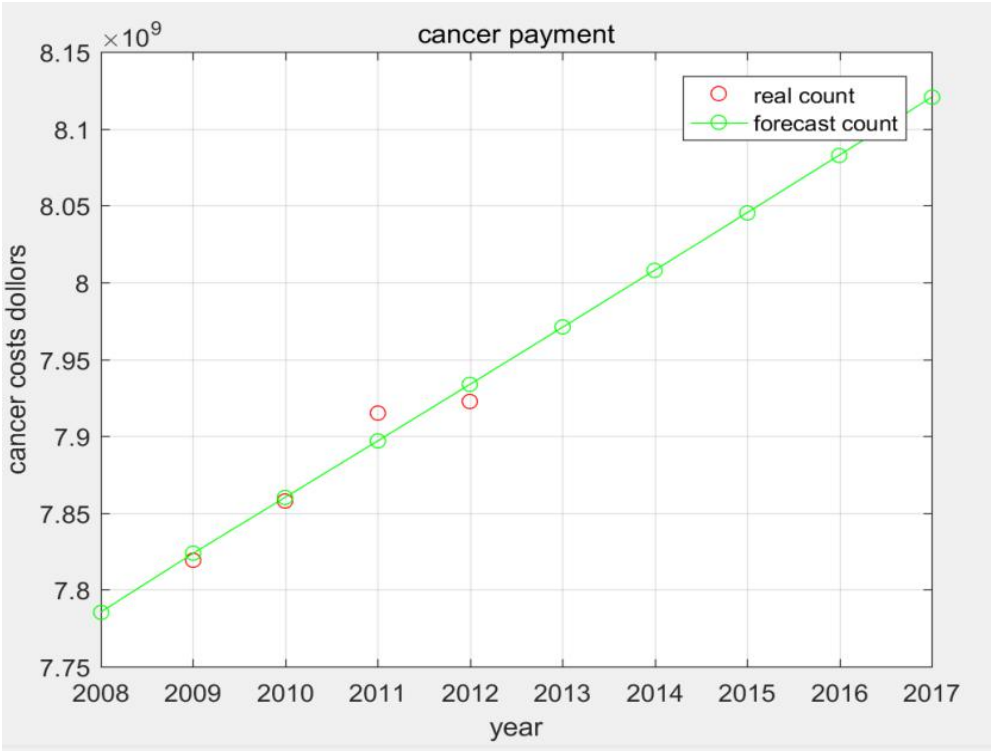

Figure 3

Relative residual Q=0.000920110933168094

Variance ratio C = 0.184849276621288

Probability of small error P=1

The prediction result is relatively accurate

It can be seen that the annual expenditure increases on an annual basis of 5*10^7 dollars.

3.

We mainly use Los Angeles' per capita annual income and permanent population to measure the city's development prospects, using the data sets "per capita personal income.csv" and "Permanent population (thousands).csv" to predict based on previous records. Per capita annual income and permanent population in the next 5 years (2020-2024).

For the forecast of per capita annual income in the next 5 years.

Programs used: GDP.m, predict_GDP.m.

Data set "Per capita personal income.csv" description:

The format of this data set is as follows, which counts the annual per capita income (USD) of Los Angeles in a total of 51 years from 1969 to 2019.

DATE	PCPI06037
1969/1/1	4819
1970/1/1	5059
1971/1/1	5226
1972/1/1	5684
1973/1/1	6130
1974/1/1	6693
1975/1/1	7282
...	...
2019/1/1	65094

Form 3

Forecast methods and selected models:

The relationship between changes in per capita annual income over time using matlab is as follows:

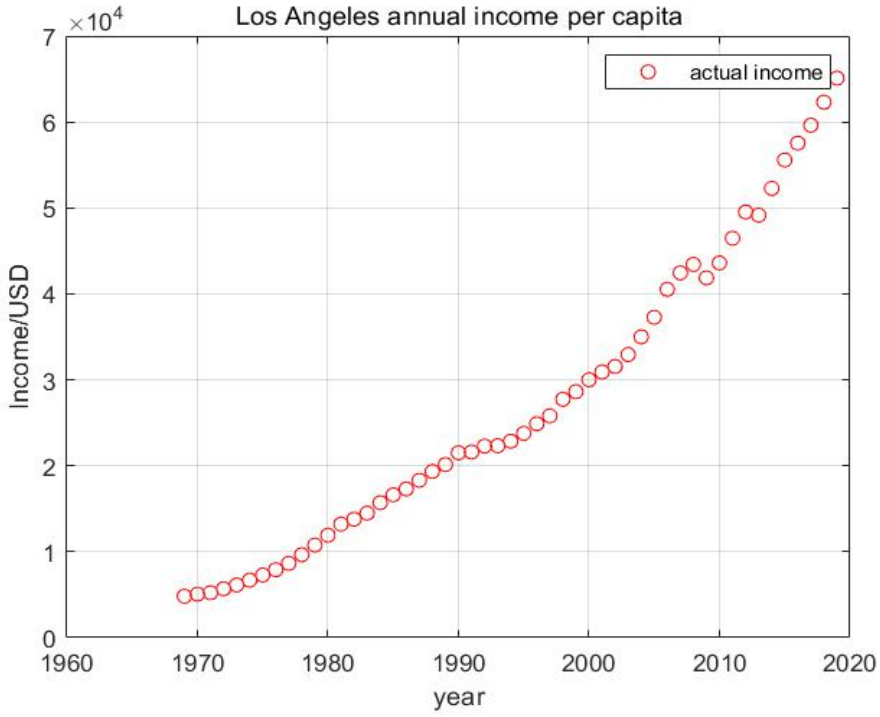

Figure 4

Observed that this is a non-linear relationship, and the forecasting time is relatively short, the GM(1, 1) model is selected for forecasting for the six years from 2020 to 2024. The main idea of the GM(1, 1) model is to use the original data to form the original sequence (0), and generate the sequence (1) by the accumulation method. It can weaken the randomness of the original data and make it show more obvious characteristic laws. To generate the transformed sequence (1), create a differential equation model, that is, a GM model. The GM(1,1) model represents a first-order, 1-variable differential equation model.

The test method here uses the relative error size test method

$$\varepsilon(k)=\frac{x^{(0)}(k)-\hat{x}^{(0)}(k)}{x^{(0)}(k)},k=1,2,...,n$$

If all $|\varepsilon(k)|<0.1$, it is considered to meet the higher requirements; if all $|\varepsilon(k)|<0.2$, it is considered to meet the general requirements. The relative error Q = 0.1229 calculated by modeling, the effect is better.

