Development of a model to forecast the external migration rate in development projects reflecting city characteristics

Ki-Bum Kim¹, Joon Park², Jee-Won Seo¹, Young-Jun Yu³, In-Hwan Hyun⁴, Ja-Yong Koo^{1†}

¹Department of Environmental Engineering, University of Seoul, Seoul 02504, Republic of Korea

²International School of Urban Sciences, University of Seoul, Seoul 02504, Republic of Korea

³Business Development Division, K-water, Deajeon 34350, Republic of Korea

⁴Department of Civil and Environment Engineering, Dankook University, Yongin 31116, Republic of Korea

ABSTRACT

In planning public service systems such as waterworks, the design population is very important factor. Owing to the limitations of the indirect method, two new models, which take into consideration urban characteristics, were developed to accurately predict external migration rate (EMR), which is an essential component in estimating reliably the design population. The root mean square error (RMSE) between the model values and observed values were 10.12 and 15.58 for the metropolitan cities and counties respectively and were lower compared to RMSE values of 27.31 and 28.79 obtained by the indirect method. Thus, the developed models provide a more accurate estimate of EMR than the indirect method. In addition, the major influencing factors for external migration in counties were development type, ageing index, number of businesses. On the other hand, the major influencing migration factors for cities were project scale, distance to city center, manufacturing size, population growth rate and residential environment. Future medium and long-term studies would be done to identify emerging trends to appropriately inform policy making.

Keywords: City characteristics, Development project, External migration rate, Quantification theory type I, Urban characteristics, Water supply

1. Introduction

Water demand forecasting in the mid- and long-term begins with predicting the design population. For this reason, the design population is the most important factor in planning public service systems, such as waterworks. However, the design population is characterized by uncertainty and variability, due to the nature of long-term planning; thus, it does not necessarily serve as a precise guide and may simply be utilized to determine a vision for the region. Given that proposing a design population unilaterally can create a psychological obstacle that immobilizes future development potential, there is one trend of opinion that its importance is low [1].

However, when the size of the design population is incorrectly estimated, all water demand plans are either over- or underestimated [2]. Insufficient water demand planning creates an unstable water supply; as water is a basic human right, this cause an imbalance in water welfare. Meanwhile, excessive water

demand planning reduces the operational efficiency of limited water resources and, further, causes waste at the national level. To ensure the effectiveness of the National Waterworks Master Plan and Waterworks Basic Plan in Korea, an accurate population forecast is required and this means setting a realistic and feasible target. At present, predictions of the design population have too much elasticity. A more accurate and reasonable estimation method is needed.

Korean Ministry of Land, Infrastructure and Transport (MOLIT) and Korean Ministry of Environment (MOE) [3, 4] have presented a methodology for estimating population for various water supply plans, including the Korean National Planning and Local Government Waterworks Basic Plans. Both studies claim that the cohort-component method using the survival model should be employed to predict the design population, while a social increment should be considered as an auxiliary means. The social increment takes into account external migration (EM) for development projects.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Copyright © 2018 Korean Society of Environmental Engineers

Received November 7, 2017 Accepted April 9, 2018

† Corresponding author

Email: jykoo@uos.ac.kr

Tel: +82-2-6490-2866 Fax: +82-2-5460-5465

Fig. 1 shows the change in population with the implementation of a development project in City A. The external migration rate (*EMR*) is defined as the ratio between the population entering the development project area and the cities outside the development project area. Regarding the migration mobility diagram shown in Fig. 1, the *EMR* is defined as Eq. (1) [3, 4]. The terms SM_{oc} and SM_{co} in Fig. 1 are definitions of social migration that occurs irrespective of development projects. SM_{ic} in the figure also, represents social migration that occurs irrespective of development projects, however, such migrations do not change the population of City A.

$$EMR = \frac{EM}{EM + IM} \times 100\% \quad (1)$$

MOLIT and MOE [3] have presented the *EMR* for cities and provinces in Korea, while MOLIT and MOE [4] have demonstrated the value of subdividing development project types, based on the results of previous studies. However, the values in previous studies have indirectly estimated the *EMR*, due to difficulties in data acquisition. The *EMR* derived using the indirect method proposed by MOLIT and MOE [3, 4], which is commonly used for designing populations can be calculated using Eq. (2). This method is problematic for the following reasons.

$$EMR = \frac{CPGR \times CP - NPGR \times CP}{DP} \times 100\% \quad (2)$$

(if $CPGR \times CP - NPGR \times CP > 0$)

First, the *EMR* has been derived based on the *EMR* of 66 residential development projects examined in 2006. It does not reflect the trends of the latest development projects. Second, it has been derived using the indirect method. Indirect method has some shortcomings. It does not take into consideration of the actual *EM*. The indirect method is based on the assumption that the amount by which the growth rate of city and county population (*CPGR*) exceeds the average growth rate of the national population (*NPGR*) represents the increase in the social population. In addition, the increase in social population is assumed to be the result of *EM*. However, the social population can increase regardless of development projects. This causes

Fig. 1. Diagram of the migration mobility when there is a development project.

a difference in population estimates, given that social population growth occurs in areas without any development projects. In addition, when estimating the *EMR*, the value derived by dividing the social population growth by the design population of the development project (*DP*) is used. For this reason, some errors may occur when calculating the *EMR*. Third, since the *EMR* is reported for provinces, the different conditions affecting external inflows to different cities in the same province are not taken into account.

