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Development of Water Conservation Indicators for Office Buildings Using Delphi Method

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Abstract

One of the main concerns in source water protection and supply relates to the savings in water consumption in the building sectors. Office buildings are responsible for a considerable amount of water consumption worldwide. Thus, regulations on office buildings' water consumption would substantially reduce water consumption in the city as a whole. In order to achieve this objective, water indicators should be determined using an appropriate method. The present study focuses on the evaluation of water consumption patterns in an office building as well as the determination of the fundamental indicators for water conservation and optimization of water consumption patterns. To design and introduce the indicators using the Delphi research method, the effective parts in water consumptions for each of the building divisions have been first identified according to the consumption control improvement tools, and the index of each section also been designed. Therefore, one of the goals of this research is to identify and compile appropriate indicators of water consumption in an office building. As the first step, an office building is divided into different sections, including showers, bathrooms, kitchens, green space, and cooling/heating systems. Then, the Delphi method is utilized to prepare effective indicators of water consumption for each section. By determining each section's aforementioned factors, 38 confirmed indicators were presented for water consumption in an office building. In the end, 36 indicators which showed good validity and reliability with Cronbach's alpha values higher than 0.79 as well as Content Validity Ratios (CVR) higher than 0.53, and Content Validity Indices (CVI) higher than 0.8 are proposed as final indicators.

Keywords: indicator; water policy; source water protection; water conservation; validity and reliability; Delphi method.

1. Introduction

Many cities in the arid regions of the world face a water crisis as a consequence of population growth and increased water consumption. Besides, climate change and the resulting decrease in water resources have intensified water shortage (dangers) in several parts of the world. Worldwide, urban regions are one of the primary users of water resources where people have a large share of water consumption. Thus, residential and office buildings have a considerable effect on the drinking water consumption balance. Therefore, it is necessary to accurately measure and evaluate the amount of water consumption in this building sector using proper indicators.

Any evaluation and controlling action should be equipped with accurate and proper decision-making and judgment indicators to be effective. These accurate, proper, and functional indicators are the primary step in evaluating water resources management performance. Preparation of indicators and transforming them into criteria help responsible individuals to determine the performance alignment to the goals besides the strength and weakness points of this issue and take effective steps in necessary corrections [1].

The prohibition of misusing water and energy demands a comprehensive implementation of relative standards and consumption patterns in various areas. This requires an appropriate determination of primary indicators in water consumption. By using indicators, the consumption rate and the relative effects are measured to help the planners in the water consumption field design proper water consumption patterns and prevent the unintended future consequences, making advantageous mutual results for environmental, agricultural, and urban profits [2].

The recent research showed that little knowledge is available regarding the performance efficiency of water consumption in office buildings. This lack of knowledge results in the inability of the market to respond to weak performances and to take suitable actions [3].

The unavailability of such acceptable water consumption indicators in office buildings makes it impossible to achieve the optimum water consumption pattern. Taking into account the preparation of indicators, the amount of functionality of indicators, and implementation of proper plans, positive results are achieved, including the decrease in water consumption, increase in construction quality, savings in energy consumption, and overcoming droughts.

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Important water consumption areas in an office building include bathrooms, showers, kitchens, green space, and cooling-heating systems. Any area can take priority over others and have higher consumption rates depending on the building application. Generally, the average amount of water consumption in different sections of a building is demonstrated in Figure 1(a). Cunliffe et al., studied the rates of water consumption in an office building in 2008 [4]. According to their study, office buildings are responsible for a considerable amount of water consumption. Yet, there are many grounds for savings. The key goal of their research is to determine those sections in an office building where savings can be achieved in water consumption. Different subsections, including taps, leakages, plants, irrigation type, and water recycling, are considered in their study, and solutions to lower water consumption are presented in each part [4]. Zoghi Moghadam researched water consumption in the Green Building of the United States [5]. Table 1 presents the water consumption in two types of buildings according to conventional standards and the optimum (LEED) conditions.

Table 1. Water consumption (per day) in different parts of the building in standard and optimal conditions [5]

Parts	**Standard (Gallons/person)**	**Efficient (Gallons*/person)**
Toilets	20.1	**5.12**
Washer	15.1	**10.6 or less**
shower	12.6	**5-10**
Faucets	11.1	**7-10.8**
Dishwasher	1	**0.5-1**
Leaks and Others	12.7	**<7.7**
TOTAL	72.5	**36-42**

* The US gallon is used in the United States and is equal to 3.785 liters.

Achieving proper water efficiencies requires efficient Strategies such as: repairing the leaking taps, using proper showerheads, installation of flow switches in bathrooms, and using low consumption washing machines. One of the essential and efficient subjects for saving in water consumption in buildings is recycling used water for appropriate applications, e.g., irrigation and bathroom flush tanks. Therefore, the maximization of sewage efficiency in buildings is one of the key goals of water consumption decrease. More than two-thirds of the consumed water in buildings relate to the bathrooms and showers, leaving these two sections among the most necessary sections for saving strategies [5].

