DETERMINATION OF THE POPULATION EQUIVALENT AND THE REQUIREMENT OF WATER IN THE EXISTING WATER SUPPLY SYSTEMS AS INPUT PARAMETERS FOR HYDRAULIC ANALYSIS, A CASE STUDY ON THE WATER SUPPLY SYSTEM FOR THE TOWN OF GOSTIVAR

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1. Abstract

The number of inhabitants including the specific water demand for one inhabited place is a primary input parameter in the hydraulic analysis of a water supply system, i.e. the optimal dimensioning of the water supply systems depends on the accurate assessment of these two parameters.

This paper, through various methods for determining the population growth in the future, i.e. the future number of inhabitants and the specific water demand, shall give a recommendation for selecting the optimal method for their assessment, from which accurate values for the required quantities would be obtained, which would be used as input parameters for the hydraulic analysis of water supply systems. As a case study for the analysis, the Water Supply System of Gostivar was selected.

Keywords: inhabitants, specific water demand, hydraulic model, population growth, water supply

2. Introduction

The basic function of the majority of water supply systems in the underdeveloped countries is to primarily provide water in sufficient quantities and of satisfactory quality for the population, while the remaining users, such as the light industry, livestock, public buildings, etc. usually have lower water demand compared to the water demand for the population. Therefore, in the determination of realistic quantities of water in one water supply system in the underdeveloped countries where the population is the most significant user, an accurate projection of the population that will use the services of the water supply system in its exploitation period should be made - for the following 30 years. In addition, the specific water demand for all the users of the system should be defined, and by that the total net quantity of water demand for water supply to be determined [1].

The aim of this paper is, through the analysis of several methods for determining the population growth, a more accurate projection about the future number of inhabitants in an existing water supply system to be made as much as possible, and that is the water supply system of the town of Gostivar in North Macedonia.

It is well known that the number of inhabitants and the specific water demand in households are primary input parameters in dimensioning the water supply systems. The value of the specific consumption of water in households is taken from the experience with similar systems in the surrounding region, while for the number of inhabitants within the period of exploitation a projection should be made so that the result will be as close as possible to the actual one, i.e. such population growth should be selected that an optimally dimensioned system for the entire period of exploitation would be obtained [1].

3. Forecast / assessment of the number of inhabitants

The term for the number of inhabitants in the water supply system, in the broadest sense means determination of the future demographic development on the basis of assumptions which in the moment of their application may be or may not be probable. Very often, the term projection is identified with the term forecast, although there is a significant difference between them. The projection of the population shows how much the future population growth would be on the basis of the assumptions which are probable for the entire period of the analysis, while the forecast is based only on assumptions which are probable at the time of beginning the analysis. This means that the projection of the population includes the forecast, but also has an aim to present what will happen with the analysis if some assumptions that might occur in the future are different from the initial ones.

Regarding the fact that there is no available relevant data on the current number of inhabitants for the considered water supply system, as population census has not been carried out in the Republic of North Macedonia since the year 2002, in this case a forecast of the population in accordance with the following sources of data has been performed:

- Data source 1: Strategy for demographic development of the Republic of North Macedonia. Methodology used in this method is accorded with the extrapolation of the future forecast about the population on the basis of values of growth taken from the Strategy for Development of the Republic of North Macedonia for the period from 2008 - 2015, where the growth is anticipated to amount to 0.38% for the whole territory of the Republic of Macedonia [2].
- Data source 2: Data from Population Census in the past. In this method, historic rates of population growth are used according to relevant statistical data from the past which have been obtained by population census. By the analysis of this data, the average population growth has been obtained, from 1981 → 2002 which amounts to 1.4%, and this growth is used for obtaining the number of inhabitants in the system exploitation period 2002 → 2015 and 2015 → 2050 [3].
- Data source 3: General Urban Plan of Gostivar. In this methodology, the population growth rates are used as defined by the General Urban Plan for Gostivar (adopted in the year 2005) and the Detailed Urban Plan for the town of Gostivar and its surrounding, where the town of Gostivar is divided into several different blocks, i.e. for the town centre, for the the outskirts and for the villages,

where for each block the population growth rate is different and ranges within the limits from 1.3% to 2% [3,4].

Figure 1 below shows a graph of obtained values on the number of inhabitants for the town of Gostivar about the three analyzed data sources.

