OCENA ZMOGLJIVOSTI VODOVODNEGA SISTEMA KOT STROKOVNA PODLAGA ZA ODLOČANJE O USMERJANJU RAZVOJA NASELIJ NA LOKALNI RAVNI*

ASSESSMENT OF WATER DISTRIBUTION SYSTEM CAPACITY AS SETTLEMENT-DEVELOPMENT DECISION-MAKING EXPERT BASIS AT THE LOCAL LEVEL*

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IZVLEČEK

Razvoj naselij je odvisen od številnih dejavnikov, med drugim od razpoložljivosti komunalne infrastrukture. V zvezi s tem znanstveniki ugotavljajo, da le integrirano načrtovanje komunalne infrastrukture in načrtovanje razvoja naselij ustvarjata razmere za trajnosten in ekonomičen urbani razvoj, kar pa se v praksi prostorskega načrtovanja v Sloveniji ne upošteva. V članku smo iskali odgovor na raziskovalno vprašanje: Na podlagi katerih podatkov in na podlagi kakšnega modela lahko v Sloveniji ocenimo zmogljivost vodovodnega sistema, ki je strokovna podlaga za odločanje o razvoju naselij na lokalni ravni? V ta namen smo analizirali rezultate že izdelanih raziskav z obravnavanega področja in oblikovali integriran dinamični model za oceno zmogljivosti vodovodnega sistema, ki izhaja iz simulacije gradnje na nepozidanih stavbnih zemljiščih in potreb novih porabnikov na teh zemljiščih po vodi. Hidravlična preveritev za oceno zmogljivosti vodovodnega sistema je izvedena z računalniškim programom Aquis 7.0. Glede na rezultate hidravlične preveritve so predlagani ukrepi in ocenjeni stroški ustreznih izboljšav obstoječega vodovodnega sistema oziroma njegove dograditve. Model za oceno zmogljivosti vodovodnega sistema je bil apliciran na primeru mestne občine Kranj.

ABSTRACT

Settlement development depends on many factors, including the availability of municipal infrastructure. Scientists find that only integrated municipal infrastructure planning and settlement-development planning create conditions for sustainable and economical urban development. This is not taken into account in spatial planning practise in Slovenia. This paper seeks a response to the research question: Based on what data, and based on what model can the capacity of the water supply system in Slovenia be assessed, which constitutes the expert basis for settlement development decision-making at the local level. To this end, we analysed the results of relevant existing research and devised an appropriate integrated and dynamic model for assessing the capacity of the water supply system, which was generated from a simulation of construction on vacant building land and relevant water requirements of new water consumers. In assessing the capacity of the public water supply system, the Aquis 7.0 Software was applied in accomplishing the hydraulic system validation. In line with the hydraulic system validation results, the respective measures are proposed, and the costs of necessary improvements of the existing water supply system or its upgrading are envisaged. The model was applied on the example of the Municipality of Kranj.

KLJUČNE BESEDE

prostorsko načrtovanje, strokovne podlage, razvoj naselij, zmogljivost vodovodnega sistema, komunalno gospodarstvo

KEY WORDS

spatial planning, expert basis, settlement development, water distribution system capacity, municipal economics

1 INTRODUCTION

Slovenia, like many other Eastern European countries, switched to market economy in the early 1990s. In transition from the so-called "per agreement" spatial planning system to the spatial planning system in market economy, the foundations for preparing expert bases of decision-making in spatial planning process should have changed as well. Not only that this was not done, as noted by Niedziałkowski and Beunen (2019) for Poland, along with principles and tools of integrated spatial planning at local level, the long-term aspect of spatial planning was ignored, though it had existed in the spatial planning acts of the former socio-economic system.

Only after 27 years from transition to the new system, the importance of professionally substantiated spatial planning with clearly defined planning stages was highlighted in the Spatial Planning Act (ZUreP - 2, 2017). Introduced were feasibility studies (Rules on feasibility studies / Pravilnik o elaboratu ekonomike, 2019), on which basis the economics of planned spatial arrangements, including the municipal infrastructure, are verified, the investment is assessed, the sources of funding and stages of implementation of planned arrangements are defined. Such expert bases facilitate a more transparent decision-making as to settlement-development orientation, where the status of existing municipal infrastructure and its capacity are taken into account.

In this regard, the following research question was posed within the research study: Based on what data and what model may already within the spatial planning process be assessed the capacity of the water supply system in Slovenia that is applied as expert basis for decision-making on settlement development at local level?

The method of work and the structure of the article are designed in accordance with the research question. First, the research already done in this field is presented. Taking into account the results of research studies accomplished, and the situation in Slovenia, the method of assessing the capacity of the water supply system is presented. Possible improvements and upgrading of water supply system are defined, as well as the associated costs, and the envisaged stages of construction. To date, such assessments have at the stage of spatial act preparation not been conducted in Slovenia, though they constitute an important expert basis in settlement development planning, and vice versa (Kafol Stojanović, 2018).

