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SURVEYS OF CONSUMER PREFERENCES OF THE OPERATION AND MANAGEMENT OF WATER SUPPLY

BADANIA SONDAŻOWE PREFERENCJI KONSUMENCKICH NA TEMAT FUNKCJONOWANIA ORAZ ZARZĄDZANIA DOSTAWĄ WODY

Abstract: The permanent and long-lasting development of the civilization influences the growth of the threat occurrence connected with the functioning of Water Supply System (WSS). The presented methodology can be used to describe the functioning of the public water supply using the evaluation of its proper functioning and allows for implementation to determine proper operation of water network. The expanded methodology of conducted surveys of recipients in the field of the effectiveness of the water supply system is the basis for a comprehensive assessment of its proper functioning. Consumer opinions may be used in determining water supply reliability standards and the rules for granting discounts and rebates in the case of restrictions and interruptions in water supply. A significant issue is the assessment by respondents nuisance interruptions in water supply (time and frequency), knowledge of the causes, inconveniencing and losses that causes lack of water supply. In the work the results of consumer survey during undesirable events in Polish water networks were presented.

Keywords: water network, consumer assessment, water supply system functioning analysis

Introduction

Assessment and analysis of proper water supply functioning is an important issue for policy development company, and is used to improve the existing organizational and operational state. A properly functioning collective water supply system should ensure a continuous water supply to the recipients, with a suitable quality and adequate quantity (required pressure), at a specific time. These parameters must be maintained at the required level, which in reality is not so simple.

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Water consumers increasing awareness of their rights causes that waterworks companies are more and more focused on the client. The recipient who bears costs in the form of fees is entitled to demand an adequate level of service [1]. More and more often the parameters of water supply are standards, according to which the agreement between the water supplier and the water recipient is concluded. In the agreements concluded between the supplier and the recipient, the recipient should have the right to negotiate the price if the supplier does not fulfil water quality standards. Specific identification of indicators describing the quality of water services prevents misuse of monopolistic position by the water supply company, also in public-private partnerships. The basis for such an agreement should be arrangements for customer service quality standards, therefore the establishment of the priority criteria (the parameters of water supply) and the permissible values of deviations of these parameters from the acceptable parameters, what can be determined in the conducted survey. Such a survey can consist of questions concerning inconveniences and losses occurring during undesirable events and crisis situations.

The issue related to the amount of fees that recipients would be willing to bear as to obtain a given level of services provided by the water company and therefore the Contingent Valuation Method (CVM) and the so-called Willingness to Pay (WTP), as well as Willingness to Accept (WTA) in case of interruption of water supply were described in works [2] and [3]. The test results contained in [4] indicate that the continuity of the water supply is an important factor in the assessment by consumer of water, who is willing to pay more for a reduction in the frequency and duration of interruptions in water supply.

The aim of the water supply system safety operation is to counteract against lack of water or its bad quality threatening health of municipal water pipe users and to supervise this action using processes, information resources in the given operating conditions, in compliance with the valid law and with economic justification [5]. However, legal regulations do not control the operation of water supply companies and conditions of receiving water with certain deficiencies. One example is the lack of clear rules that would strictly define minimum level of services provided to water customers by water companies. These rules are based on local legislation that is approved by the local authorities.

It is worth to mention, that consumers in water supply system functioning are exposed to numerous threats, as for example failures of each subsystems of water supply systems, lowering groundwater table, also some incidental undesirable events as droughts, floods and other factors causing deterioration of the quality of raw water. But among all these mentioned events, consumers are most prone to get water, which quality does not meet the relevant standards.

Also water companies experience the effects of negative events including penalties resulting from deliver water with inadequate quality or interruptions in the water supply, costs incurred for the failure removal, lower profits from the water sale, material cost needed to restore damaged or destroyed infrastructure, other costs related to the transport of materials. Therefore in the examined water supply systems an emphasis was

put on the issue connected with water services assessment including analysis of safety functioning, as well as performed survey through conjoint analysis implementation.