Schuetze et al. studied different coefficients of water consumption in buildings in 2013 [6]. The potential for saving of water consumption was discussed using environmentally sound technologies (ESTs) and the relative measurements using the Wise Water software. Required studies, were determined in buildings, for which a considerable water consumption saving was possibly obtained with relatively small efforts and no limitations. Also, different methods of estimating the recycled water, rainwater, and the potential for using it as drinkable water-in-access were evaluated. According to their study, using proper taps and shower heads with low flow rate (low-consumption), can result in considerable water consumption savings, since more than 50 percent of the total water consumption occurs at these units. The actual amount of saving in this section depends on various factors, e.g., water pressure, types of taps and showerheads, flow distribution in taps, and the type of application in water consumption. A decrease in flow rate in valves from 14 to 7 lit/min results in an approximate saving value of 29 percent. More than 50 percent of the residential water consumption occurs using these connectors, for washing (kitchen) and bathrooms (which account for at least 46 percent of the total consumption) and toilets. Eventually, when the attitude regarding the washing level and taps is changed, saving between 23 to 43 percent is achievable. In this research, other strategies were introduced for savings, in water consumption [6].

Chebaane and Hoffman researched water consumption in office buildings in 2017 [7]. Any saving in water consumption relating to decreasing the amount of greywater and sewage led to a decrease in demand for energy used to heat or cool the water, resulting in a lower consumption as well as energy expenses. Their study showed that the office buildings are one of the main consumer sections of drinkable water in countries, and as it is shown in Figure 1(b), they are responsible for 38 percent of the total drinkable water consumption [8]. Based on their study, the most extensive consumer sections of water in an office building include bathrooms, toilets, and kitchens. Figure 1(c) indicates this division [7].

Chebaane and Hoffman described the gardens of office buildings as the largest consumer section outside the building area and presented strategies, including appropriate selection of plants for each climate, and proper selection of irrigation methods, using proper fertilizers, to achieve savings in water consumption. The next part of their research is related to the soil type in regions, which indicated a strong influence on the water consumption rate in green spaces [7].

Das et al. studied the optimization of water in the United States Green Building in 2015, describing the required water for irrigation purposes as the most extensive consumer section in an office building. They presented operational strategies to decrease water consumption in different consumer sections, including bathrooms, showers, green spaces, kitchens, and rainwater collectors. Using greywater and rainwater was shown to be an effective method for improving water consumption patterns to acceptable extents. Therefore, based on Das's research, the green space is considered as one of the largest water consumer sections in an office building for the preparation of indicators in the present study [8]. Table 2 shows a number of articles used to identify and introduce the indicators in this study.