Forecast curve and actual curve

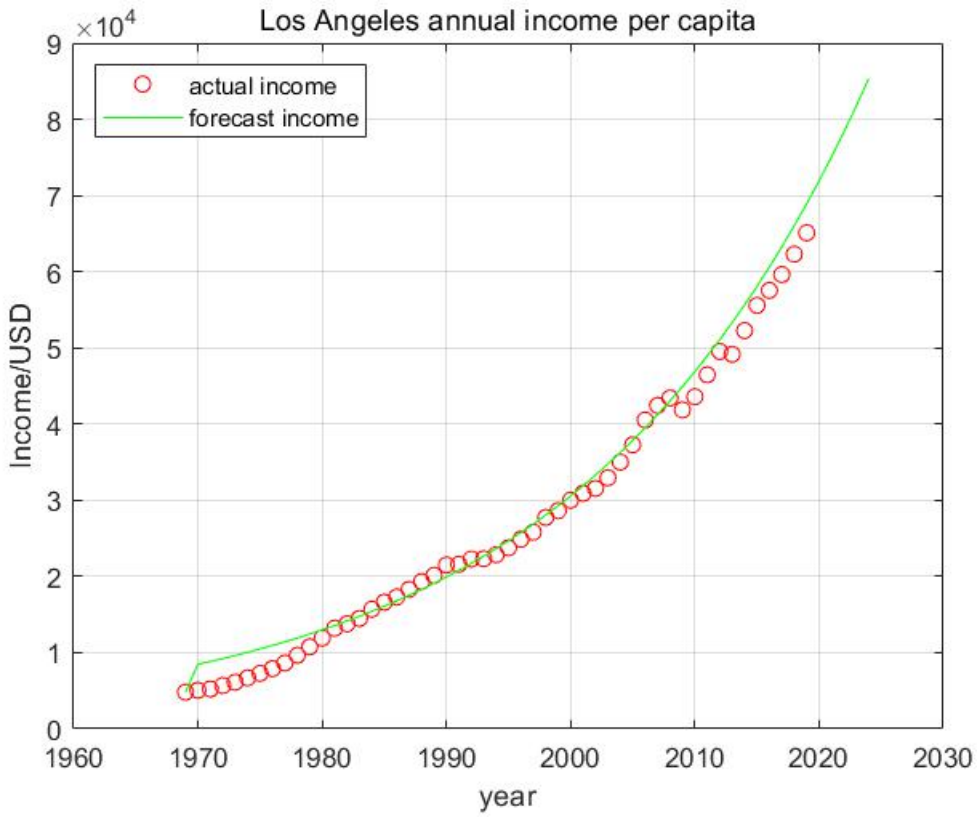

Figure 5

The final forecast for 2020-2024 per capita income is as follows:

year	Forecast per capita annual income
2020	71918
2021	75061
2022	78341
2023	81765
2024	85338

Form 4

It is predicted that the average growth rate of per capita income from 2020 to 2024 will be:

Year	Growth rate compared to the previous year
2020	16.6%
2021	4.4%
2022	4.4%
2023	4.4%
2024	4.6%

Form 5

Average growth rate r = 6.88%

Forecast of the permanent population in the next 5 years.

Programs used: population.m, predict_popupation.m

Data set "Per capita personal income.csv" description:

The format of this data set is as follows, which counts the permanent population (thousands) of Los Angeles in a total of 50 years from 1970 to 2019.

DATE	CALOSA7POP
1970/1/1	7041.982
1971/1/1	7103.6
1972/1/1	7056.6
1973/1/1	7040.4
1974/1/1	7085.8
1975/1/1	7116.8
...	...
2019/1/1	10039.107

Form 6

Forecast methods and selected models:

After using matlab to make the relationship of the permanent population over time, it is found that the graph is similar to the S-shaped curve. The increase of the permanent population is fast and then slow, which is in line with the application of the retarded growth model (Logistic model), so logistic is selected for modeling :

$$x(t) = \frac{x_m}{1 + (\frac{x_m}{x_0} - 1)e^{-rt}}$$

x_m represents the total population capacity, $x_0$is the population of the initial statistics, r is the population growth rate, the concrete realization of this formula is realized by population.m. The initial value x_0 = 7041.982 (the statistical population in 1970), and the final plan The combined effect is as follows:

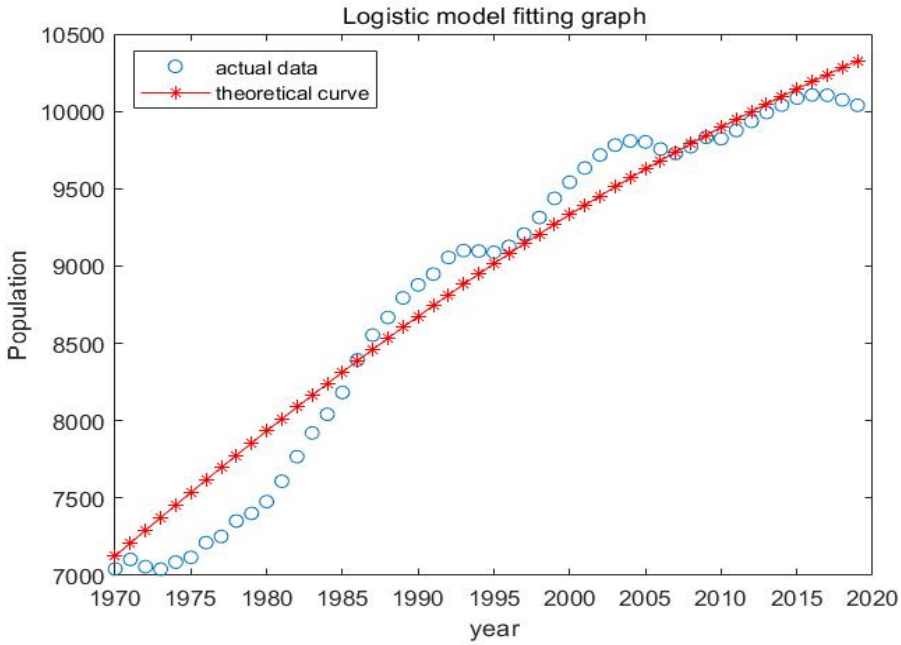

Figure 6

The fitting effect is better. The final forecast of the permanent population for 2020-2025 is as follows:

year	Forecast permanent population
2020	10370
2021	10413
2022	10454
2023	10495
2024	10535

Form 7

Through the above prediction and analysis of Los Angeles' per capita GDP and permanent population in the next five years (2020-2024), it can be concluded that the per capita GDP growth rate is expected to maintain 6.88% in these five years, which is a considerable growth rate. The resident population remains at around 10.45 million. According to our country's current classification standards for cities, a megacities with a resident population of more than 10 million. Judging from these two indicators, the development prospects of Los Angeles in the next five years are very good.

4.

We would like to analyze the impact of urban development on farmland protection and food security from two aspects.

The first is the change in the area of arable land. We collected data on cultivated land area in Los Angeles from 1982 to 2017, which is recorded every five years. The data set is shown in the figure below:

Year	Farm Land (acres)
1982	317,757
1987	280,156
1992	183,569
1997	130,838
2002	111,458
2007	108,463
2012	91,689
2017	57,809

Form 8

Due to the small amount of data, we use the GM(1, 1) model for analysis and predict the area of cultivated land in Los Angeles before 2057. The results are as follows:

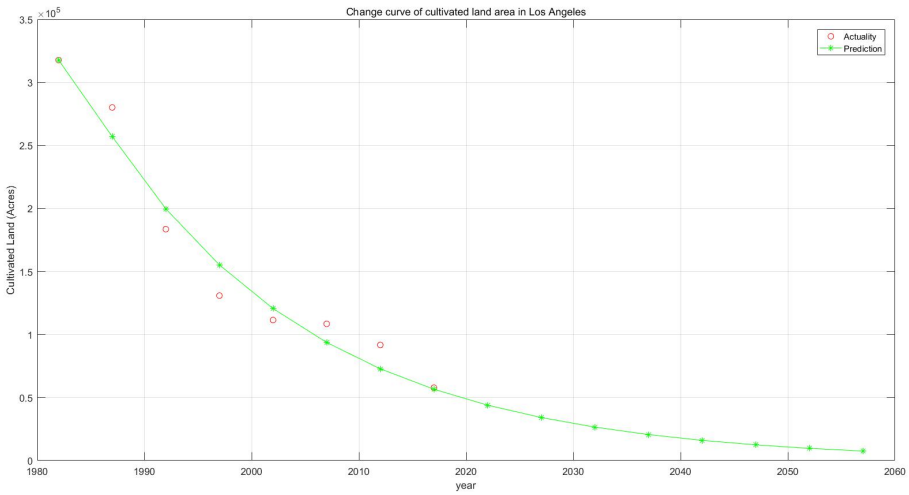

Figure 7

It can be observed that the area of cultivated land in Los Angeles will continue to decrease in the next 30 years. After 2020, it will be reduced to less than 5×10^4 acres, and by 2057 it will drop to an astonishing 7.51×10^3 acres. Although the rate will tend to flatten, the substantial reduction in numbers is still an issue worthy of attention.