The main areas of the application of conjoint analysis in water supply system consider environmental and social improvements [6], consumer's selection attribute of the bottled water on the premium market [7], evaluate participant's preferences for various attributes of recycled water for various uses and the transformation of urban water supply [8].

The proposed approach will facilitate the management, provide the centralized control and comparison of water supply companies, which will ensure that the services provided by them will be at a certain level [9–12]. It will also protect against reaching a monopoly position by a given company, such a situation could result in higher prices for supplied water while the level of service is lowering [13]. Such procedures of safety assessment of quality services involving functioning analysis or failure and losses analysis will help to protect different group of recipients [14–18].

The scientific objective of the paper is to develop an innovative methodology for operation analysis and assessment, associated with consumer's safety, in the water supply system. Also issues related to the risk of non-delivery water in everyday life in order to prevent or minimize such risk with regard to hazardous situation occurrence.

Analysis of the water supply system operation from the consumer perspective

The basic quality parameter of service is its availability, including the duration of interruptions in water supply. This nuisance is proportional to the size of failure, the number of people affected by failure and the duration of interruptions in water supply, what can be described in the following way:

$$IR = I_u / R_i \tag{1}$$

where: IR – the customer interruption;
I_u – the sum of unplanned interruptions of water supply;
R_i – the total number of recipients.

and

$$T_{avg} = D_T / I_T \tag{2}$$

where: T_{avg} – the average time necessary to restore the water supply in case of unplanned interruptions in water delivery;
D_T – the sum of the duration of all interruptions in the water supply;
I_T – the total number of water interruptions.

The average time necessary to restore the water supply in case of unplanned interruptions in water delivery in the examined water network is shown in Fig. 1.

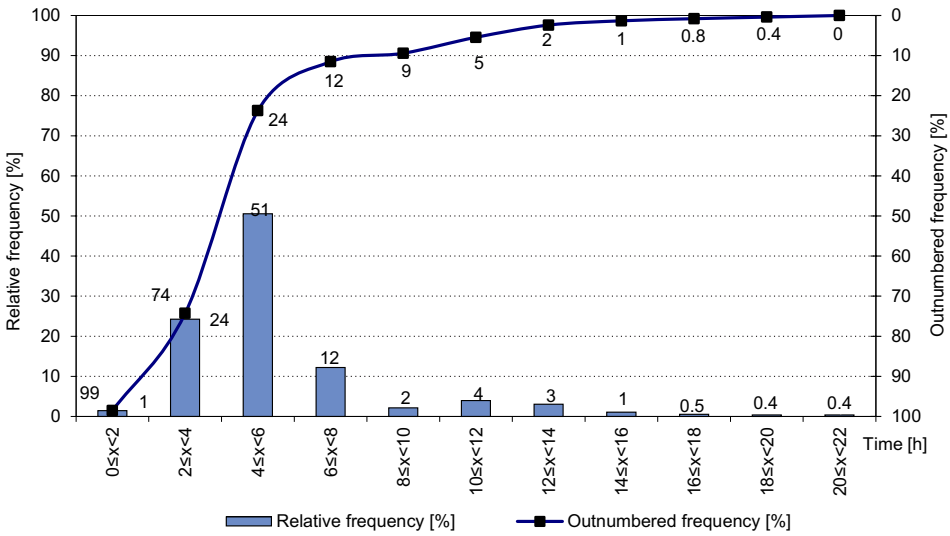

Fig. 1. Histogram of relative frequency and time-frequency summed renewal curve of water pipes

The service availability determined quotient of the time of the continuous water supply throughout the year and the time when there was the demand for water, can be reflected through following expression:

$$SA = (R_i \cdot 1 \text{ year} - R_i \cdot D_T) / (R_i \cdot 1 \text{ year}) \tag{3}$$

where SA is the availability service indicator.

The average values of presented indicators from 7-years period of time, on the example of the examined water supply system, were as follow: IR = 1.4 no of failures per recipient and year, T_{avg} = 2.5 h per failure and SA = 0.9127.