To address the above problems and apply an accurate *EMR*, researchers have been asked to calculate an *EMR* that takes into consideration the actual transfer population in development project areas, based on the latest development projects trends, and applies the *EMR* best suited to each city. Accordingly, this study has developed a model that takes into consideration the urban characteristics that affect the overall *EMR*. The main objective of this study is to provide basic data, based on reasonable population forecast results for predicting water demand.

2. Literature Review

Balogun *et al.* [5] examined the impact of population changes on water supply and proposed a practical solution to reduce the gap between water supply and demand. As changes in population may cause great changes to public services such as the water supply, many studies have attempted to estimate the accurate population.

The present study examines prior research related to external migration mobility. As the *EMR* comprises social population movement, it is necessary to estimate it considering the factors that influence population movements; that is, urban characteristics. The previous studies that have identified urban characteristics that affect population movement are summarized below.

Molloy *et al.* [6] have argued that job changing has an effect on domestic migration, with gender, age, education, race/ethnicity, nativity, the presence of children in the household, the number of working adults, income, employment status, homeownership, and the percentage of married households made an internal migration in the United States. McCatty [7] has developed three models (migration and the dual sector model of economic development, the family/household migration model, and the Todaro model of migration), concluding that job finding, family changing, health, and education affected migration. Clark and Withers [8] have suggested that patterns of migration change due to changes in family composition. Miheretu [9] has claimed that the distance between two areas, density of population, education, and employment affect population movement.

Previous studies have indicated that social population movements are affected by the characteristics of people behaviors. However, previous studies involving Korea, which is a developing country, have indicated that social population movements are more affected by city characteristics than by people's

behavior. The previous studies that have identified urban characteristics that affecting population movement are summarized below.

In researching factors that influence population movement, Yoo [10] has found that when wage levels and housing supply rates increase, *EM* also increases. Kim and Jang [11] have observed that the expected income ratio and educational opportunity ratio can create population growth, triggering significant *EM*. Lee [12] has analyzed the correlation between population movement and influence factors, discovering that the number of pharmacies, the gas coverage rate, and the housing area all affect population movement. Moreover, Lee [13] has discovered that income opportunities, job opportunities, the tax burden, comfort, housing construction, capital area readjustment zone separation, population size, and migration distance as population movement factors in Gyeonggi Province. Lee and Park [14] have noted that population movement into a residential development project area occurs because people want to purchase a house or improve workplace proximity, education, or their residential environment. In particular, those aged 20-29 usually move for the purpose of purchasing a house, those aged 30-39 predominantly move in order to be closer to their workplace, those aged 40-49 relocate for the purpose of education, and those aged 50-59 migrate in order to improve their residential environment. Migration has thus been shown to be associated with the life cycle. Furthermore, the shorter the migration distance, the higher the rate of relocating for individuals aged 20-29 and 40-49, whereas those aged 30-39, there is a higher rate of migration for longer distances.

Kim and Jang [15] have found that in many cases of population movement, migration occurs to areas that have social and economic characteristics that are similar to their existing residential environments. Kim and Choi [16] calculated the *EMR* of housing development projects in capital and metropolitan cities by analyzing the external inflow rate for 11 residential land development project districts in cities across the country during the 1990s. Kwon [17] has found that age, gender, educational level, manufacturing ratio, labor rate, and rural/urban status are factors that affect population migration to metropolitan areas, while Choi and Kim [18] have found that land development areas, design population, local downtown distances, population density, and industrial structures affect population movement. Lee and Lee [19] have analyzed the characteristics of population movement into new cities, discovering that, in the case of migration within the capital city, educational level, housing scales, occupancy types, and household type had the biggest impact.

Jeon [20] has analyzed the *EMR* of 594 new apartment buildings in Gyeonggi-do and subsequently comparing the results with the *EMR* applied when establishing the city basic plan. Areas involving large-scale housing development projects were found to have high *EMR*, in comparison to other areas. It is necessary to consider the in-migration rate when making such calculations, given the strong correlation between the type of development project, the size of development project, and the *EMR*. Hur [21] has analyzed the *EMR* in relation to local government,

development project size, development project type, and distance from Seoul by targeting 594 apartment buildings constructed in Gyeonggi Province since 2005. Based on the analysis results, the factors were divided into project district factors and regional factors, and while project type and project enforcer influenced the *EMR*. As a complement to Hur's [21] study, Lee [22] has found the *EMR* to be higher as the distance from Seoul decreases and employment conditions become more favorable.

From this comprehensive analysis of prior research, the common factors influencing the *EMR* are found to be development project size and type, distance from capital city, and factors related to economic activity. However, these results reflect the fact that most previous studies have used data drawn solely from Gyeonggi Province. In this study, additional city characteristics are identified and applied to the model to predict the *EMR*.

3. Research Methods and Data

3.1. Investigation of Development Projects

To create a prediction model of *EMR* according to urban characteristics reflecting the latest trends in development projects, the present study has used a sample of 113 development projects completed by the end of 2014. These projects were selected from among development plans listed in the land use regulation information system of the MOLIT. They have been categorized by development project type and area, as shown in Table 1.

The first limitation of this research is in here. Due to the time and effort required to obtain population data associated with migration to development project areas, a relatively small number of samples was used for model development. The analysis results regarding factors influencing *EMR* can therefore change, depending on the level of data scale. Future studies need to consider data in the medium to long term in order to analyze the influence factors in more detail.