2 SPATIAL PLANNING AND MUNICIPAL INFRASTRUCTURE

In the past, the dilemma existed as to whether or not the municipal infrastructure constituted one of the bases of dimensioning different functions and sizes of settlements and of determining the use of space. Nowadays, scientists (Brown, Keath and Wong, 2009) find that this does not apply. By consecutively taking into account the individual factors in settlement development planning, the conditions for sustainable and economical urban development are not created, and this is currently confirmed by the works of many authors (Kathlene et al., 2010; Beckwith, 2014; Grimaldi, Pellecchia and Fasolino, 2017; Sproul, 2017).

In their respective research studies, they highlight the importance of integrated municipal infrastructure planning and settlement development planning. Frequent problems mostly appear because the municipal infrastructure planning system does not take into account the planned use of space in a certain area, the assessment of future service needs does not take into account the envisaged settlement development spatial plans, and because of insufficiency of spatial data on distribution of service needs and future investments (Grimaldi, Pellecchia and Fasolino, 2017). Similarly, the municipal infrastructure management elements should be taken into account in spatial planning and included in spatial plans (Kathlene et al., 2010).

Construction of municipal infrastructure is associated with relatively high costs, so it is extremely important for rational and economical planning to take into account not only its physical presence, but also its capacity, including the relevant overdimensioning. In our case, the capacity of municipal infrastructure is defined as the capability of municipal infrastructure to satisfy a certain scope of needs. The capacity of municipal infrastructure may be higher or lower than the existing or anticipated needs, or very rarely, it may be on an equal level.

In the municipal infrastructure planning process it is also important to assess the feasibility of different options for municipal infrastructure development, which means a more sustainable approach to planning and deciding on further settlement development (Mitchell, Mein and McMahon, 2001; Hardy, Kuczera and Coombes, 2005; Mitchell and Diaper, 2005; Brown, Keath and Wong, 2009). To this end, a number of water supply system design models have been developed that include different elements affecting their water balance.

First, static models of water supply system planning were developed that do not include the long-term aspect of settlement development due to population number changes and changes in the economy. Models suitable for long-term planning of water supply systems need to be dynamic and include social and economic variables (Mitchell et al., 2007). In a dynamic water supply planning model applied in Dublin, Willuweit and O'Sullivan (2013) combined the urban water balance concepts with the land use dynamics model and the climate model, thus providing a platform for the long-term planning of urban drinking water supply and water demands.

There are also integrated models of municipal infrastructure planning that include different variables and models from other fields (Schönhart et al., 2018). An example of integrated model is the DynaMind model used in a study by Mair et al. (2014), which comparatively analyses the impacts of new connections on changes to the existing sewage system.

The VIBe (Virtual Infrastructure Benchmarking) and DynaVIBe (Dynamic Virtual Infrastructure Benchmarking) models play an important role in the field of models for municipal infrastructure planning and land use. The tools can be used to generate a network of urban water supply systems for an area, taking into account the population change and land use data. The models facilitate the inclusion of probability scenario analysis in the future (Sitzenfrei et al., 2010; Sitzenfrei, Möderl and Rauch, 2013).

Currently in Slovenia, the practice of inclusion of municipal infrastructure in spatial planning process is in its initial development phase. The applicable municipal spatial plans (Spatial Planning Act / Zakon o prostorskem načrtovanju. ZPNačrt, 2007) mostly do not adequately define the envisaged municipal infrastructure, including the envisaged dynamics of its construction as a consequence of the spatial development needs. This is normally planned only in the following phases of the detailed spatial planning, or when preparing the conceptual design or project documentation for the issuance of a building permit (MOP, 2018); the financial and time aspects are frequently ignored (Štravs, Dekleva and Ivanič, 2010).

For this reason, a first attempt of setting up the relevant data and creating an integrated dynamic model for deciding on the future settlement development at local level according to the status and capacity of the water supply system is presented hereinafter.

3 METHODOLOGY OF ASSESSMENT OF WATER SUPPLY SYSTEM CAPACITY AS EXPERT BASIS FOR SETTLEMENT DEVELOPMENT DECISION-MAKING

The model designing methodology for water supply system capacity assessment is designed in several steps. As first it is necessary to set up new data on envisaged surfaces for spatial development of settlements and the envisaged drinking water consumption. Hydraulic evaluation of the water supply system capacity is conducted and, based on hydraulic analysis results, the necessary capacity improvement measures are decided on, and costs of such measures are estimated.

The capacity of the water supply system, appropriate measures and related costs represent one of the criteria for defining the intended use of space and the stages of development of settlements. The capacity evaluation is periodically repeated according to the dynamics of changes in the development of settlements.

3.1 Hypotheses and limitations

The water supply system capacity evaluation model is based on several hypotheses and limitations.