As to find the importance of calculate indicators from customers point of view, the initial survey was conducted among the recipients, concerning summary of loss and inconveniences caused by lack of water supply and kind of complaint for failure of not meeting quality standards of water supply. Based on this analysis three parameters where chosen to perform the further dissection: the service availability, price of delivered water and possibility to negotiate the discount for not delivered water.

Assessment of interruption in water supply through assumptions of willingness to accept method

In the preliminary study surveyed respondents were asked if the water supplier, in this case water company should compensate financial losses associated with the lack of water supply.

In the Fig. 2 the dependence between the response to the question of compensation by the supplier financial losses associated with the lack of water supply land the gender of the respondents.

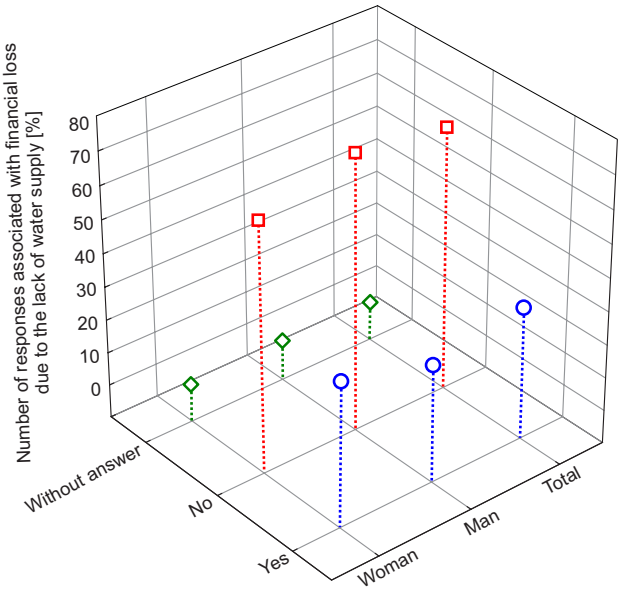

Fig. 2. Dependence between the response to the question of compensation the financial loss associated with the lack of water supply by the water supplier and the gender of the respondents

Among the surveyed about two-third answered that the supplier should not compensate the financial losses occurring during a lack of water supply. A different opinion have 29.5% of the respondents, while 1.5% did not answer this question. When taking into account the gender of the respondents, 65% of women and 73% of men believe that the supplier do not need to pay compensation for failure to meet certain parameters of water supply. Based on these results, it is concluded that gender does not have much connection with the opinion on compensation for financial losses due to the interruption of water supply. In the case of age category the highest percentage (about 70%) of people who believe that the supplier should compensate the resulting financial losses are people from 36 to 50 years old. The detailed analysis showed that people with the lowest income do not demand any compensation for financial losses for lack of water supply.

In the next question the respondents were asked about consent to pay higher water bills in return for reducing the number of interruptions in water supply.

In the Fig. 3 the dependence between the response to the question of approval for payment of higher water bills in return for reducing the number of interruptions in the water supply and the respondents gender was presented.

The majority of respondents, as many as 79%, did not agree to pay higher bills, the remaining 21% expressed such a willingness. As can be seen, the respondents are reluctant to agree to increase water charges in return for reducing interruptions of water

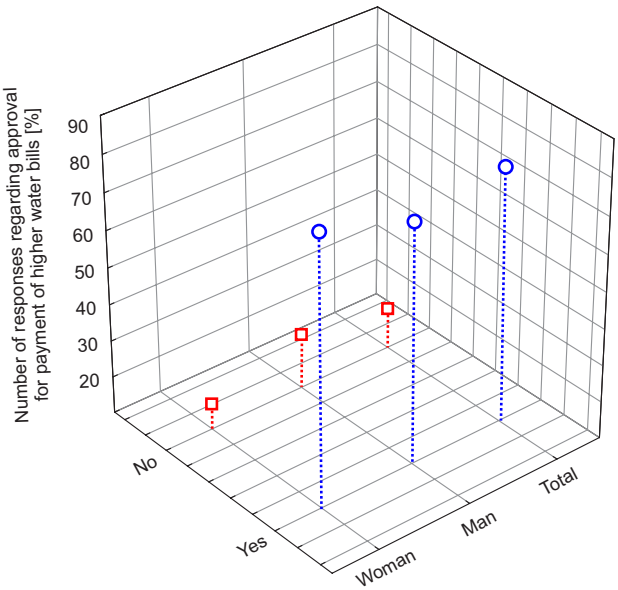

Fig. 3. The dependence between the answer to the question of approval for payment of higher water bills in return for reducing the number of interruptions in water supply