In the running results of the GM(1, 1) model, we get the relative residual Q = 0.100; the variance ratio C = 0.1830; the small error probability P = 1. According to the relevant knowledge of the prediction accuracy level (when P> 0.95 and C <0.35, the prediction accuracy is better), we can judge that the result we get is more reasonable.

Then analyze the changes in nursery produce. We collected the area data of nursery agricultural products in Los Angeles from 2006 to 2017, as shown in the figure below:

Year	Field Acres
2006	3496
2007	2608
2008	2513
2009	2161
2010	2071
2011	1866
2012	1720
2013	1718
2014	1530
2015	1571
2016	1240
2017	1248

Form 9

Similarly, using the GM(1, 1) model for analysis, and predicting the area data of Los Angeles nursery agricultural products before 2026, the results are as follows:

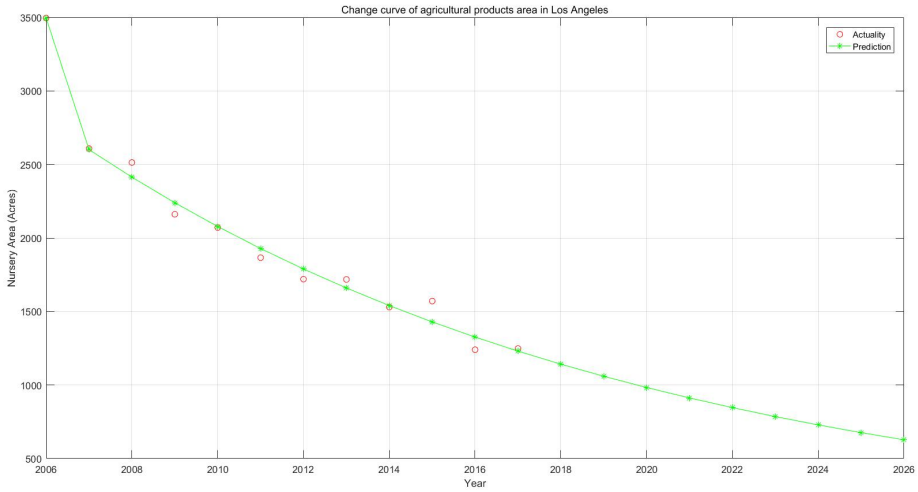

Figure 8

It can be seen that in the next few years, the area of nursery agricultural products in Los Angeles will also be in a state of shrinking year by year.

Although it is not easy to find output-related data, we can still draw some conclusions from the above analysis results: if corresponding measures are not taken, food shortage will also become a more serious problem. This is because a substantial reduction in cultivated area will inevitably lead to a decline in food production to a large extent.

5.

After forecasting through our modeling and collecting relevant data, we came to the following conclusions,

As the second largest city in the United States after New York, Los Angeles has a rapid population growth in the past ten years, and it is predicted

In the five years from 2020 to 2024, the average resident population growth rate reached 6.88%, which means that the city's resident population will remain above 10 million. The resident population is very large. On the one hand, it shows that the city has very good development prospects, but at the same time it also brings some problems, such as the relatively rapid growth of the number of private cars, which brings relatively large traffic pressure. After modeling and analysis, it is also found that the city's cancer medical expenditure is increasing year by year, part of which is due to the health problems of residents caused by environmental problems caused by population growth. At the same time, due to the expansion of cities, the area of arable land is also decreasing, which brings hidden dangers to food safety. Therefore, we suggest that Los Angeles should mainly control the number of resident population, while developing public transportation, pay attention to protecting the ecological environment, control the expansion speed of the city, and ensure the basic farmland area.