- In the research, we limited ourselves to drinking water supply activity and water supply system capacity assessment. The water supply system facilities and network are divided into the main, primary and secondary, which are entirely in public domain. Privately owned connections (tertiary network) are not included in the research.
- In contrast to many studies from the more arid areas of the world (Kathlene et al., 2010; Urban Water Management Plan, 2010; Sproul, 2017), we hypothesized that in the area under consideration, i.e. in the area of the selected local community, water resources are sufficiently abundant, and our interest was limited to water supply system capacity only. In the opposite case, the model should include an estimate of sufficient water quantity to supply new consumers.
- In capacity assessment, the essential input data constitute the existing and envisaged consumption of water in the selected and/or hypothesized period. Water consumption is not constant, but depends on numerous factors, changes during the year, month or day. Typology of settlements and density of built areas are strongly impacting the consumption of water (Rakar, 1980; Urban Water Management Plan, 2010; Kenway et al., 2013). To a large extent, water consumption depends also on activities and/or consumer groups, changes in numbers of population, climate conditions, impacts of infrastructure ageing, economic development, technological development, changes in land use, settlement sizes, standard of living, and behaviour of consumers (Petrešin, 1980; Panjan, 2005). In dimensioning the water supply system, we took into account fluctuations in water consumption during the day, calculated on the basis of the coefficient of diurnal water consumption, which represents the ratio between the maximum daily and average daily water consumption.
- Initial data for deciding on settlement development at local level include also the envisaged areas of unbuilt building land, and areas envisaged for densification, renovation or restructuring. Included in the analysis is the unbuilt building land that is not identified in the existing municipal spatial

planning acts and/or in other building land records. In their definition within the research we took into account the detailed intended use of the space, the spatial implementing conditions, the size, and legal regimes within the relevant areas of unbuilt building land. The envisaged water consumption is estimated on the basis of the envisaged size and activity of unbuilt building land, taking into account the hypothesis that the relative existing water consumption per capita will not increase in the future.

– The existing water supply system capacity is the key initial point in the process of spatial planning and deployment of activities in space (Haynes et al., 1984). The capacity of a water supply system can be verified by hydraulic evaluations of the existing water supply system, i.e. by simulation of actual operation of the water supply system, using mathematical models. The basic condition for conducting different simulations is an established and calibrated model of the water supply system (Walski et al., 2003). To assess the water supply system capacity, we applied in the research the Aquis 7.0 (Petrol d. d., 2018) computer software.
– An important element in verifying hydraulic conditions in the network in the future, which frequently constitutes an unknown, is the future development by stages of settlements within the area of local community (Haynes et al., 1984). Dependent on the envisaged development by stages are the scenarios for which the water supply system capacity is subjected to hydraulic verification. Water supply planning models are usually applied for analysing different planned scenarios as to the water supply system capacity: current status, envisaged status in five years, ten years, twenty years, and the status when the envisaged water supply system capacity is fully attained (Planning Guidelines ..., 2010). Mutschmman and Stimmelmayr (2011) indicate that periods coinciding with the national and municipal plans should be selected for scenarios. It is reasonable to analyse water supply system capacity first, provided that all the envisaged construction is instantly implemented. If the water supply system capacity is not sufficient for all the envisaged construction, then verifications are to be conducted for every five years at least. The subsequent planning by stages of settlement development depends on when all the system capacities are filled.
– In assessment of costs for implementation of measures enabling the envisaged settlement development, only the investment costs for the implementation of measures and for construction of new network within the water supply system shall be taken into account.

3.2 Model for water supply system capacity assessment and for decision on development of settlements in the selected local community

Step 1: Estimation of envisaged water consumption according to construction by stages.

First, the extent of unbuilt building land in the local community shall be determined. The existing records do not contain such data, and thus, for the purposes of this research, we defined the unbuilt building land in accordance with the law (ZUreP-2, 2017). These are plots, where it is possible to construct facilities requiring municipal infrastructure for their operation (ZUreP-2, 2017) or, in our case, drinking water supply. Areas in which the detailed intended land use does not envisage the construction of buildings (for instance, green surface areas, and transport infrastructure areas) are not taken into account. Nor are taken into account the areas, in which the legal regimes, area size, or other spatial implementing conditions from the spatial act do not permit the construction of buildings.

For each area of unbuilt building land, the envisaged water consumption is estimated on the basis of the existing average annual water consumption in comparable built-up areas. The comparability of areas is determined according to the location of the area, the envisaged intended use of space, spatial implementation conditions, area size, the envisaged activities, and the type of construction.

Step 2: Hydraulic verification of the existing water supply system according to the estimated water consumption.

The hydraulic verification is conducted using the Aquis 7.0 (Petrol d. d., 2018) computer software. A point layer of new water consumers is prepared (obtained in step 1), then the points are connected on the shortest distance to the existing water supply network according to the Thiessen polygon principle. Fluctuations in water consumption during the day, i.e. coefficients of diurnal water consumption, are defined.

The hydraulic verification shall be performed for the hour in the day, when the consumption is highest, or when the coefficient of non-uniformity of hourly consumption is highest, in the following order:

– Hydraulic evaluation of the existing water supply system (without new consumers).
– Hydraulic evaluation of the existing water supply system with added new water consumers.
– Adequacy verification of water tank capacities in terms of additional water consumption.
– Adequacy verification of the existing water supply system for fire flow loading conditions at average daily water consumption on the day with the highest annual water consumption, i.e. the highest annual unevenness coefficient.

Step 3: Deciding on measures to cover water needs, and estimation of costs.

Results of hydraulic evaluation of the existing water supply system show whether the capacity of the existing water supply system meets the increased needs even after connection of envisaged new water consumers. If the capacity of the water supply system as a whole is insufficient, the construction of a new water supply network is envisaged and, where applicable, incorporation of new water source or water tanks in the system. In case of insufficient capacity of a certain network part, concrete improvements are envisaged there, including installation or replacement of pumping units, replacement of individual pipeline sections with larger diameter pipes, and similar. All measures are cost-related.