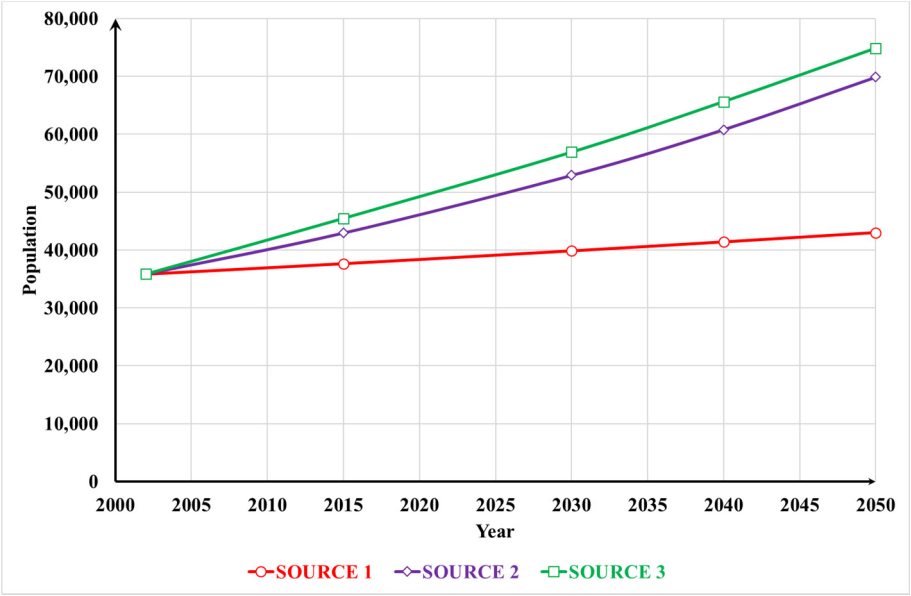

Figure 1. Number of inhabitants for the town Gostivar

From the data obtained, it can be concluded that:

In source data 1, the projection of the growth solely for the town of Gostivar is substantially lower than the actual one, and according to that, this Methodology should not be used for the water supply system of Gositvar.

Data source 2 represents a solid ground regarding the fact that the average population growth in the past 35 years is expected to be similar to the growth in the following 30 years. However, the fact that for the last 17 years there has not been any relevant statistical data on the population in the town of Gostivar, this Methodology has also high probability of an error, and also, the Methodology applied in this manner refers to the entire town, while for the hydraulic analysis of the water supply systems it is important to have data on the population per sectors, both in the town centre and on the outskirts, i.e. with this method the population growth is the same for all the parts of the town, which is different in reality. This method can be used only for some preliminary analyses, whereas it is not recommendable for more precise analyses.

The method with data source 3 is considered as the best one since the assessments are closest to the actual ones and the big advantage with this method is obtaining information on the number of inhabitants per sectors – blocks, both in the central area and on the outskirts. However, close consideration should be taken here for the high rates of growth, especially in the central area, which are expected to decrease in the future since there will be satiation of the space.

According to the previously stated, in the following analyses for determination of the

required realistic quantities of water supply, the third Methodology was used in this paper, for which detailed calculations on the number of inhabitants are given below.

4. Assessment of the number of equivalent inhabitants

4.1 Equivalent populations for the Town of Gostivar

By applying the Methodology for assessment of the population for the town of Gostivar based on the General Urban Plan in order to make classification of the sectors, a separation into four types of blocks has been made as follows:

- Type 1: Central town area, which includes blocks of flats, shopping centers, public buildings and administrative buildings;
- Type 2: Near outskirts, which consists of collective and individual buildings, commercial buildings, which is considered as a zone with possible intensive population growth;
- Type 3: Outskirts, consisting of household buildings;
- Type 4: Remote outskirts, in which only the industry is located.

For all the blocks defined in this way, by using data from the General Urban Plan, the population growth is determined, which is presented in the following table:

Table 1. Population Growth per Blocks for the Town of Gostivar

Block Type	2015 [%]	2015-2020 [%]	2020-2030 [%]	2030-2040 [%]	2040-2050 [%]
1	1.7	2.0	1.4	1.2	1.0
2	1.7	1.8	1.6	1.4	1.0
3	1.7	1.4	1.4	1.4	1.4
4	1.7	0	0	0	0

Whereas the number of inhabitants is determined with the following formula:

$$P=r*(Y-Y0)*P0+P0$$

Where:

P – estimated number of inhabitants

R – growth [%]

Y – year with a number of inhabitants P

Y0 – year with a number of inhabitants P0

P0 – reference number of inhabitants

For the purpose of obtaining more precise results in separating the population in blocks, there has been a separation performed within the blocks into buildings and houses, where it is anticipated that the density of buildings is three times larger than the density in the individual houses. From the results obtained, especially in the centre (Type 1), it can be noticed that the population density is very high (about 85 inhab./ha), and therefore, the density for this type will be reducing in the future, while on the outskirts the situation is opposite and increase in the population density is expected. The results of the analysis

performed in this manner are presented in figures 2 and 3 as follows:

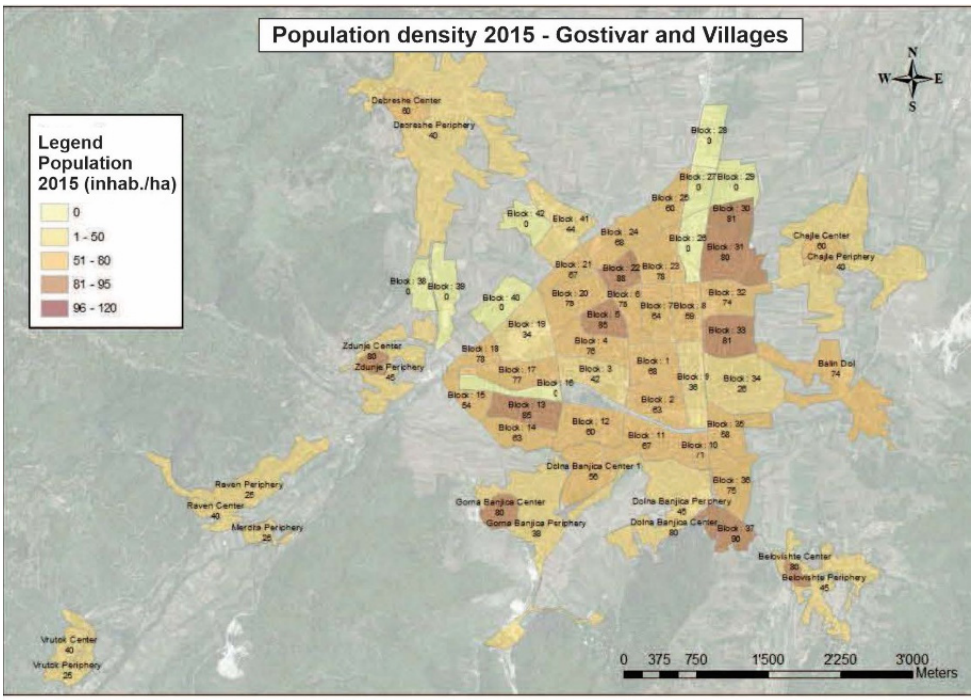

Figure 2. Population Density in 2015 for Gostivar and Villages

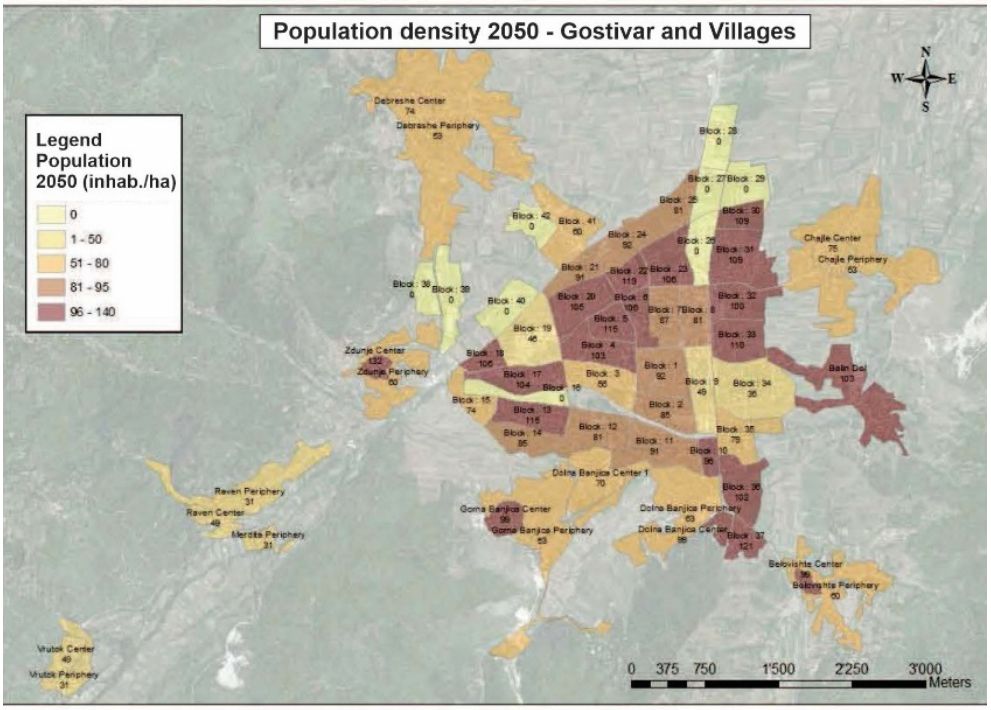

Figure 3. Population Density in 2050 for Gostivar and Villages

4.2 Equivalent populations for the Villages

In the villages, the estimation of the population growth is different from the town of Gostivar as there is no General Urban Plan made for the villages, i.e. the classical method is used for the villages based on using satellite photos in order to define the population density according to the houses for each area, thus identifying three types of villages:

- Type 1: small villages far from the town and with small development in the future,
- Type 2: villages of medium size, with expected development in the future, and
- Type 3: large villages near the town with expected big development in the following years.