supply, which may be caused by the lack of certainty as to reducing the risk of lack of water supply. In detail, 75% of men and 83% of women do not agree to increase the water bills in return for a reducing the number of interruptions in the supply. Considering the dependence between the response to the question of approval for paying higher water bills and respondents age, in case of disagreement on the increase in bills, the largest percentage (about 88%) occurs in the youngest age group, between 18 and 25 years. In other age group, the results are not varied enough to say on this basis that the age of the people is important for the agreement to increase the bills in return for reducing the number of interruptions of water supply. Identical situation as in the previous question was for net income per family member, when in the least-earning group, 90% of respondents did not agree to an increase in water bills.

Another question concerned the maximum amount of increase in water bills in return for reducing the number of water interruptions. To this type of question only those people respond who in the previous question have agreed to pay higher bills. The respondents had unlimited choice in terms of the amount of the maximum increase of bills in return for reducing the number of interruptions of water supply. In the Fig. 4 the results of the analysis were shown.

Most people, as many as 65% would agree for payment of higher bills, provided that it will not increase by more than 5 EUR. In other categories, the number of people systematically decreases along with the increase in water bills. Nearly 90% of the respondents gave the increase of the bills should not exceed 12 EUR. The respondents generally do not decide to highly increase the bills in return for reducing the number of interruptions of water supply.

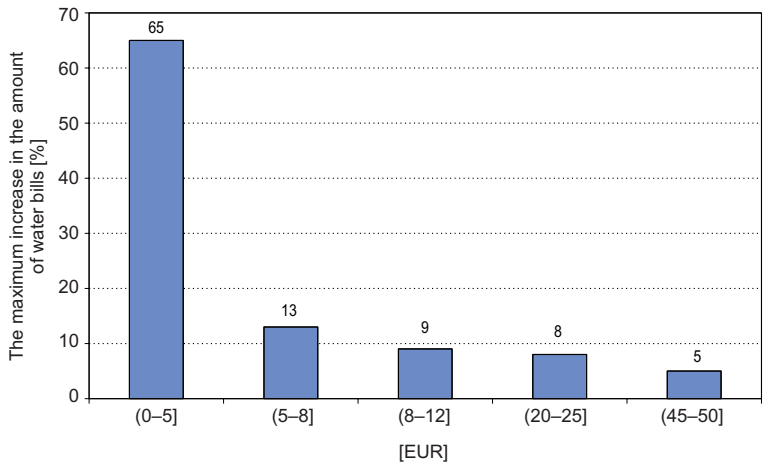

Fig. 4. The maximum amount of increase in the water bills for reducing the number of interruptions in the water supply

Determination of the risk of lack of water supply based on the performed consumers survey

The important issue in the assessment of the operation of water supply systems is risk analysis, an essential component in developing Water Safety Plans recommended by the WHO. They are considered as a basis for taking effective preventive measures to increase the level of protection of water consumers.

Risk is the product of the probability of undesirable event occurrence and the possible losses related to this event [10]. After having the answer to the question: Do You experience any interruptions in the water supply during last year? the probability of the risk associated with such event was calculated, also losses associated with the lack of water supply were established.

The next step was to determine the risk of non-delivery water according to the formula [10]:

$$R = \Sigma P \cdot C \tag{4}$$

where: P – the probability of undesirable event occurrence;
C – the amount of losses caused by the occurrence of undesirable event.

The empirical probability of the occurrence of undesirable event in the last year in the consumer's opinion is:

$P = 0$ – if the number of failures is zero,

and

$P = 1$ – if the number of failures is greater than zero.

