Review on Population Projection Methodology for Radiological Dose Assessment

M-S Jang [a*], H-S Kang [a], W-T Hwang [b], Y-H Yang [c], S-R Kim [a]
[a]*NESS, No.704, 96 Gajeongbuk-ro, Yuseong-gu, Daejeon, Korea*
[b]*KAERI, 111, 989-gil, Daeduk-daero, Yuseong-gu, Daejeon, Korea*
[c] *KHNP, 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon, Korea*

[*]*Corresponding author: msjang@ness.re.kr*

1. Introduction

Radiation environment report (RER), one of the essential documents in plant operating license or continuous operation license, includes population projection. Population estimates are utilized in determining the collective dose at the operation or restart time of nuclear power plant.

Many population projection models are suggested and also under development.

We carried out the sensitivity analysis on various population projection models to Daejeon city as a target. Daejeon city showed the increase or decrease in the cross-sectional population, because of the development of Sejong city, Doan new town and etc.

2. Methods and Results

2.1 Population Projection Model

The population projection is performed by cohort-component tool, extrapolation tool, prorating projection tool and etc..

At present, the Statistics Korea (KOSTAT) carries out the population projection analysis using cohort component model[1]. It uses the age-sex structure and is modeled by considering the components of demographic change – fertility, mortality and migration. The demographic balancing equation[1][2] is

$$P(y+t) = P(y) + B(y) - D(y) + I(y) - E(y)$$

Where, *P(y)* is population at the last census year, t is number of unit time for projection, *B(y)* and *D(y)* are number of births and deaths, respectively, occurring between *y* and *y+t*, *I(y)* and *E(y)* are the number of immigrants and of emigrants, respectively, during the period *y* to *y+t*.

Extrapolation is a simple technique that uses aggregated data from the past. There are five extrapolation models: Linear, Exponential, Modified Exponential, Logistic and Gompertz models. Linear model is useful for the slow growth areas, whereas Exponential model for rapidly growing areas and Modified exponential model for areas experienced high growth rate and experiencing slower growth pace. Logistic model is assumed that the rate of reproduction is proportional to both existing population and the amount of available resources. Logistic curve[3] of S shape is as follows;

$$P(y+t) = \frac{K}{\left(1+e^{(c_1+c_2 t)}\right)}$$

Where, *K* is upper limit of population and *c1* and *c2* are constants.

Gompertz function permits to have an asymmetric sigmoid curve. Gompertz curve[3] has a sharply rising characteristic after any time t.

$$P(y+t) = K \times e^{-e^{c_1+c_2 t}}$$

Linear model[4] is

$$P(y+t) = P(y) + at$$

Where, *a* is average growth rate per unit time.

Exponential model[4] is

$$P(y+t) = P(y)(1+r)^t$$

Where, *r* is population change rate.

Modified exponential model[5] is

$$P(y+t) = K - \left[(K - P(y)) \times V^t\right]$$

$$V = \frac{1}{m}\sum \frac{K - P_t}{K - P_{t-1}}$$

Where, *m* is number of historical intervals.

There are two prorating projection models: Ratio and Apportionment models. Ratio model is useful for projecting the total population for 5~10 years or longer period. Apportionment model is useful for areas experiencing population decline or slow growth.

The several simple models, such as Linear, Exponential, Modified exponential and Logistic models, are selected in this study and projecting population by these models was compared with the analysis result of KOSTAT using Cohort component model.

2.2 Statistical Population forecasting

The population of Daejeon has been increased steadily over the past 20 years as shown in the Fig. 1. Average annual population growth rate is about 1.45%.

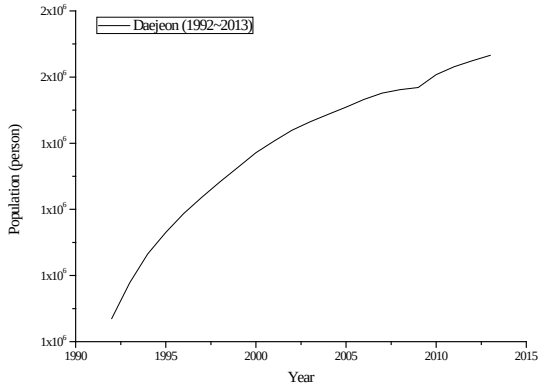

Fig. 1. Daejeon population trend during 1992~2013

Auto-Regressive Integrated Moving Average (ARIMA) Model is used to optimize the population projection in Daejeon. The first-order autoregressive model(ARIMA(1,1,0)) is applied. Table 1 shows the summary of the ARIMA(1,1,0) model results. Fig. 2 indicates the forecasting population using ARIMA(1,1,0) statistical model. The estimates of ARIMA(1,1,0) model are about 10% larger than those of KOSTAT.