Population density values and the expected growth are given in the following table:

Table 2. Population Density and Growth in the Villages

	Density [inhab./ha]		Growth [%]	
	Centre	Outskirts	Centre	Outskirts
Type 1	40	25	0.80	0.9
Type 2	60	40	0.90	1.2
Type 3	80	45	0.90	1.4

5. Net water demand

5.1 Net water demand for the Town of Gostivar

The total water demand for the town of Gostivar consists of the requirements of water for the households, collective demand and the industrial demands, where the water demand for the households are estimated to amount to:

- 110 l/d/PE. for the inhabitants living in buildings, and
- 130 l/d/PE. for the inhabitants living in houses

Since there was no available data on the collective water demand consisting of the public institutions and commercial buildings, this consumption of water has been estimated to amount to 20% of the water requirements for the households.

Regarding the water demand for the industry, also there has not been any available relevant data on the requirements since in this moment there are no larger factories in the town of Gostivar and it is estimated as daily requirements for the area of the industrial complex and amounts to 10 m3/day/ha.

5.2 Net water demand for the Villages

The water demand for the villages consists of the water demand for the households which is estimated to amount to 130 l/d/PE., the collective requirements which are estimated to amount to 10% of the requirements of water for the households and for the livestock which are estimated to amount to 30 l/day per head of cattle and amounts to 5 l/day per head of small animals.

According to the previous, the total net requirements of water are presented in the following graph, figure 4.

In the previous figure, there is a graphic presentation of the total net requirements of

water for the entire water supply system of Gostivar while the losses of water which can be of technical of administrative origin have not been analyzed in this paper since in the models of hydraulic analysis of the water supply systems the losses of water represent a separate input parameter which does not depend on the net required quantities of water.

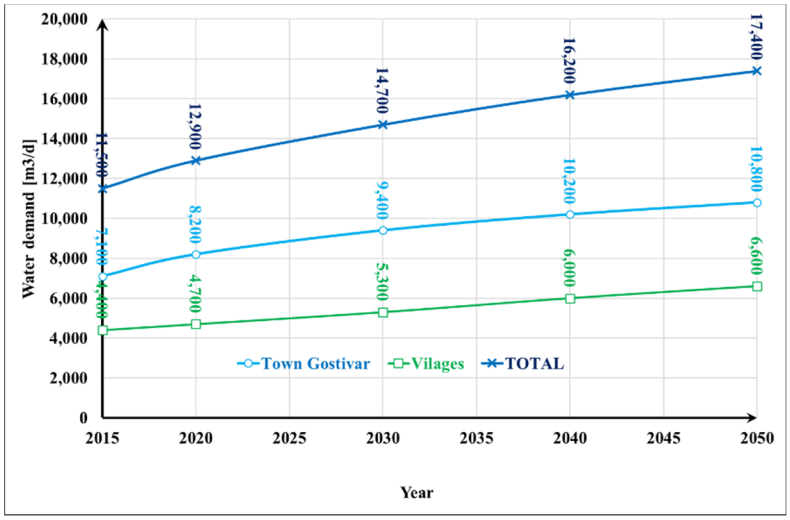

Figure 4. Net water demand

6. Conclusions

From the performed analyses in this paper, it can be concluded that determination of realistic required quantities of water in one water supply system is best to be carried out through relevant – accurate data, and in this case it is the General and the Detailed Urban Plan. This manner of analysis is also significant from the aspect of distribution of the total of required water quantities per junction of the future hydraulic model which is well known to be dependent on the population density per areas, i.e. on the number of inhabitants in the urban blocks.

While using this Methodology, attention should be specially paid on the assessment of the future population growth, especially in the central town areas where satiation of the space is expected in the future, while on the nearby outskirts increase in the population growth should be expected.

As the most significant conclusion, we can say that if we had relevant statistical data from censuses carried out in at least every 10 years, the method of using the growth in the past in that case would also be acceptable for solid assessment of the future number of inhabitants for one water supply system.

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