The research takes into account the results of studies (Rakar, 1979; Rakar and Makuc, 1985; Komunala Kranj, 2018), which reflect the situation in Slovenia. The cost of water supply system construction consists of the costs of material, excavation, backfilling and laying (work). It depends on the location of and type of soil, as well as the length of the pipe and its diameter.

Step 4: Inclusion of results of estimated water system capacity and costs into decisions on settlement development at local level.

Results concerning the estimated water supply system capacity, measures and costs for ensuring the envisaged water consumption are taken into account in defining the new intended use of space or spatial implementing conditions in the spatial planning process and in planning settlement development by stages. Through properly planned settlement development stages, the envisaged water consumption needs may be covered, and costs for ensuring the envisaged water consumption may be optimised, so that the envisaged needs may be covered with minimum costs.

These four steps are repeated every five years at least, so that the dynamics of settlement development changes at the local level is included in the model.

4 APPLICATION OF THE MODEL FOR EVALUATION OF WATER SUPPLY SYSTEM CAPACITY: EXAMPLE OF WATER SUPPLY SYSTEM IN THE MUNICIPALITY OF KRANJ

Evaluation of water supply system capacity and of costs for improvement of the existing water supply system and its possible expansion was prepared for the Municipality of Kranj. Municipality of Kranj is one among eleven city municipalities of Slovenia, it is located in the Gorenjska statistical region in the west of Slovenia, and has an area of 151 km2; in 2018, it had a population of 55,795 (SORS, 2019). Komunala Kranj, a public utility company, provides drinking water in seven communities (the Municipality of Kranj, and the communities of Naklo, Preddvor, Šenčur, Jezersko, Cerklje na Gorenjskem, and Medvode), while managing 19 water supply systems.

First, unbuilt building land within the Municipality of Kranj was determined according to the listed criteria, estimating the envisaged water consumption on such land. Hydraulic evaluation of water supply system was conducted, taking into account that all the existing and envisaged new water consumers on unbuilt building land would be connected to the existing water supply system. Hydraulic evaluation of the system was done based on verification of pressure conditions in the existing water supply system, and on verification of adequate water tank capacity. Additionally, hydraulic evaluation of pressure conditions for fire flow conditions was conducted as well.

Through hydraulic evaluation of existing water supply system, the difference between the pressure in the system at existing water consumers and upon connection of envisaged new water consumers was determined. This is important information, on which basis the possible inadequate parts of the system are identified in terms of pressure and reasons for inadequate properties (Figure 1). At most water supply system junctions, these differences were minimal (maximum 0.1 bar) and pressures within the adequate range from 2.5 to 6 bar. Greater differences were found only in junctions of the network part close to Hrastje business zone, where upon connection of new consumers the pressure dropped by 0.86 and down to 0.78 bar. Noticeable difference in pressure was recorded also in a small area in the north of the Municipality of Kranj, where the pressure increased by 0.25 bar.

Hydraulic evaluation of pressure conditions during fire flow loading conditions showed in one area that due to large flows through a secondary pipe of smaller diameter (DN 80) the energy losses in that pipeline section increased, with resulting pressure in the system that was too low. Thus, in the pipeline section with inadequate conductivity, the existing pipes shall need to be replaced for pipes of larger diameters.

Based on hydraulic evaluation within the research we found that the existing water supply system of the Municipality of Kranj can withstand an increase in drinking water consumption even when all new consumers are connected to it. So there is no need for construction of new main lines, primary lines or integration of new water sources or water tanks into the water supply system. Thus, no additional verification of short-term scenarios, i.e. in every five years, was reasonable in this case. To connect new consumers, a connection to the network only shall need to be constructed, including the upgrading of the existing secondary network, or upgrading and additions to the existing secondary network.

Costs of envisaged measures for individual areas of unbuilt building land were calculated based on hydraulic evaluation results and with the help of average lengths of water supply network per hectare of gross building land.