Fig. 2 shows the location of the development projects. The project name in Fig. 2 is expressed as "NNN_XX_DDDM", where "NNN" represents the development project number, "XX" is an abbreviation that stands for the area listed in Table 1, "DDD" indicates the type of development project; and "M" represents the number of development projects.

3.2. Investigation of External Migration Rates

Since the indirect method used previously is inaccurate, data relating to the population moving into a development project area must be used to calculate the *EMR* of the development project accurately. The population data used to derive the *EMR* of the 113 development projects sampled in this study, have been drawn from the resident-registration data of populations that moved into development project areas during the year that followed the completion date of each development project. These

Table 1. Investigated Development Project by Project Type and Area

Area	Abbreviation in Fig. 2	Development project type					Total
		<i>RSD</i>	<i>CID</i>	<i>RED</i>	<i>RCD</i>	<i>REI</i>	
Seoul	SO	1	2	1	5	1	10
Busan	BS	3	1	-	-	1	5
Daegu	DG	3	-	1	3	-	7
Incheon	IC	3	3	2	4	3	15
Gwangju	GJ	3	-	-	-	-	3
Daejeon	DJ	-	1	-	1	2	4
Ulsan	US	1	-	-	-	-	1
Gyeonggi	GG	19	5	2	4	-	30
Gangwon	GW	3	1	-	2	-	6
Chungbuk	CB	5	-	-	-	-	5
Chungnam	CN	1	-	-	-	-	1
Jeonbuk	JB	3	-	-	-	-	3
Jeonnam	JN	2	1	-	-	-	3
Gyeongbuk	GB	5	3	-	-	2	10
Gyeongnam	GN	4	3	-	3	-	10
Jeju	-	-	-	-	-	-	-
Total		56	20	6	22	9	113

Fig. 2. Location of investigated development project.

data have been used in cooperation with the MOLIT and Korean Ministry of Public Administration and Security (MOPAS); they cover, 60 of the total 229 cities, counties, and districts in which the 113 development projects were implemented.

Using these data, the present study has analyzed both the populations that migrated to development project areas within cities and counties and the populations that migrated to development project areas outside cities and counties. To calculate the *EMR*, among the population that migrated into the development project areas, the population that migrated from outside cities was used to calculate the ratio of the total population that moved into development project area.

3.3. Investigation of Factors Affecting the External Migration Rate

As mentioned previously, one of the problems related to the *EMR* presented by the MOLIT and MOE [4] was the application of the same *EMR* throughout the province, regardless of different city characteristics within the province. To address this problem, this study has considered the urban characteristics of each city, county, and district; that is, those urban characteristics that affect the *EMR*.

As a result of a comprehensive review of previous studies, the factors affecting the *EMR* can be largely classified into three types: factors related to development projects (such as development project size), factors related to population characteristics in historical development projects, and economic and industrial factors of the development project area, including the employ-

ment rate and the number of businesses. In this study, 11 sub-factors derived from the three main factors affecting the *EMR* have been analyzed for the 113 development projects sampled, as shown in Table 2. The effect of these factors on the *EMR* has also been examined.

The second limitation of this research is in here. The analyses of various influential factors also need to be considered. For example, the direction of government policy can have a significant impact on population migration and water supply planning. If a government-level development project is undertaken, as described in the example above, population migration rates may be much larger than expected.

To discover the relationship between *EM* and its influencing factors, the standard correlation coefficient was calculated using Eq. (3). When a sample is small, the standard correlation coefficient is used as an index to determine the correlation in the significance probability of the *t* distribution. If the correlation coefficient between the factors is larger than the standard correlation coefficient, there is a correlation between the two factors.

$$R_0 = \frac{t_\alpha}{\sqrt{n - 2 + t_\alpha^2}} \quad (3)$$

Here, R_0 = standard correlation coefficient,
 n = number of sample (113 development projects)
 t_α = *t* value of *t* distribution at significance α
 (t value for 113 samples at 95% significance level = 1.661)

Table 2. Factors Influencing External Migration Rate

Category		Research contents
Development project	Development project type (P_t)	5 development project types (residential development project, city development project, redevelopment project, reconstruction project, residential environment improvement project)
	Development project scale (P_s)	Number of projected households (number of households)
	Completion year (YC)	Year of completion of development project (year)
Population	Distance to city center (D)	Distance from development project area to metropolitan city hall or shortest distance among calculated distances to provincial government office (shortest distance by vehicle) (km)
	Population growth rate (PGR)	Average population growth rate for the three years prior to completion (%)
	Demographic structure (DGS)	Average aging index for three years prior to completion (rate of population under 14 y of age compared to population over 65) (%)
Economy and industry	Daytime population index (DPI)	Daytime active population ratio compared to the most recent resident population based on year of completion of development project (%)
	Employment rate (R_e)	Average percentage of employed persons in the population aged 15 y or older for three years prior to completion (%)
	Number of industry for business (N_{ib})	Number of industry for businesses compared to average area for three years prior to completion (number of businesses/km ²)
	Manufacturing ratio (R_m)	Rate of the number of manufacturing businesses compared to total number of businesses for three years prior to completion (%)
	Gross regional product per person (GRP)	Gross regional product compared to average regional population for three years prior to completion (million won/person)

3.4. Development of Model to Forecast the External Migration Rate

The prediction method for the *EMR* used quantification I analysis, which comprises quantitative numerical analysis of qualitative variables. This method was used because, as shown in Table 2, the qualitative variables of the factors influencing the *EMR*, such as the development project type, were included.