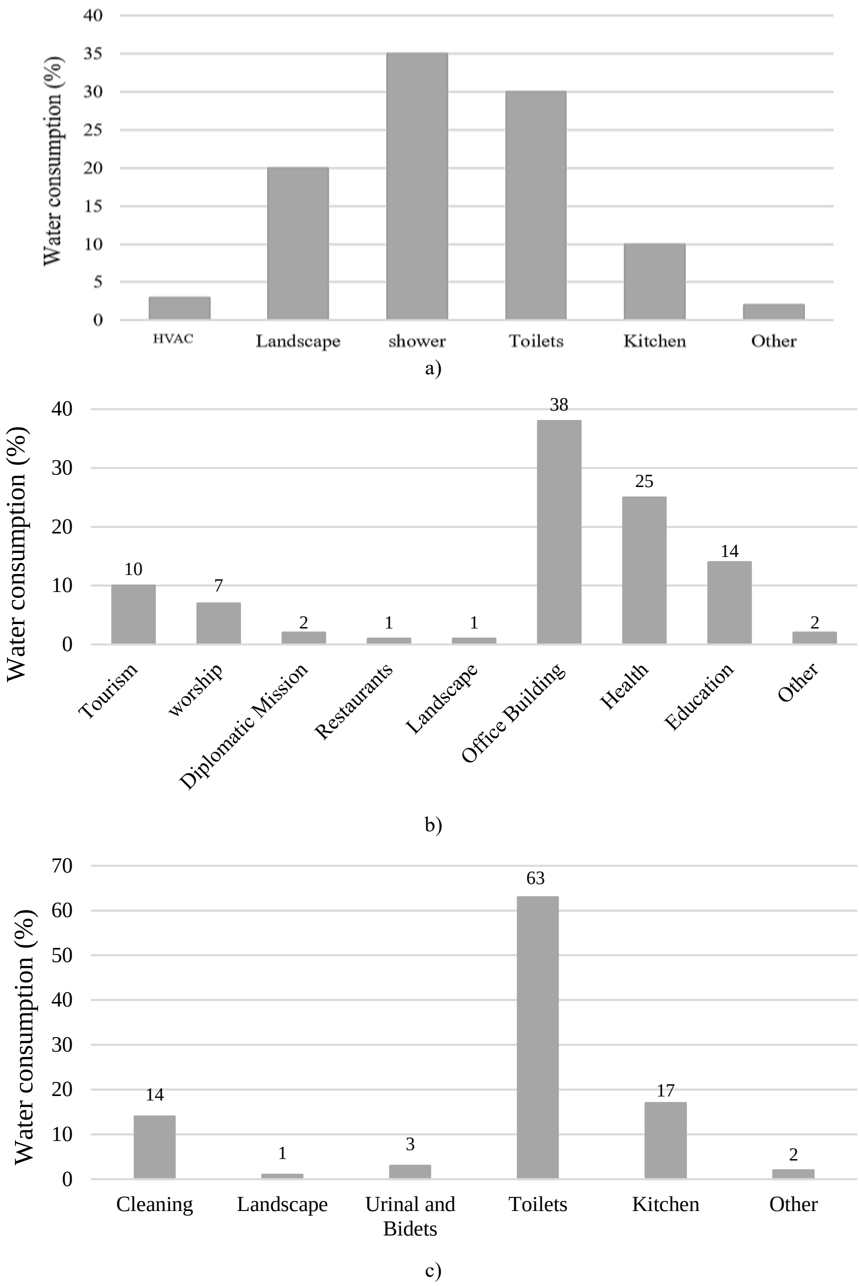


Figure 1. Percentage of water consumption, a) in different parts of an office building (HVAC: Heating, ventilation, and Air conditioning), b) in different consumer sectors of a country [8], c) in different parts of an office building [7].

Table 2. Reviewed articles to identify practical indicators for saving and protecting water consumption in buildings

Reference	**Author** (.et al)	**Year**	**Conservation agent in the building**	**Measurement criteria (ideas for defining indicators)**
[25]	Proença	2010	Toilets, faucets	Flow rate, drain tanks
[26]	Ghisi	2014	Rainwater, gray water, equipment, toilets	Amount of water recycling, equipment consumption rate
[27]	Soares	2021	Plumbing equipment, fittings, toilets	Flow rate, tank drain, equipment consumption rate
[28]	Praveena	2021	Rainwater, toilets, plumbing	Amount of water recycling, flow rate, emptying of tanks, equipment consumption rate
[29]	Marinoski	2018	Rainwater, gray water, equipment	Amount of water recycling, equipment consumption rate
[30]	Bennett	2015	Vegetation	Consumption in different climates
[31]	Shikuku	2021	Rain water, gray water	The amount of water recycled
[32]	Şahin	2019	Rainwater, toilet, bath	Amount of water recycling, flow rate, emptying of tanks, equipment consumption rate
[33]	Gultekin	2018	Equipment, rainwater, gray water, bathroom, kitchen, toilet	Amount of water recycling, equipment consumption rate, flow rate, emptying of tanks
[34]	Chu	2021	Rain water, gray water	The amount of water recycled
[35]	Beithou	2011	Gray water	The amount of water recycled

1.1. Comparison of the present work with previous studies

According to the literature, as mentioned above, many researchers in this field seek strategies for savings in water consumption in buildings. However, none of them has focused on indicators or criteria to control the (total) amount of water consumption in the office buildings.

The present study can be argued to be the first comprehensive one in this field.

Previous researchers have categorized different parts of a building in respect of different methods. In the present study, similar schemes are selected for an office building.

This study focuses on the determination and preparation of appropriate indicators for the correction of water consumption patterns in office buildings.

Since, many of the indicators presented in this research are new because of their design, the Delphi research method has been used as an effective way to provide innovative research.

It aims at investigating the determination and preparation of existing indicators in different countries to correct water consumption patterns.

This study is composed of two main parts. The first section, determining Indicators, consists of three parts, including identifying water consumption sectors (spaces) in office buildings, identifying water consumption terms in consuming sectors (spaces), and development of the indicators for each water-consuming term. In the first section, a comprehensive study has been conducted on factors affecting water consumption.

The study, using the Delphi method, has resulted in the determination of 30 new indicators in the field of office building water consumption, which had not been investigated in the previous research works.

In the second section, the determined indicators (including 30 new indicators and six existing ones) were analyzed using CVR, CVI, and Cronbach's alpha methods for the first time, which ascertained the validity and reliability of the indicators (Table 3). By using this method, the validity of the proposed indicators in terms of water consumption control in an office building has been determined.