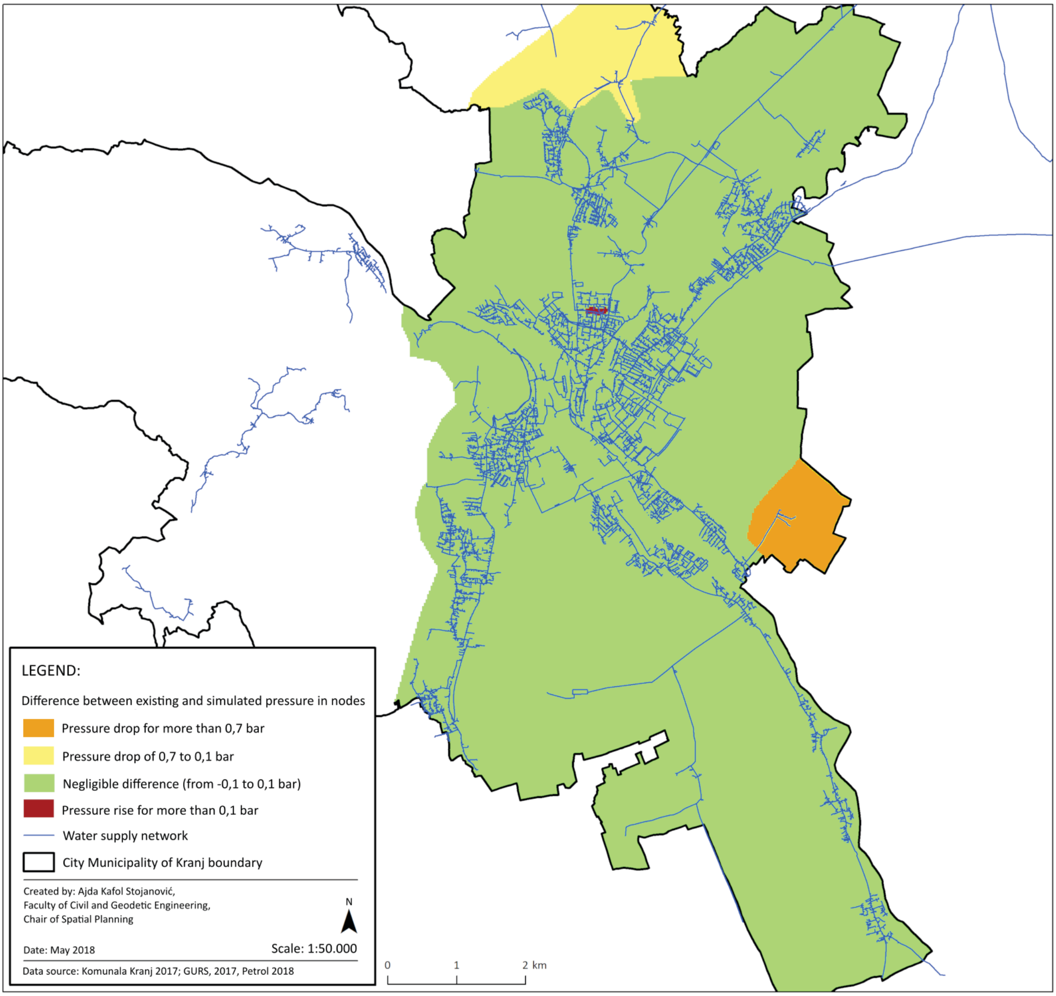

Figure 1: Difference between existing and simulated pressure in water supply system, arising from connection of new consumers on currently unbuilt building land.

Areas (Figure 2) marked with numbers 1–4 constitute the areas with highest envisaged drinking water consumption. For these areas, the estimated costs of investment into the existing water supply network are shown in Table 1. As many as 78 % of unbuilt building land areas in the Municipality of Kranj do not require any additional investment; connection to existing network is possible by constructing a connection and, where applicable, installing a pressure regulation instrument at the outlet point. In the remaining 22 % of unbuilt building land areas, the secondary water supply network shall need to be constructed, or replaced, for which the construction cost has been estimated based on locality, soil type, and pipe length and diameter.