Quantification I analysis can typically be understood as a dummy regression analysis, and multiple regression analysis is an analytical method used to develop a model that can describe or predict the value of a dependent variable using more than two variables. The following Eq. (4) indicates the general formula that was derived through the quantification theory type I analysis.

$$Y = A_0 + A_1X_1 + A_2X_2 + \dots + A_PX_P + \varepsilon \quad (4)$$

Here, Y: Dependent variable
 $X_1, X_2, \dots, X_P$: Independent variable
 $A_0, A_1, \dots, A_P$: Regression coefficient
 ε : error

Each independent variable was selected as an influencing factor in the *EMR*, and the quantification I analysis was carried out using SPSS 23.0. The step selection method was used for the process of developing the regression model. In this method, the statistical significance of each independent variable is verified as the variables are added, step by step. If the F value for the input value is greater than the entry value, the variable is included in the regression model. In case of the inclusion of a new variable, when the F value for the value that is input by recalculating the F value is greater than the rejection value, the variable contained in the regression model is removed. When there is no independent variable for which the F value is greater than the entry value and no variable that needs to be removed, the phase of the

regression model ends. In this case, as the sample size was small, 0.15 and 0.25 were applied as the significance probabilities of the F value including the independent variable, for the significance probability of the F value's entry and the significance probability of the F value's removal.

Regarding the derived final quantification I model, the significance of the model itself was examined by conducting a significance test (variance analysis). A significance test was also carried out on the regression coefficient included in the final model. Lastly, the fitness of the estimation model was derived through a collinearity test of the independent variable included in the final model.

4. Research Results

4.1. Result of Investigation of External Migration Rate in Development Project

Using the examined resident registration computer processing information data, with the cooperation of the MOLIT, the MOPAS, and 60 cities, counties, and districts, the actual *EMR* was calculated for 113 development projects. The development project with the highest *EMR* was found to be the *RSD* in Gyeong, Ulju-gu, Ulsan, with an *EMR* of 86.74%. The project with the lowest *EMR* was Chuncheon Hyoil *RCD* with a rate of 12.52%.

Overall, the development projects were found to have higher *EMRs* than those presented by the MOLIT and MOE [4]. The *EMR* of metropolitan cities was higher than that of cities and counties. This is because the *EMR* determined by the MOLIT and MOE [4] was derived by dividing an increase in social population, estimated using a specific point in time by the design population. Some deviation occurred because the method of estimating the social population increment was based on the national average population growth rate. The population data

Fig. 3. External migration rate by development project type (a: average, b: Box plot).

Fig. 4. External migration rate by area (a: average, b: Box plot)

surveyed in this study consisted of resident registration information data. As this dataset was based on the actual lot number, it is a more accurate way of determining the *EMR* of development projects.

The mean value of the estimated *EMR* for the 113 development projects was 47.25%. The *EMRs* by development project type (P_i) are shown in the left figure in Fig. 3. The average *EMR* of *CID* was the highest, at 49.92%, the average *EMR* of *RCD* was the lowest, at 42.42%. The right figure in Fig. 3 illustrates the box plot for the *EMR* by P_i . There is a significant deviation within the P_i and for this reason, it is difficult to clearly identify the characteristics of the *EMR* using P_i alone.

Fig. 4 shows the calculated average *EMR*, in which 113 development projects are classified by area (metropolitan cities/Gyeonggi-do/other cities and counties) and results of the box plot diagram.

The average *EMR* of metropolitan cities was 55.87%. The *EMR* of Gyeonggi-do was 44.74%, and that of other areas was 39.01%. The average *EMR* of metropolitan cities was found to be 10% higher than the average *EMR* of other areas. This was consistent with the results of previous studies, which found that shorter distances to the city center were associated with higher *EMR*.

The results of Jeon's [20] study found that the *EMR* of Gyeonggi-do was 39.9%. Jeon [20] conducted a census-type survey, with a different sample for Gyeonggi-do than the one used in this study. Accordingly, it is difficult to directly compare results. However, for the *EMR* of Gyeonggi-do, the resulting value does not show any large deviation from the previous result; it can thus be concluded that the reliability of the present survey is high.

Meanwhile, as shown in the right figure in Fig. 4, when some outliers were removed, the *EMR* showed deviations between metropolitan cities and other areas. When that was taken into account, it was judged that the prediction model of *EMR* should be divided into metropolitan cities and other areas. The prediction model of *EMR* developed in this study also used these divisions.

4.2. Result of Analysis of Factors Influencing External Migration Rate

Table 3 displays the results of an analysis of the correlation between factors that influence the *EMR*, as shown in Table 2 and the derived *EMR*. As the influencing factors vary by period, data based on development project completion date were analyzed.

As the D was shorter, the *EMR* was found to be higher. The higher in-migration population rate of cities and counties in areas that are close to the city center, which tends to be economically active areas, is judged to be the natural result of economic activity focused in city centers in Korea.