2. Research Methodology

The Delphi method is used in the present study. This method is mainly used to seek novel and reliable ideas or to gather appropriate data for decision-making [9]. The Delphi method is a structured process to gather and categorize the knowledge of a group of experts [10]. The experts answer questionnaires; then a facilitator provides an anonymized summary of the experts' forecasts as well as the reasons they provided for their judgments. Perez emphasizes the importance of the Delphi method and describes it as one for a “single-variable research” to forecast the future of technologies. On the other hand, the Delphi method is used in futures studies. The Delphi method is a structured process for collecting and classifying the knowledge available to a group of experts,, which is done by distributing questionnaires among these people and controlled feedback on the answers and comments received. On the other hand, one of the purposes of this article is to introduce indicators by which all effective factors in saving and conserving water can be identified. Therefore, the purpose of using the Delphi method is, firstly, to confirm the extracted indicators according to the opinion of experts, and secondly, according to their opinions and ideas, the number of indicators is completed and in a way all possible indicators can be covered.

The most important point in this process is understanding the objectives of using the Delphi method by experts. Answerers must have enough knowledge in the relative field and be familiar with the literature of the subject [11]. The diagram of the research process (research methodology) is shown in Figure 2.

Table 3. Different parts, methods, and innovations of the current work.

Part		**Method**	**Innovation**
Indicator determination	Identifying water consumption sectors (spaces) in office buildings	Library research	-
	Identifying water consumption terms in consuming sectors (spaces)	Library research and Delphi method	The comprehensive conclusion of factors affecting water consumption in each section
	Determining Indicators for each water consuming term	Library research and Delphi method	Determining 30 new Indicators
Indicator analysis	Examining the Validity and reliability of the determined indicators	CVR, CVI, and Cronbach's alpha methods-	Validity and reliability analysis of the determined water consumption indicators

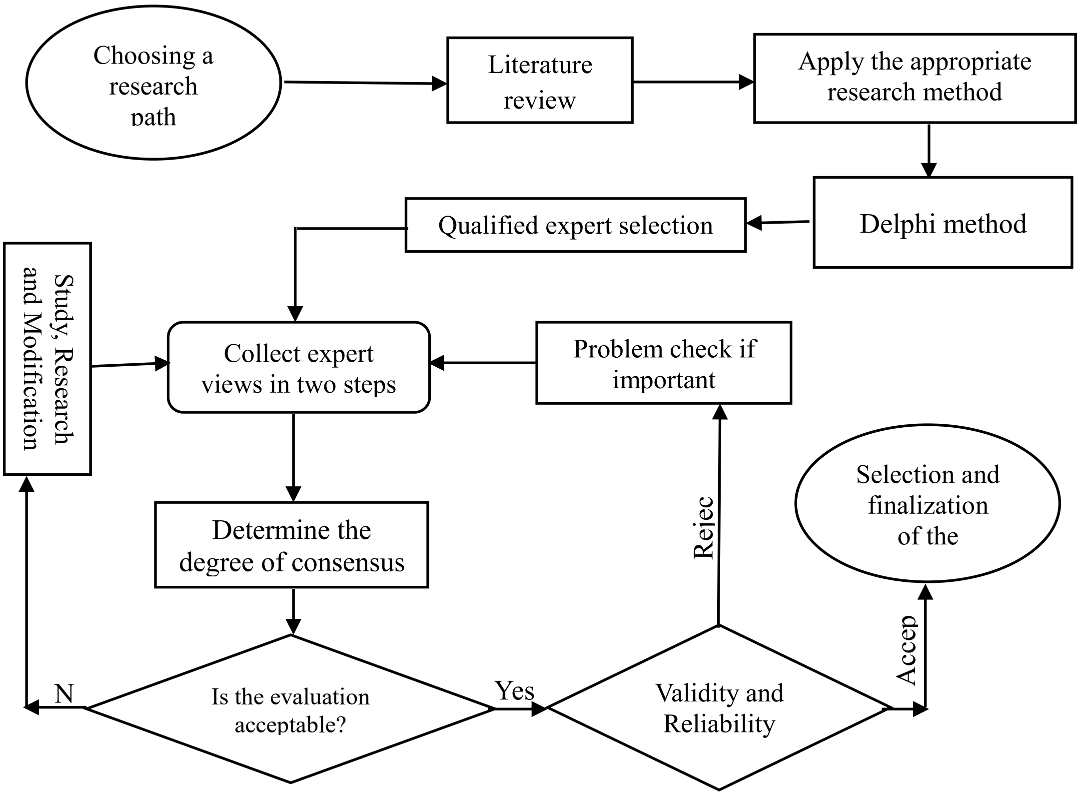


Figure 2. Diagram of research steps

2.1. Data collecting

The requirement of every research project is the proper gathering of the relative data to the research subject in terms of accurate and updated data. Therefore, two methods are used in the present study for collecting data: library studies and field studies. Libraries are the first suitable place to gather necessary data on every research subject. Thus, to have a literature survey of previous works on proposing patterns for optimization of water consumption in an office building, the required information was gathered. On the other hand, for field studies, the researcher has to go to the respective environment or desired group of users, communicate directly with the analysis units, including users, organizations, and institutes, to gather the required data. Two types of questionnaires are used in the present study for the field study [12]. Using questionnaires is preferred over other methods of data gathering methods such as interview and observation, for this method involves fewer errors due to orientations, lack of attention to considerations while answering the questions, simpler execution, the similarity of words and clauses and less consumed time [13].