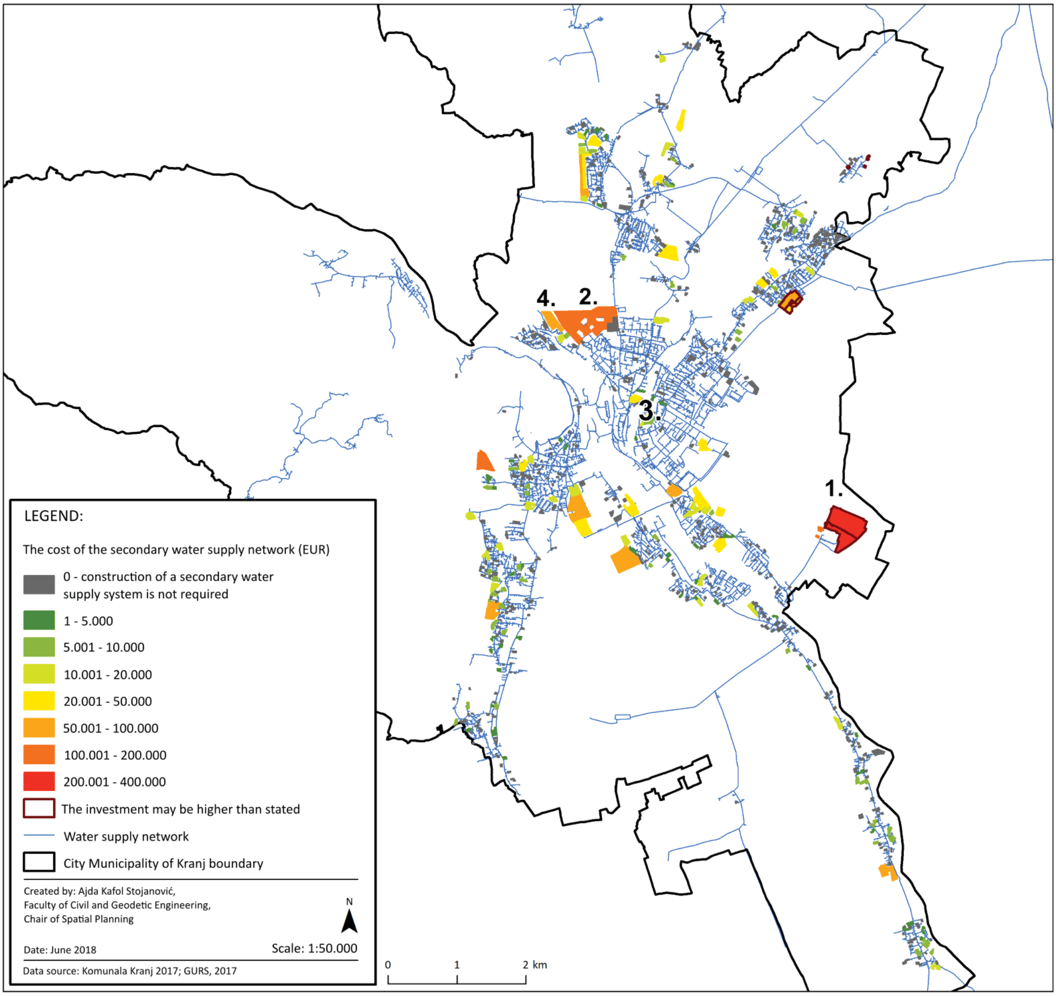

Figure 2: Areas of unbuilt building land according to the class of estimated costs of construction of a secondary water supply system.

Table 1 shows areas with envisaged maximum drinking water consumption, and envisaged measures and costs, which constitute the quantitative basis for reciprocal comparison of areas, and the expert basis for deciding on development by stages of individual areas or settlements, and for planning the water supply system development. In addition to total costs, in the case of deciding on development by stages of settlements, also the relative costs relevant to the number of newly supplied inhabitants per particular areas of unbuilt building land, and other similar relative costs would be possible to define, depending on spatial policy objectives within the local community.

Table 1: Estimation of measures, including costs, for areas with envisaged maximum water consumption.

	1. 'Hrastje' business zone	2. 'Zlato polje' education and other central activities	3. 'Planina' residential community	4. 'Struževo' business, trade, supply and service activities
Average drinking water consumption (L / s)	2.03	1.69	0.78	0.73
Envisaged pipeline - pipe length (m)	3,585	2,563	347	624
Envisaged pipeline - pipe DN (mm)	125 and 100	125 and 100	100	100
Indicative costs (EUR)	**430,720**	**316,500**	**64,000**	**71,500**

5 DISCUSSION AND CONCLUSIONS

The research provides answers to the following questions: (1) based on what data, and (2) based on what model can we assess water supply system capacity in Slovenia that is applied as expert basis for deciding on settlement development at local level already within the spatial planning process, as follows:

(1.) To assess water supply system capacity, we need data on the envisaged unbuilt building land areas, and on estimated drinking water consumption by inhabitants envisaged for these areas. Currently, data on envisaged unbuilt building land areas cannot be obtained from any existing database, so we have estimated them for the purposes of this research. Estimation of envisaged water consumption in individual areas is difficult in the early spatial planning process stages due to unknown numbers of potential inhabitants or water consumption in each area. Such estimation is associated with uncertainty and risk. Numbers of inhabitants and their water needs were estimated with the help of data on unbuilt building land areas for each detailed intended land use, on envisaged activity, and on current average water consumption in comparable areas.

(2.) Based on the presented integrated dynamic model, the water supply system capacity may be estimated. The model is so designed as to allow continuous system capacity monitoring, and system free capacity monitoring. The model may be applied also for planning of settlement development by stages, and for verification of cost-effectiveness of planned arrangements. Hydraulic evaluation results within the model constitute the basis for estimation of measures, and of costs of their implementation. Additionally, they constitute an adequate expert basis for decision-making within the spatial planning process. It is reasonable that in interpreting the results obtained, experts in spatial planning cooperate with those in water supply system design and management.

Key added value of hydraulic evaluation in the model presented is the identification of weak points of a water supply system as a whole, at different numbers of new consumer connections. In phases of spatial planning in greater detail, with particular areas in focus, this is frequently overlooked. It is reasonable therefore that hydraulic verification is conducted several times, for different scenarios of development in space, simultaneously with spatial act preparation, settlement planning and other activities in space, at the level of the entire local community. Water supply system capacity is not the only factor influencing the decisions on settlement development, and results of analysis of water supply system capacity are only one of expert bases for decision-making in spatial planning process. The very decision on settlement development depends on many other factors (Fischel, 1999). According to Deng et al. (2013), the decisions on long-term projects, as in infrastructure, are difficult to make or linked to uncertainties and risks on account of climate changes and rapid urbanization.

To integrate such models into spatial planning practice and into water supply system planning, the appropriate, comparable and accessible set of input data should be set up for at least: unbuilt building land areas; existing drinking water consumption quantities per activity on built building land; and costs of construction / replacement of individual parts of the water supply system. A greater circle of professional public should get familiarised with hydraulic verification, and an interdisciplinary expert team should be set up for interpreting the results in conjunction with settlement development in local community. The model presented could be part of expert bases in preparing municipal spatial plans, as for instance the feasibility study (Rules on feasibility studies / Pravilnik o elaboratu ekonomike, 2019), within which, and in conjunction with the building land records (ZUreP-2, 2017), the data necessary for application of the aforementioned model would be set up.