Although the increasing population growth rate (*PGR*) has been associated historically with an overall high *EMR*, the range was found to be insignificant. However, when this finding examined in detail, the trend was found to be based on a *PGR* of 1.0%, as shown in Fig. 5. When a development project is being constructed, population outflows will be larger than population inflows in comparison to metropolitan cities until the development project is completed. When a development project is completed, the population that has temporarily migrated to other cities and counties will relocate to areas surrounding the development project. In other words, the phenomenon of a high *EMR* in areas that have a *PGR* of less than 1.0% compared to areas with a rate exceeding 1.0% is probably due to this pattern.

However, when several factors are considered simultaneously, a phenomenon occurs whereby the correlation between certain factors may change or reverse. Accordingly, it is necessary to estimate influence factors by comprehensively considering of various factors.

As is evident from the results of previous studies, one cause of population migration to other areas involves economic activity. Fig. 6 depicts the relationship between the daytime population index (*DPI*) and the *EMR*. Areas with an index of more than 100 can be categorized as business areas, while those with an index of less than 100 can be categorized as residential areas.

Table 3. Results of Analysis on Influencing Factors of External Migration Rate

Category		Correlation coefficient with external migration rate	Standard correlation coefficient (113 samples, confidence level of 95%)	Results of correlation review
	P_t	-	-	-
Development project factor	P_s	0.1111	0.1557	+ (Low correlation)
	YC	-0.0089	0.1557	- (Low correlation)
	D	-0.2203	0.1557	+ (Correlated)
	PGR	0.1747	0.1557	+ (Correlated)
Population factor	DGS	0.1236	0.1557	+ (Low correlation)
	DPI	0.3187	0.1557	+ (High correlation)
Economy and industry factor	R_e	0.0831	0.1557	+ (Low correlation)
	N_{ib}	0.2640	0.1557	+ (High correlation)
	R_m	0.1899	0.1557	+ (Correlated)
	GRP	0.3721	0.1557	+ (High correlation)

Fig. 5. Box plot of external migration rate by population growth rate. **Fig. 6.** External migration rate by daytime population index.

The correlation between business/residential areas and the *EMR* has also been analyzed.

In business areas, an increasing *DPI* was associated with an

increasing *EMR*. This phenomenon implies that the rate of population migration to business areas for economic activity is high. This result is consistent with the results of previous studies, which have found that economic activity is one of the factors responsible for population migration. Conversely, for residential areas, a lower *DPI* was associated with an increasing *EMR*. This result implies that people pursuing a more comfortable living environment regardless of economic activity migrate when there is a newly developed residential complex, regardless of the distance from their current residence.

The results shown in Fig. 7, Fig. 8, and Fig. 9 show the *EMR* according to the number of industry for businesses (N_{ib}), the manufacturing ratio (R_m), and the gross regional product per capita (GRP). Each influencing factor demonstrates a tendency that is directly proportional to the *EMR*.

For N_{ib} , the *EMR* characteristics can be divided based on 250 businesses/km², while they can be divided based on 10% in the case of R_m . For GRP , they can be classified based on

Fig. 7. Box plot of external migration rate by number of industry for businesses.

Fig. 8. Box plot of external migration rate by manufacturing ratio.

Fig. 9. Box plot of external migration rate by gross regional product per capita.

10 million KRW/person. Overall, economic/industrial factors were found to contribute to population migration. The conclusion

can therefore be drawn that, in future, economic/industrial factors in a target area must be taken into account when predicting *EMR*. Meanwhile, regarding employment rates (R_e), the correlation with the *EMR* was somewhat lower. The standard deviation (σ) of the R_e surveyed was ± 2.76 , indicating that they had no significant effect on the *EMR* with little regional variation.

4.3. Results of the Model Developed To Predict the External Migration Rate

As shown in the *EMR* investigation results, there was a clear difference between metropolitan cities and other cities and counties. Taking this finding into consideration, the prediction model was divided into one model (model Y_A) for metropolitan cities and another model (model Y_B) for other cities and counties. The development results are as follows. The model derived as the result of quantification I analysis for influencing factors of *EMR* Y_A corresponds to Eq. (5), and Table 4 shows the description of regression coefficient in Eq. (5).

$$Y_A = 30.959 + 16.600 \times RCD + 12.768 \times CID + 10.438 \times RED + 6.598 \times RCD + 7.608 \times PGR + 12.994 \times DGS + (-8.420) \times N_{ib} + 13.835 \times GRP \quad (5)$$

Here, Y_A : External migration rate of metropolitan cities (%)

As a result of the development of model Y_A , the hit ratio of the predicted value for the investigated value was 71.11% with a confidence level of 95%. This shows that the influencing factor of the *EMR* used as an explanatory variable expresses the *EMR* well.