After the extraction of criteria and indicators from documents, instructions, regulations, and consultations of the authors with experts in this subject, at the first stage, the first questionnaire was released between the knowledgeable and experts. A new questionnaire was prepared after the collection of the previously answered questionnaire from the experts and further studies. In this research, a semi-structured questionnaire has been used, which means that before delivering the questionnaire to each of the experts, first the model presented in the questionnaire was explained to them and then the questionnaire was completed by the experts. The research questionnaire is a researcher-made questionnaire that consists of 8 parts: examining the validity of the question, examining the ability to measure indicators, assessing the impact on water consumption and in fact the importance of the index in an office building, examining the application of the index in different climates , Examining the existence and non-existence of index improvement strategies to reduce water consumption in an office building, examining the characteristics of an appropriate and acceptable index in the developed indicators, examining the scalability and coefficient for the developed indicators and examining the possibility of calculation Indicators are formed in different seasons of the year (Table 4). In the second stage, the questionnaire was sent to the experts and knowledgeable about finalizing the mentioned criteria and evaluations. The final version of the questionnaire was designed after the evaluation of the selected indicators. This final questionnaire was approved by the experts and given to 30 by the experts in this field.

To quantify the opinions of the answerers, the five options Likert scales were used. The Likert scales consist of five qualitative clauses that the answerer decides one, based on their mental judgment over the importance of each criterion. Five qualitative clauses for the mentioned scale and their score equivalence and quantitative values are 1(very low), 2 (low), 3 (average), 4 (high), and 5 (very high). [14].

2.2. Statistical Population

A statistical population is a group of users or units with at least one common indicator [15]. The sampling scheme in the present study is based on the improbable snowball methodology. In the improbable snowball method, sample units are selected by the researcher as a representative of the population. The benefits of this method include the possibility of using the researcher's skills and knowledge in the selection of answerers and gathering the required information until the subjects are saturated [16].

In order to design proper indicators for water consumption in an office building, noting the technicality of the subject, it was necessary to refer to a statistical population, consisting of 30 experts, including individuals such as the authorities and experts in the fields of water, agriculture, aerology, geography, environment and management and operation of water resources with academic backgrounds, professional and managerial experience.

In the present study, efforts were made to select experts from different regions to differentiate between regional and universal indicators as one of the most important indicators of every reliable index. Figure 3 shows the frequency percentage of the statistical population used in this study based on the type of activity and expertise.

Table 4. An example of a questionnaire designed to evaluate indicators (for CVR)

	Indicator	Category	Questions	Evaluation				
1	Ex: discharge per minute	Ex: valves	Measurability?	very low	low	average	high	Very high
			Effectiveness on water consumption?	very low	low	average	high	Very high
			Usability in different climates?	very low	low	average	high	Very high
			Is there a tool or solution to improve this indicator?	very low	low	average	high	Very high