The calculations were made in two groups: to the first group were included all the respondents and to the second group only those recipients who take water from the public water supply.

The risk of lack of water supply in both groups is the same, approx. 4050 EUR. This is due to the fact that all people who do not have the access to the public water supply, although sometimes experienced interruptions in water supply, assessed the water losses at 0 EUR. The risk value determines the losses that consumers would incur in the lack of water supply. Based on these results the further statistic was made.

The value of the average financial loss per a recipient for people using the public water supply system is 11 EUR, and for all the people 6 EUR.

Greater losses affected the recipients having access to the public water supply system, which is associated with the same level of the total financial losses.

Also the standard deviation for the financial loss was determined, which for all the respondents is σ = 24 EUR, and in the case of using public water supply system is σ = 29 EUR. The standard deviation characterizes the dispersion of data around the arithmetic mean. Results of the recipients having access to the public water supply system are more dispersed than for all the respondents.

Based on the answers of the respondents in several intervals relating to interruptions experienced in the last year, the average amount of financial losses for one break in water supply was calculated.

A smaller average amount of financial losses for one break in the water supply concerns all the respondents and slightly exceeds the amount of 5 EUR, while for people provided with tap water from the public system this value is about 6 EUR.

Conjoint analysis as a method of measuring the customers' preferences

In order to propose a contract for the water supply, concluded between the water supply company and the various categories of customers, de-compositional method was used, based on multivariate measurement (*ie* measuring the total coexistence of variables) – conjoint analysis [19–21].

In this method, the recipients make an assessment of attribute sets of provided services. The choice of attributes involves information regarding the services characteristics, on this basis the decomposition of generalized priorities preferences relating to the levels of services characteristics is made.

As a result, the preferences are aggregated, and therefore the preference measurement occurs at the level of services characteristics. The steps of conjoint analysis are shown in Fig. 5 [20, 21].

Firstly, the subject of research was defined, that is the choice of the individual parameters describing the service and levels. In the next stage the model form was specified, then the method of data collection and the choice of preference measurement scale were defined. In the last step the method for model estimation was assumed and the total utility was interpreted and used to assess the performance of the proposed service.