On the example of water supply system capacity analysis in the Municipality of Kranj it was found that all new water consumers can be connected to the existing water supply system. Construction by phases in terms of water supply system capacity could be conducted with regard only to different costs of investment into the existing water supply system, or with regard to construction of a new (secondary) water supply network. Should the existing water supply system capacity be insufficient, the procedure would need to be repeated by hypothesizing different settlement development scenarios, and by analysing, what period of time would elapse for the water supply system to reach its full capacity. This would impact decisions as to which area to build in first.

Prior to incorporation of municipal infrastructure capacity assessment into spatial planning procedures for the purposes of reasonable settlement development, it would be necessary to conduct subsequent research so as to verify the assessment methods for areas under renovation, concentration or restructuring, which are important in terms of changing municipal infrastructure needs in the future. It is reasonable to develop and test the capacity assessments for other types of municipal infrastructure as well, especially for the sewage system and power supply system. Owing to the nature of municipal systems that exceed the municipality boundaries, the municipal infrastructure planning and capacity verification is reasonable at regional level as well.

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Literature and references:

Beckwith, D. (2014). Integrating land use and water planning. Journal – American Water Works Association, 106 (9), 75–79. DOI: https://doi.org/10.5942/jawwa.2014.106.0131

Brown, R. R., Keath, N., Wong, T. H. F. (2009). Urban water management in cities: historical, current and future regimes. Water Science & Technology, 59 (5), 847–855. DOI: https://doi.org/10.2166/wst.2009.029

Deng, Y., Cardin, M.-A., Babovic, V., Santhanakrishnan, D., Schmitter, P., Meshgi, A. (2013). Valuing flexibilities in the design of urban water management systems. Water Research, 47 (20), 7162–7174. DOI: https://doi.org/10.1016/j.watres.2013.09.064

Fischel, A. W. (1999). Zoning and Land Use Regulation, Boudewijn, Bouckaert and Gerrit De Geest, (Ed.) Encyclopedia of Law and Economics, Volume II. Civil Law and Economics, Cheltenham, Edward Elgar, ISBN 1 85898 985X, https://www.dartmouth.edu/~wfischel/Papers/WAF-zoning%20ELEpdf.pdf, accessed 12. 4. 2019.

Grimaldi, M., Pellecchia, V., Fasolino, I. (2017). Urban Plan and Water Infrastructures Planning: A Methodology Based on Spatial ANP. Sustainability, 9 (5), 1–23. DOI: https://doi.org/10.3390/su9050771

Hardy, M. J., Kuczera, G., Coombes, P. J. (2005). Integrated urban water cycle management: the UrbanCycle model. Water Science and Technology, 52 (9), 1–9. DOI: https://doi.org/10.2166/wst.2005.0276

Haynes, K. E., Krmenec, A. J., Georgianna, T. D., Whittington, D., Echelberger, W. F. (1984). Planning for Water Capacity Expansion. Journal of the American Planning Association, 50 (3), 359–364. DOI: https://doi.org/10.1080/01944368408976604

Kafol Stojanović, A. (2018). Ocena kapacitete vodovodnega sistema kot strokovna podlaga v procesu prostorskega načrtovanja [Estimation of Water Distribution System Capacity as an Expert Basis for Spatial Planning Process]. Master Thesis. Ljubljana: University of Ljubljana. https://repozitorij.uni-lj.si/IzpisGradiva.php?id=103594, accessed 18. 2. 2019.

Kathlene, L., Lynn, J., Greenwade, A., Sullivan, W., Lung, Q. (2010). Colorado Review: Water Management and Land Use Planning Integration. Denver: Center for Systems Integration.

Kenway, S. J., Turner, G. M., Cook, S., Baynes, T. (2013). Water and energy futures for Melbourne: implications of land use, water use, and water supply strategy. Journal of Water and Climate Change, 5 (2), 163–175. DOI: https://doi.org/10.2166/wcc.2013.188

Komunala Kranj (2018). Stroški gradnje in obnove vodovoda. Personal communication, accessed 30. 5. 2018.

Mair, M., Mikovits, C., Sengthaler, M., Schöpf, M., Kinzel, H., Urich, C., Kleidorfer, M., Sitzenfrei R., Rauch, W. (2014). The application of a Web-geographic information system for improving urban water cycle modelling. Water Science & Technology, 70 (11), 1838–1846. DOI: https://doi.org/10.2166/wst.2014.327

Mitchell, V. G., Mein, R. G., McMahon, T. A. (2001). Modelling the urban water cycle. Environmental Modelling & Software, 16 (7), 615–629. DOI: https://doi.org/10.1016/S1364-8152(01)00029-9

Mitchell, V. G., Diaper, C. (2005). UVQ: A tool for assessing the water and contaminant balance impacts of urban development scenarios. Water Science & Technology, 52 (12), 91–98. DOI: https://doi.org/10.2166/wst.2005.0435

Mitchell, V. G., Duncan, H., Inman, M., Rahilly, M., Stewart, J., Vieritz, A., Holt, P., Grant, A., Fletcher, T. D., Coleman, J., Maheepala, S., Sharma, A., Deletic, A., Breen, P. (2007). State of the Art Review of Integrated Urban Water Models. In Novatech 2007, Workshop 2, GRAIE, Lyon, France. http://hdl.handle.net/2042/25394, accessed 15. 1. 2019.