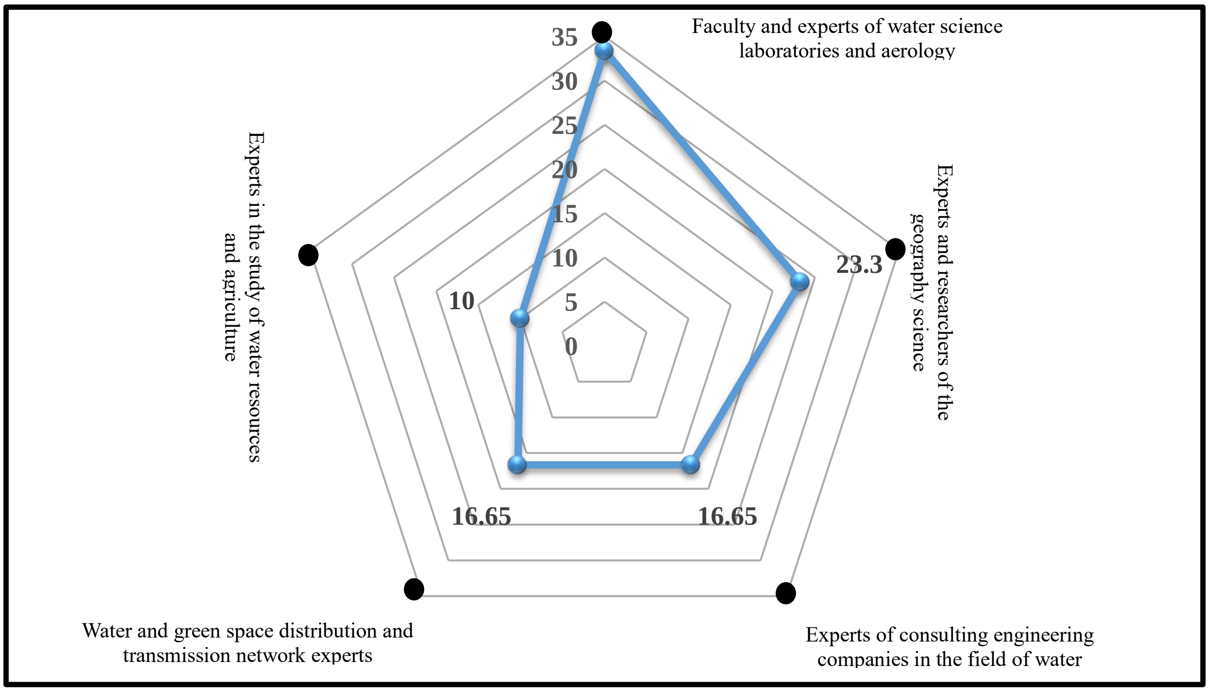


Figure 3. Graph of frequency percentage of statistical population by type of activity and specialty

2.3. Data Analysis

Gathered data are analyzed with descriptive and illative statistic methods. Descriptive and illative statistics are used for population and collected data analysis of the present study, respectively. Moreover, the commercial software MATLAB and SPSS are used for the analysis of data. To analyze the quality of indicators, illative statistical methods, e.g., the weighted average method, are used. The mean score of each factor, regarding its effectiveness, was calculated and categorized using the arithmetic mean, according to the description of scorings, 1 for: very few, 2 for: few, 3 for: average, 4 for: high, and 5 for: very high. Therefore, factors with a mean equal to or above three were selected as effective factors, and the remaining were deleted.

2.4. Validity and Reliability of Evaluation Tools (CVR & CVI)

The validity concept clarifies how well the measurement tool evaluated the desired indicator. One of the applicable methods in the determination of the validity of evaluation tools is the utilization of the content credit evaluation, proposed by Lawshe in 1975 [18]. This method measures the rate of the agreements of the knowledgeable and evaluators in "suitability or essentiality" of a criterion or the content of a model or a specific question [17]. The Lawshe coefficient needs to be calculated for each indicator and criterion according to equation 1 for illative evaluating. The content validity ratio (CVR) is calculated as follows:

$$\mathrm{CVR} = \frac{\mathrm{ne} - \frac{\mathrm{N}}{2}}{\frac{\mathrm{N}}{2}} \tag{1}$$

In the above relation, CVR indicates the Lawshe coefficient, N and ne represent the total number of experts and the number of users who had a positive view of the model or each of its evaluation criteria, respectively. The minimum value of CVR in the unilateral examinations of Lawshe was 0.33 for a statistical population of 30 users (Table 5) [18].

Table 5. The minimum values of CVR of Lawshe for suitability of content illation.

Minimum value of content illation ratio							
N of examiners	10	15	20	25	30	35	40
CVR	0.62	0.49	0.42	0.37	0.33	0.31	0.29

After the determination and calculation of CVR, the CVI index can be calculated. In order to calculate this index, examiners should state their opinion regarding three criteria of relativity or specificity, simplicity or fluency, and transparency or clearness, based on the 4-option Lickert scales for each item on the used instrument. As an example, for the criterion of measurement, options of not measurable=1, slightly measurable=2, measurable=3, and absolutely measurable=4, are used and then, using the equation 2, the content validity index (CVI) is calculated [19].

$$\mathrm{CVI} = (\text{the number of examiners who gave a score of "very high; high; yes and approved" to an indicator})/(\text{total number of examiners}) \tag{2}$$

The minimum value of the CVI index is 0.79. Hence an index with a CVI value of less than 0.79 must be omitted [20]. Reliability is defined as the capability of each tool to produce compatible results. Thus, it relates to the precision and accuracy of the measurement tools. Besides, reliability is the necessary condition for stability; therefore, reliability is a means of measurement on how close, accurate and reliable will the results of (a) measurement be, if the same questionnaire is repeated on the measured indicator [21].