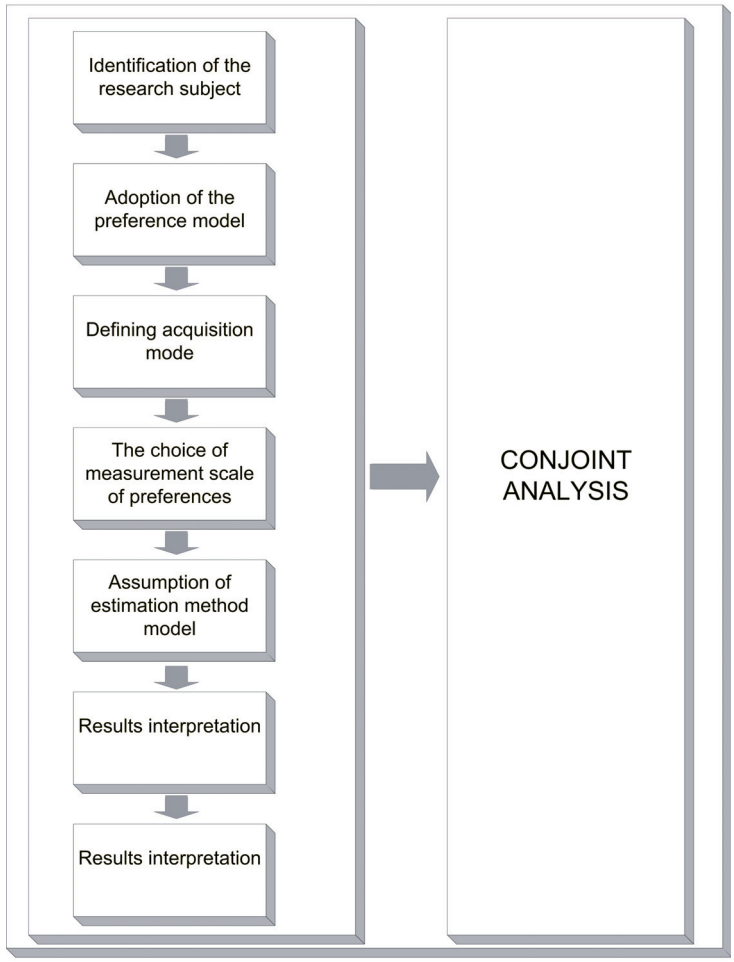

Fig. 5. Steps of conjoint analysis

Conjoint analysis was performed using Statistica software. Developing a proposal for an agreement between the supplier and the recipient, three variables and categories that describe the variable data, were distinguished:

– price levels for 1 m^3 of delivered water: 5 EUR, 7 EUR, 12 EUR, 15 EUR,

– the availability ranges of water services depended on the duration of interruptions in water supply throughout the year: $\leq 6\ h \cdot a^{-1}$, $(6–10]\ h \cdot a^{-1}$, $(10–12]\ h \cdot a^{-1}$, $(12–16]\ h \cdot a^{-1}$, $> 16\ h \cdot a^{-1}$,

– the possibility to negotiate discounts for failure to meet water supply standards: yes, no.

At the beginning of the analysis the subject matter of research was defined, that is the choice of the individual parameters describing the service and levels. In the next stage the model form was specified, then the method of data collection and the choice of

preference measurement scale were defined. In the last step the method of estimating model was assumed and the total utility was interpreted and used to assess the performance of the proposed service.

On the basis of certain variables and their levels 32 product variants were created. However, such situation does not resolve the dilemma of the product purchaser, because he does not know which version of the product would be best for him. This situation is more difficult, when there are more options of contract to choose from. In order to facilitate the option choice by the customer it is proposed to implement a conjoint analysis.

This method consists in selecting 6 the most contrasting options of given product or service, which significantly reduces the number of options helping customers in choice. After analysis the most contrasting contracts, a total of eight contrasting contracts, were proposed to recipients. In this way, a customer can easily rank them from the most to the least preferred [19].

Total utility for the *i*-th offer and *j*-th respondent is calculated as follows [20]:

$$X_{ij} = \sum_{k=1}^{m} X_{ik}^{j} + b_{0j} \tag{5}$$

where: X_{ij} – total utility for *i*-th offer for *j*-th respondent;
X_{ik}^{j} – total utility of category of *k*-th attribute, which occur in the *i*-th offer;
b_{0j} – is absolute term for *j*-th respondent.

For each respondent the indicator of the relative importance for various parameters of offer was determined as [20]:

$$W_k^j = \frac{\max\{X_{ik}^{j}\} - \min\{X_{ik}^{j}\}}{\sum_{k=1}^{m} (\max\{X_{ik}^{j}\} - \min\{X_{ik}^{j}\})} \tag{6}$$

where: W_k^j – the relative importance of *k*-th attribute of offer for *j*-th respondent;
X_{ik}^{j} – theoretical partial utility of *i*-th level of *k*-th attribute for *j*-th respondent.

Zero-one coding was applied, because the independent variables are qualitative in nature and, therefore, will be presented by means of artificial variables. In the zero-one coding *n*-categories of variables are replaced by $n - 1$ artificial variables, where the omitted category is the reference category [20]. Then the utility function coefficients were calculated, thereby obtaining the utility of each category. Utilities have been designated for each respondent and individual profile. In this way, the information on the utility of each profile, defined by a given category assessed by individual respondents, was obtained. On this basis, the ranking of individual profiles was calculated.