Ministrstvo za okolje in prostor, Direktorat za prostor, graditev in stanovanja (2018). Elaborat ekonomike. Personal communication, accessed 4. 6. 2018.

Mutschmman, J., Stimmelmayr, F. (2011). Taschenbuch der Wasserversorgung. Wiesbaden: Vieweg Teubner Verlag.

Niedziałkowski, K., Beunen, R. (2019). The risky business of planning reform – The evolution of local spatial planning in Poland. Land Use Policy, 85, 11–20. DOI: https://doi.org/10.1016/j.landusepol.2019.03.041

Panjan, J. 2005. Osnove zdravstveno tehnične infrastrukture: vodovod in čiščenje pitnih voda, odvodnjavanje in čiščenje onesnaženih voda in komunalni odpadki. Ljubljana: University of Ljubljana, Faculty of Civil and Geodetic Engineering, Department of Civil Engineering.

Petrešin, E. (1980). Vodovodni sistemi. Ljubljana: [s. n.].

Petrol d. d. (2018). Vodovodni sistem v Mestni občini Kranj in hidravlični model vodovodnega sistema Kranj. Personal communication. (1. 3. 2018, 10. 3. 2018, 28. 3. 2018, 15. 5. 2018 in 8. 6. 2018.)

Pravilnik o elaboratu ekonomike [Rules on feasibility studies]. Official Gazette of the Republic of Slovenia, No. 45/2019, 12. 7. 2019.

Rakar, A., Makuc, J. (1985). Valorizacija objektov in naprav komunalne hidrotehnike na osnovi podatkov GPKN – primer mesta Maribor. Geodetski vestnik, 29 (2-3), 91–104.

Rakar, A. (1979). Nekateri vidiki rasti urbanih aglomeracij [Some aspects of urban agglomeration growth]. Doctoral Dissertation. Ljubljana: Edvard Kardelj University in Ljubljana, Faculty of Architecture, Civil and Geodetic Engineering.

Schönhart, M., Trautvetter, H., Parajka, J., Blaschke, A. P., Hepp, G., Kirchner, M., Mittera, H., Schmida, E., Strennb, B., Zessner, M. (2018). Modelled impacts of policies and climate change on land use and water quality in Austria. Land Use Policy, 76, 500–514. DOI: https://doi.org/10.1016/j.landusepol.2018.02.031

Sitzenfrei, R., Möderl, M., Rauch, W. (2013). Assessing the impact of transitions from centralised to decentralised water solutions on existing infrastructures – Integrated city-scale analysis with VIBe. Water Research, 47 (20), 7251–7263. DOI: https://doi.org/10.1016/j.watres.2013.10.038

Sitzenfrei, R., Fach, S., Kleidorfer, M., Urich, C., Rauch, W. (2010). Dynamic virtual infrastructure benchmarking: DynaVIBe. Water Science and Technology: Water Supply, 10 (4), 600–609. DOI: https://doi.org/10.2166/ws.2010.188

Sproul, K. (2017). Chapter 594: Making California's Water Supply Planning Process More Fluid with Large-Scale Development Projects. University of the Pacific Law Review, 48, 647–669.

SORS (2019). Statistical Office of the Republic of Slovenia. SiStat. https://pxweb.stat.si/SiStat, accessed 20. 5. 2018.

Štravs, L., Dekleva, J., Ivanič, L. (2010). Opremljanje stavbnih zemljišč. Komunalni prispevek, pogodba o opremljanju. Ljubljana: GV založba.

Urban Water Management Plan. Section 2: Land Use and Water Demand. (2010). Vallecitos Water District, 1–15. http://vwd.org/home/showdocument?id=869, accessed 20. 5. 2018.

Walski, T. M, Chace, D. V, Savic, D. A, Grayman, W., Beckwith, S., Koelle, E. (2003). Advanced Water Distribution Modelling and Management. Civil and Environmental Engineering and Engineering Mechanics Faculty Publications, 18. https://ecommons.udayton.edu/cee_fac_pub/18, accessed 20. 5. 2018.

Willuweit, L., O'Sullivan, J. J. (2013). A decision support tool for sustainable planning of urban water systems: Presenting the Dynamic Urban Water Simulation Model. Water Research, 47 (20), 7206–7220. DOI: https://doi.org/10.1016/j.watres.2013.09.060

ZPNačrt (2007). Zakon o prostorskem načrtovanju [Spatial Planning Act]. Official Gazette of the Republic of Slovenia, No. 33/2007, 70/2008 – ZVO-1B, 108/2009, 80/2010 – ZUPUDPP, 43/2011 – ZKZ-C, 57/2012, 57/2012 – ZUPUDPP-A, 109/2012, 76/2014 – odl. US, 14/2015 – ZUUJFO in 61/2017 – ZUreP-2.

ZUreP-2 (2017). Zakon o urejanju prostora [Spatial Planning Act]. Official Gazette of the Republic of Slovenia, No. 61/2017.

Kafol Stojanović A., Kozelj D., Šubic Kovač M. (2020). Assessment of water distribution system capacity as settlement-development decision-making expert basis at the local level. Geodetski vestnik, 64 (3), 389-401.
DOI: https://doi.org/10.15292/geodetski-vestnik.2020.03.389-401

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