The main purpose of using Cronbach's Alpha examination is to evaluate the internal similarity of the variables of a scale that is provided through introducing indicators process. This test is a way to examine the similarity of the individual's response to a variable in comparison with each of the other variables of the scale (the variable's correlation with the variable). Therefore, the reliability of the whole scale is evaluated. In fact, to measure the reliability of variables using the Cronbach's Alpha examination, the internal similarity or reliability of variables is measured [22]. Cronbach's alpha is calculated using Equation 3 for all indicators.

$$\alpha = \frac{\mathrm{k}}{\mathrm{k}-1}\left(1 - \frac{\sum_{\mathrm{i}=1}^{\mathrm{k}} \mathrm{s}_{\mathrm{i}}^2}{\mathrm{s}^2}\right) \tag{3}$$

Where, k, s_i^2, and s^2 indicate the number of questions, the variance of each question, and the variance of all questions, respectively. The closer the resulting coefficient is 1, the more reliable the questionnaire is. Note that an Alpha of less than 0.6 is generally considered to be weak. A value between 0.7 and 0.8 is considered acceptable, and values above 0.8 are appropriate. Closer values to 1 indicate better conditions.

3. Results and Discussion

An office building can be divided into different sections regarding previous studies. Division of water consumption of an office building includes bathroom, toilet, kitchen, green space, cooling/heating, and others. According to studies [7], it can be stated that the kitchen, shower, and green space are responsible for more than 97 percent of the consumed water in an office building. These sections take 35 and 30 percent of the total water consumption in an office building, respectively. This issue indicates the importance of these sections in preparing the indicators.

To fully divide sections of an office building, one must determine the influential factors on water consumption in any section, and then prepare the appropriate indicators. In showers, units, and parameters such as taps, showerheads, area, and the number of showers are among the key affecting items on water consumption. On the other hand, the flushing cistern, flush valves, taps, area, and the number of toilets are among effective items in bathrooms. Green space is one of the most important water consumption sections in an office building. Factors including the type of plants, irrigation method, water requirement of the plants, precipitation rate, irrigation with wastewater, depth of plant roots, evaporation and transpiration, soil moisture, area, and water supply are among the effective items on water consumption in green space.

When dividing a kitchen into different sections, most of the consumption relates to sanitary taps and kitchen floor area. Cooling-Heating is another part of water consumption in an office building. It has different consumption rates in respect of the type of the system. In this section, the rate of usage, exposure of cooling systems to sunlight, and insulation of pipelines can have a strong influence on the respective water consumption.

In addition to the aforementioned items, other factors exist that can affect the rate of water consumption in an office building. Among the most important of these are the technology used in the building, water pressure, greywater, storage tanks, the total amount of consumption, climate, and equipment. Figure 4 denotes the final division of an office building into different consumption sections.

Prior to the design and introduction of indicators, the various significant factors in water consumption, concerning the means of consumption control or optimization tools need to be determined for each section of the building. Table 6 shows the indicators developed in each section.

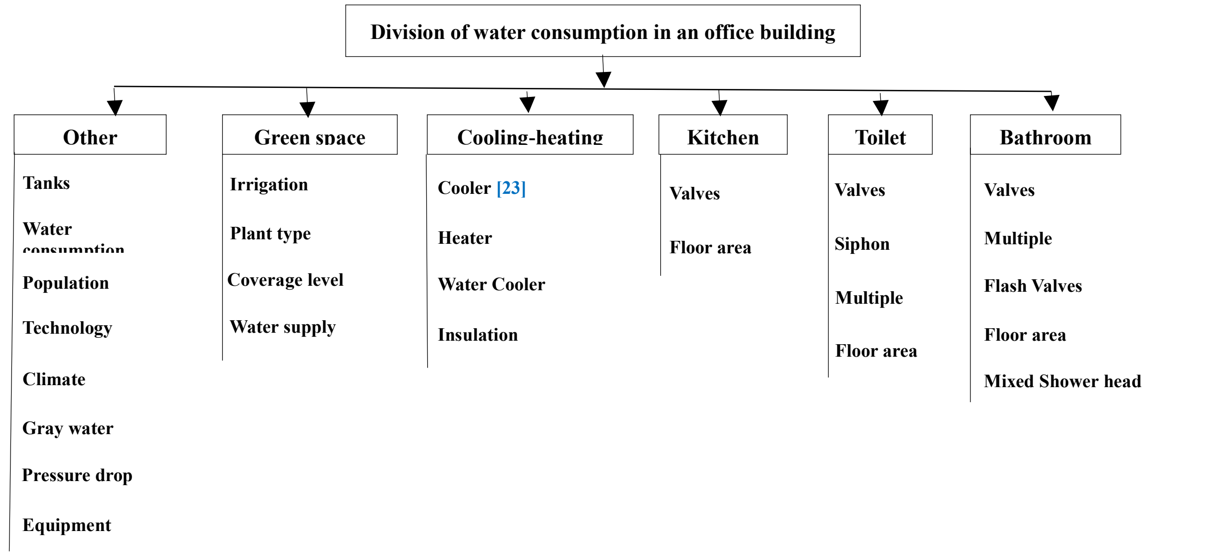


Figure 4. A final schematic diagram for categorizing water consumption in an office building

Table 6. Designed indicators in an office building.