Determination of the utility functions of three important variables for each individual customer and its partial utility were as follows:

– price per 1 m^3 of delivered water: 5 EUR (0.27), 7 EUR (0.1), 12 EUR (0), 15 EUR (–0.4),

– the availability of water services depended on the duration of interruptions in water supply throughout the year: ≤ 6 h $\cdot$ a^{-1} (0.38), (6–10] h $\cdot$ a^{-1} (0.34), (10–12] h $\cdot$ a^{-1} (–0.36), (12–16] h $\cdot$ a^{-1} (–0.41), $>$ 16 h $\cdot$ a^{-1}, (–0.55),

– the possibility to negotiate discounts for failure to meet water supply standards: yes (0.7), no (–0.1).

The partial utility of the variable describing the price is a decreasing function, the lowest price is preferred. The largest decline occurred in the interval between 12 and 15 EUR, so recipients negatively react to changes associated with higher price levels. In the case of ranges of water services availability, we deal with a nominal scale. Preferred in this case are the category of water interruptions lasting less than 6 hours, also the possibility to negotiate discounts for failure to meet water supply standards is chosen.

The final step of the analysis was to obtain information about the relative importance of each factor for each respondent.

Determination of the utility functions of three variables for each individual customer, including validity factor were as follows:

– price per 1 m^3 of delivered water: 5 EUR (31%),

– the range of services availability depending on the duration of interruptions in water supply during the year: ≤ 6 h $\cdot$ a^{-1} (32%),

– the possibility to negotiate discounts for failure to meet water supply standards (36%).

Preferences of the respondents in the entire group were the most influenced by the ability to negotiate discounts for failure to meet water supply standards, then the availability of water services, the weakest factor proved to be the price per 1 m^3 of delivered water.

According to the statistical analysis the highest-ranked agreement made by the recipient of water supply system was the contract containing the following attributes: price per 1 m^3 of delivered water: 5 EUR, the range of services availability depending on the duration of interruptions in water supply during the year: ≤ 6 h $\cdot$ a^{-1} and the possibility to negotiate discounts for failure to meet water supply standards.

If it turns out that the contract with the highest degree of preference cannot be realized, then the producer (in this case, the water company) will have knowledge of the alternative contract – the next best in terms of preference. The proposed analysis of services level assessment provided by the water companies using the conjoint analysis enables the presentation of characteristics differentiation indicating which water supply systems are characterized by high quality services.

Conclusions and perspectives

This paper considers the application of the survey analysis method, in order to assess the water quality services proposed by the water company. Using conjoint analysis the

importance and order of the individual preferences of recipients can be determined, by adjusting the profile of the needs of the market and the possibility to adjust the criteria for services to customer needs. An important advantage of survey analysis is the study of the market in real conditions.

Continuation of the subject of the work should be directed to assess the financial losses caused by lack of water supply, as to develop quality standards for water service levels taking into account the consumer and water companies opinion. The presented methodology and the results obtained using the survey through risk analysis is an important set of information from the water consumers point of view.

The proper management of public water supply consequently will allow to control the quality of services related to the supply of drinking water of the required parameters.

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BADANIA SONDAŻOWE PREFERENCJI KONSUMENCKICH NA TEMAT FUNKCJONOWANIA ORAZ ZARZĄDZANIA DOSTAWĄ WODY

Zakład Zaoaptrzenia w Wodę i Odprowadzania Ścieków
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Abstrakt: Stały i długotrwały rozwój cywilizacji wpływa na wzrost występowania zagrożeń związanych z funkcjonowaniem systemu zaopatrzenia w wodę (SZW). Prezentowana metodologia może być stosowana w celu oceny prawidłowego funkcjonowania wodociągów. Opinie konsumentów mogą być stosowane przy określaniu standardów niezawodności usług wodociągowych oraz zasad udzielania bonifikat i upustów w przypadku ich niedotrzymania. Ważnym zagadnieniem jest ocena przez respondentów uciążliwości (czasu oraz częstotliwości), uniedogodnień, a także wielkości strat finansowych spowodowanych brakiem dostawy wody. W pracy przedstawiono wyniki badań oceny konsumentów podczas zdarzeń niepożądanych w polskich systemach wodociągowych.

Słowa kluczowe: sieć wodociągowa, ocena konsumencka, analiza funkcjonowania systemu zaopatrzenia w wodę