For model Y_A , the factors with a statistically significant effect on the *EMR* were found to be P_t , PGR , DGS , N_{ib} , and GRP . Regarding the *EMR* by P_t , RSD had the highest rate, followed

Table 4. Description of Model Y_A Regression Coefficient

Development project type	<i>RSD</i>	<i>CID</i>	<i>RED</i>	<i>RCD</i>
<i>RSD</i>	1	0	0	0
<i>CID</i>	0	1	0	0
<i>RED</i>	0	0	1	0
<i>RCD</i>	0	0	0	1
<i>REI</i>	0	0	0	0
Population growth rate (%)	Less than 1.0%		More than 1.0%	
<i>PGR</i>	1		0	
Demographic structure (%)	More than 70.0%		Less than 70.0%	
<i>DGS</i>	1		0	
Number of industry for businesses (number/km ²)	More than 250 businesses/km ²		Less than 250 businesses/km ²	
N_{ib}	1		0	
Gross regional product per capita (1 million KRW/person)	More than 20 million KRW/person		Less than 20 million KRW/person	
<i>GRP</i>	1		0	

Table 5. Model Y_A Regression Coefficient's Significance Test Results

Variable	Standardized coefficient	t-value	Significance probability	Variance inflation factor
Constant	-	4.227	0.000	-
RSD^{**}	0.515	2.818	0.008	2.614
CID^*	0.310	2.020	0.051	1.844
RED	0.199	1.408	0.168	1.565
RCD	0.201	1.160	0.250	2.335
PGR	0.219	1.609	0.116	1.452
DGS^{**}	0.427	3.238	0.003	1.358
N_{ib}^*	-0.274	-1.841	0.074	1.728
GRP^{**}	0.437	3.189	0.003	1.470

* Significant at confidence level of 90%

** Significant at confidence level of 95%

Table 6. Description of Model Y_B Regression Coefficient

Development project type	RSD	CID	RED	RCD
RSD	1	0	0	0
CID	0	1	0	0
RED	0	0	1	0
RCD	0	0	0	1
REI	0	0	0	0
Development project scale (number of households)	More than 3,000 households		Less than 3,000 households	
P_s	1		0	
Distance to city center (km)	Less than 15 km		More than 15 km	
D	1		0	
Population growth rate (%)	Less than 1.0%		More than 1.0%	
PGR	1		0	
Daytime population index (%)	More than 100%		Less than 100%	
DPI	1		0	
Manufacturing ratio (%)	More than 10.0%		Less than 10.0%	
R_m	1		0	
Gross regional product per capita (1 million KRW/person)	More than 20 million KRW/person		Less than 20 million KRW/person	
GRP	1		0	

by CID , RED , RCD , and REI . This tendency is similar to that found by Jeon [20]. The EMR was higher when the development project was completed in an area with a recent PGR of less than 1.0%. This tendency is due to the outflow of population resulting from the development project. Areas featuring a DGS exceeding 70.0% were associated with an increasing EMR . This reflects the trend in Korea in which the DGS is rising, along with the higher migration rate associated with the completion year of development projects (YC) in metropolitan cities with a higher EMR . The EMR of areas with high GRP

was also found to be high. A variance analysis carried out to determine the adequacy of the model found that the significance probability of the F value was less than 0.05 at 0.000, this demonstrates that the applicable model had statistically significant results.

The regression coefficient significance test results for model Y_A are shown in Table 5. Of the explanatory variables comprising the model, the dummy variables indicating the P_i (RED , RCD) and the PGR variables had low explanatory power. All other variables were statistically significant. The statistical sig-

Table 7. Model Y_B Regression Coefficient's Significance Test Results

Variable	Standardized coefficient	t-value	Significance probability	Variance inflation factor
Constant	-	2.501	0.015	-
<i>RSD</i>	0.024	1.071	0.244	9.026
<i>CID</i> *	0.260	1.952	0.063	6.712
<i>RED</i>	-0.073	-1.470	0.150	2.175
<i>RCD</i>	-0.331	-1.314	0.194	5.712
P_s	0.203	1.566	0.123	1.505
D^{**}	0.381	2.681	0.010	1.818
<i>PGR</i>	-0.179	-1.454	0.151	1.360
<i>DPI</i> *	-0.255	-1.766	0.083	1.879
R_m^{**}	0.353	2.952	0.005	1.285
<i>GRP</i>	0.210	1.517	0.135	1.719

* Significant at confidence level of 90%

** Significant at confidence level of 95%

nificance was low due to the small number of variables included in each dummy group. However, these variables had a significance probability of less than 0.3 and explained the dependent variable sufficiently with a confidence level of 70%. Thus, they were not excluded from the variable. The *PGR* could explain the dependent variable at the 90% level and was thus not excluded from the variable.

Model Y_B , for cities and counties, is equal to Eq. (6), and Table 6 shows the description of regression coefficient in Eq. (6).

$$\begin{aligned}
 Y_B = & 28.252 + 0.772 \times RSD + 10.540 \times CID + \\
 & (-6.892) \times RED + (-15.577) \times RCD \\
 & 6.824 \times P_s + 12.170 \times D + (-5.909) \times PGR \\
 & (-8.439) \times DPI + 12.340 \times R_m + 6.695 \times GRP \quad (6)
 \end{aligned}$$

Here, Y_B : external migration rate of cities and counties (%)

As a result of the development of model Y_B , the hit ratio of the predicted value for the investigated value was 75.00% at a confidence level of 95%. Accordingly, the influencing factors in the *EMR* that were used as explanatory variables expressed the *EMR* well.

In the case of model Y_B , factors that had a statistically significant effect on the *EMR* differed from model Y_A . The *EMR* increased as the development project scale (P_s) increased, the D decreased, and the R_m and *GRP* increased. The *EMR* was high for areas with a *PGR* of less than 1.0% and for areas classified as residential areas with less than 100% of the *DPI*. This pattern indicates that factors related to economic activity have a significant effect on the *EMR*. Meanwhile, the association of a higher *EMR* with larger P_s implies that the population that migrates to development projects in cities and counties does not migrate simply to be close to economic activity. Instead, they move after having comprehensively considered factors related to economic activity as well as factors related to the living residential environment. When predicting *EMR* in future, these trends need to be considered.