Table 1. Summary of ARIMA Model Results

Parameter	Estimate	Stnd. Error	t	P-value
AR(1)	0.94	0.03	30.25	0.00

Backforecasting : yes
Estimated with noise variance = 2.84E7 with 20 degrees of freedom
Estimated white noise standard deviation = 5330.3
Number of iterations : 4

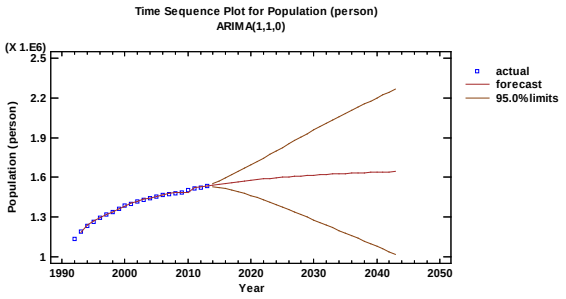

Fig. 2. Time Sequence Plot for Population using ARIMA(1,1,0) model

2.3 Population forecasting using various population projection models

Fig. 3 shows the estimates projected using various population projection models based on population trend during 2000~2013.

As shown in the Fig. 3, the estimates of Modified exponential model were similar with those of KOSTAT. Population upper limit of Daejeon city is assumed to be 1,550,000, similar as the registration population in 2014.6.30 considering the migration from Daejeon city to Sejong city.

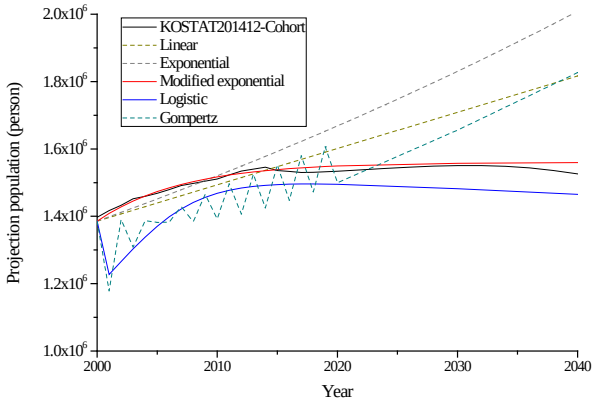

Fig. 3. Comparison with various population projection models

3. Discussion

The over-prediction of population leads to costly due to redundant investment in SOC(social overhead capital) and urban infrastructure. Although there is no domestic nuclear regulatory standard for the collective dose, a reasonable population prediction would require in order to properly establishing the public protective actions and planning around nuclear power plants.

4. Conclusions

We analyzed the population of Daejeon city using statistical ARIMA model and various simple population projection models. As a result, the estimates of Modified exponential model that Daejeon population is assumed to be stagnated from July 2014, were similar with those of KOSTAT using Cohort component model.

It is important to determine the population limit in Modified exponential model but it is not easy. Therefore, the various properties of the area such as the decrease and increase of population, new town development plan, social and natural environment change and etc., should be carefully reviewed to estimate the future population of any area.

REFERENCES

[1] KOSTAT, Statistics KOREA, Population Projection by Province : 2013~2040, 2014.
[2] UNFPA, " Cohort-component population projections", RAPP101-S10: Population projections: Concepts and methods.
[3] Charles P. Winsor, " The Gompertz Curve as a Growth Curve", Proc Natl Acad Sci USA, 18(1): 1-8, 1932.
[4] C-J Son, " A Study on Future Population Projects on Cities and Counties in Gyeongnam", Master' s thesis, 2012.
[5] USAID, Measure Evaluation Center, " Population Analysis for Planners", online lecture note Lesson 6.