The results of a variance analysis confirming the model's adequacy found that the significance probability for the F value was less than 0.05 at 0.002, demonstrating that the applicable model had statistically significant results.

The significance test results of the regression coefficient for Model Y_B are shown in Table 7. Of the explanatory variables that comprised the model, dummy variables indicating the P_i (*RSD*, *RED*, and *RCD*) and P_s , as well as the *PGR*, and *GRP* variables had low explanatory power. All other variables were statistically significant. The reason for this low statistical significance is that the number of variables included in each dummy group was small. If additional samples are considered in the future, a more sophisticated model will result.

The developed models Y_A and Y_B are statistically significant, given the results of the variance analysis and coefficient significance test, with a hit ratio over 70%. Furthermore, the variables included in the model are also considered logically appropriate. Comprehensively, the models are considered valid.

4.4. Comparison to the Investigated External Migration Rate

The investigated *EMR* of the 113 development projects, the estimated values resulting from the newly developed model in this study, and the estimated values achieved using the previous indirect method are shown in Fig. 10 and Fig. 11. The model developed in this study is closer to the investigated value than the value derived from the previous indirect method. In case of model Y_A , the root mean square error (RMSE) between the predicted value and the investigated value was 10.12. On the other hand, the RMSE between the value derived from the previous indirect method and the investigated value was 27.31. In the case of model Y_B , the RMSE was 15.58 and 28.79 for the predicted value and indirect method, respectively, in comparison to the investigated value. Considering the errors discussed above, the newly developed model has been shown to be more accurate and useful than the indirect method.

Fig. 10. Comparison to the investigated value with developed model (Y_A) and indirect method.

Fig. 11. Comparison to the investigated value with developed model (Y_B) and indirect method.

4.5. Results of the Application of the Model to Predict External Migration Rate

The *EMR* presented by the MOLIT and MOE [4] is used for the water service maintenance basic plan, which is currently derived from water supply demand forecasts. However, the presented value, as described in the introduction, contains inaccuracies.

First, the presented value was established using the value of the *EMR* presented in the MOLIT and MOE [4]. Table 8 shows the results of using the value presented by the MOLIT and MOE [4] to derive the *EMR* of future development plans in comparison to the results obtained using the *EMR* derived from models Y_A and Y_B , which were developed in this study for five examples of development projects completed since 2009. These samples were not included when the model was developed.

Table 8. Comparison of the Results of Application of External Migration Rate

	Area	Development project	Actual external migration rate (%)	MOLIT (2009) (%)	This study developed model (%)
Metro-Politan	K district in P city	KC city development project	77.01	24.4	74.39 (using Y_A)
	D district in I city	DS residential environment improvement project	58.90	32.4	56.98 (using Y_A)
City and county	B city in K province	YD reconstruction project	43.06	22.9	43.10 (using Y_B)
	P city in K province	SJ reconstruction project	29.30	22.9	35.10 (using Y_B)
	K city in K province	OK city development project	47.10	37.6	49.39 (using Y_B)

In the case of metropolitan cities, compared to the actual *EMR*, the *EMR* applied by the MOLIT and MOE [4] was significantly low and, as a result, the error between the two values was significant. When the prediction model developed in this study was applied, the error was reduced to less than 3.0%.

Furthermore, although City B in Province G and City P in Province G applied the same *EMR* because they fell within the same province, the resulting errors were significant, at 20.16% and 6.40%, respectively. When the prediction model developed in this study was applied, different *EMR* values were used to reflect the individual characteristics of each city, the error was significantly reduced.

The KC City development project shown in Table 8 is a large-scale development project with a planned population of 80,000. Following the government announcement of the new city development policy, this is an area in which the population growth rate was already high before the project. The actual increase in population has been 61,610, as a result of *EM*. When employing the indirect method, the *EM* expected for the development project was 19,520, an underestimation totaling less than 35% of the actual *EM*. However, when the model developed in this study is applied, the *EM* is estimated at 59,512, a figure very similar to the actual *EM*. The baseline population of the development project area is approximately 300,000. The predicted population error is about 42,000, or 14%, which can cause problems, even when considering the 10% margin in water supply planning.

5. Conclusions

This study has shown that the indirect method incorrectly estimates *EMR*, which is a key component in estimating design population for infrastructural projects. Underestimating the design population can lead to insufficient water demand plans, which can cause unbalanced water welfare issues. Meanwhile, excessive water demand planning reduces the operational efficiency of limited water resources and causes waste at the national level.

To overcome this challenge, two new models were developed using quantification analysis. The models were developed for both counties and cities, after identifying the major factors influ-

encing *EM*.

The major findings of this study were:

1) A high *EMR* was associated with the following factors: a shorter distance to the city center, a business area with a higher population growth rate and weekly population index, and areas with favorable conditions for economic activity, including a high number of businesses, a high manufacturing business ratio, and a high gross regional product per capita.

2) Two prediction models, one using quantification analysis for metropolitan cities (Y_A) and for cities and counties (Y_B) were developed; both models were shown to be statistically significant. These models can be used to predict *EMR* based on data drawn from target cities and counties.

3) RMSE between the model values and the observed values were 10.12 and 15.58 for metropolitan cities and counties respectively; they were lower than the RMSE values of 27.31 and 28.79 obtained using the indirect method. Thus, the newly developed models provide a more accurate estimate of *EMR* than the indirect method

However, as described previously, this research has the following limitations. First, a relatively small number of samples were used for model development. Second, 11 influential factors were considered in this research; however, various influential factors need to be considered additionally.

Consequently, future medium and long-term studies should aim to cover more counties and cities in order to comprehensively identify important trends and significant factors that affect *EMR*. Such results would be useful for both governments and the private sector when planning public infrastructural projects.

Acknowledgments

This study was funded by the Ministry of Land Infrastructure and Transport (MOLIT) and K-water.

Nomenclature

EMR The ratio of the population entering the development

	project area to the cities outside the development project area
EM	Number of people who lived in outside the city moving into the development project area
IM	Number of people who lived in the city relocated to the development project area
SM_{oc}	Number of social migration moving from the other city to correspondence city irrespective of development project
SM_{co}	Number of social migration moving from correspondence city to the other city irrespective of development project
SM_{ic}	Number of social migration moving in a city irrespective of development project
$CPGR$	Growth rate of city population
$NPIR$	National population growth rate
CP	Population of city
DP	Design population of development project
RSD	Residential development project
CID	City development project
RED	Redevelopment project
RCD	Reconstruction project
REI	Residential environment improvement project
P_t	Development project types
P_s	Number of projected households
YC	Year of completion of development project
D	Distance from development project area to metropolitan city hall or shortest distance among calculated distances to provincial government office (Shortest distance by vehicle)
PGR	Average population growth rate
DGS	Average rate under 14 y of age compared to population over 65 y
DPI	Daytime active population ratio
R_e	Average percentage of employed persons in the population aged 15 y or older
N_{ib}	Number of industry for businesses compared to average area
R_m	Rate of the number of manufacturing businesses compared to total number of businesses
GRP	Gross regional product compared to average regional population

References

- Kent TJ. The urban general plan. Chicago: Planners Press; 1990.
- Kwon HB. A study on the application of external migration rate in the population forecast – Focused on the Pyeongtaek city [master thesis] Gyeonggi: Gachon Univ.; 2012.
- MOLIT and MOE. Guidelines for predict water supply. Daejeon: MOLIT and MOE; 2008.
- MOLIT and MOE. Guidelines for predict water supply. Daejeon: MOLIT and MOE; 2014.
- Balogun II, Sojobi AO, Galkaye E. Public water supply in Logos State, Nigeria: Review of importance and challenges, status and concerns and pragmatic solutions. *Cogent Eng.* 2017;4:1329776.
- Molloy R, Smith CL, Wozniak A. Job changing and the decline in long-distance migration in the United States. *Demography* 2017;54:631-653.
- McCatty M. The process of rural-urban migration in developing countries. An honours essay submitted in fulfilment of the degree of Bachelor of Arts to Department of Economics, Carleton University, Ottawa, Ontario; 2004.
- Clark W, Withers S. Family migration and mobility sequences in the United States: Spatial mobility in the context of the life course. *Demogr. Res.* 2008;17:591-622.
- Miheretu BA. Causes and consequences of rural-urban migration: The case of Woldiya town [doctoral dissertation]. North Ethiopia; 2011.
- Yoo KM. An empirical analysis on the determinants of population movement: In case of Korea (1966-1985). *The Korean Econ. Assoc. Kyongjehak Yongu* 1991;39:157-209.
- Kim ST, Jang JH. Empirical analysis on the economic determinants of regional migration in Korea during 1970-1991 period. *The Korea Int. Economic Assoc. Kukje Kyungje Yongu* 1997;3:175-197.
- Lee EW. Quality of life and interregional migration in Korea. *J. Korean Natl. Econ.* 1998;7:233-254.
- Lee W. A study on the determinants on migration in Kyonggi-Do. *J. Korea Plan. Assoc.* 2000;35:67-76.
- Lee W, Park EK. A study on the migration to large-scale residential development areas. Gyeonggi: Kyonggi Research Institute; 2001.
- Kim GS, Jang W. The study on characteristics of population movement within Busan. *J. Korea Plan. Assoc.* 2001;36:39-55.
- Kim HB, Choi JS. A study on population projection for infrastructure sizing in housing development sites. Korea Planning Association – 2001 autumn conference proceeding 1; 2001. p. 483-501.
- Kwon SC. Migration to the capital region in Korea: Assessing the relative importance of place characteristics and migrant selectivity. *J. Korean Assoc. Region. Geogr.* 2005;11:571-584.
- Choi DS, Kim TG. The estimation of the intra-regional ratio of moving-in population into residential land development area. *Seoul Stud.* 2009;10:105-119.
- Lee W, Lee JE. A study on in-migration characteristic in the second generation of newtown, the capital area. Gyeonggi: Kyonggi Research Institute; 2007.
- Jeon YS. A study on population immigration effect of different types of development project in Kyeonggi-do. *J. Korea Plan. Assoc.* 2009;44:113-123.
- Hur JW. An empirical analysis on the determinants of the external migration rate in the housing development sites in Gyeonggi province. *J. Korean Region. Dev. Assoc.* 2010;22:47-61.
- Lee MH. A study on the determinants of the external migration rate to the residential development project areas – In and around the metropolitan residential development project areas [master thesis]. Seoul: Chungang Univ.; 2011.