Section	coding	Indicator No.	Categories	Indicator name	Indicator type	Calculation requirements
Bathroom (1)	$I_{1,1}$	1	Valves	Bathroom valves Discharge per minute	absolute	pipe diameter nozzle diameter nozzle type discharge outlet/discharge
	$I_{1,2}$	2	mixed Shower head	Air to Water ratio in the air and water mixed Shower head in bathroom	relative	pipe diameter nozzle diameter nozzle type discharge outlet air discharge
	$I_{1,3}$	3	Bathroom area	Maximum area of the bathroom floor	absolute	Bath floor area Building area
	$I_{1,4}$	4	Population	The ratio of the number of bathrooms to the average number of personnel in the office building per month	relative	number of bathrooms number of users per month
Toilet (2)	$I_{2,1}$	5	Valves	Toilet valves Discharge per minutes	absolute	Diameter of pipe nozzle diameter discharge outlet/discharge
	$I_{2,2}$	6	Siphon tank	Capacity of Toilet Siphon tank at each discharge	absolute	Siphon tank volume tank Dimensions
Kitchen (3)	$I_{3,1}$	7	Toilet area	Maximum area of the Toilet floor	absolute	The floor area of the toilet The total floor area of the building
	$I_{3,2}$	8	Population	The ratio of the number of Toilets to the average number of users per month	relative	number of toilets number of users per month
	$I_{3,3}$	9	Flush Valve	The volume of discharged water from the flash valve at each discharge	absolute	Discharge and volume of Discharged water pipe diameter water pressure
	$I_{3,4}$	10	Flush Valve and Siphon Tank	The supplied water ratio for the flush valve and the Siphon tank from recycled water (rain and gray) to the total water consumption for these two parts	relative	Precipitation gray water amount tank volume valve flash water volume
	$I_{3,5}$	11	Valves	Kitchen valves Discharge per minute	absolute	Diameter of pipe nozzle diameter nozzle type discharge outlet/discharge
	$I_{3,6}$	12	Kitchen area	Maximum area of the kitchen floor	absolute	Kitchen floor area Building area

Green space (4)	$I_{4,1}$	13	Irrigation	Difference in the amount of irrigation, evaporation and evapotranspiration divided by the plant's water demand	relative	amount of irrigation location of evaporation and evapotranspiration plant type plant water requirement soil moisture - root depth and ...
	$I_{4,2}$	14	Plant type	plant's Water requirement divide on available water	relative	area Water balance Plant type Plant water requirement Precipitation Runoff Humidity Penetration Evaporation and transpiration
	$I_{4,3}$	15	Coverage surface	green space to total space area (maximum area of green space)	relative	total area- green space area floor area
	$I_{4,4}$	16	Irrigation	ratio of amount of green space irrigation water to available water in the area	relative	area Water balance Plant type Plant water requirement Precipitation Runoff Humidity Evaporation and transpiration amount of Irrigation
	$I_{4,5}$	17	Water consumption	The amount of supplied irrigation water from gray water to the plant's water requirement per month	relative	Volume of gray water tank evaluation of purification system- plant type plant water requirement amount of precipitation
	$I_{4,6}$	18	Coverage surface	The ratio of the lawn area to the total area of green space	relative	measuring the green space area measuring the lawn area
	$I_{4,7}$	19	Recycled Water-Irrigation	The ratio of green space irrigated water from recycled water (rain, gray water) to the total water used for irrigation	relative	Precipitation amount of gray water water used for irrigation
Cooling – Heating (5)	$I_{5,1}$	20	cooler	ratio of the water required for cooling systems to the amount of water used for the best available cooler	relative	required water for building cooling system and base cooler
	$I_{5,2}$	21	heater	ratio of the water required for heating systems to the amount of water used for the best available heater	relative	required water for building heating system and base heater
	$I_{5,3}$	22	water cooler	the ratio of the duration in which the cooler is exposed to sunlight to the duration of sunshine in that climate	relative	Climatic Sun Length Per Day the duration in which the cooler is exposed to sun
	$I_{5,4}$	23	insulation	the ratio of length of insulated pipes to the length of total building pipes	relative	length of total building pipes and insulated pipes
Other section (6)	$I_{6,1}$	24	storage tanks	ratio of total water storage tanks to the number of people	relative	number of tanks number of people volume of each tank volume of total tanks
	$I_{6,2}$	25	total building consumption	ratio of total consuming water to the number of people per month	Relative	number of people Water meter numbers per month
	$I_{6,3}$	26	population	ratio of total annual consuming water to number of available people	Relative	number of people Water meter numbers per month for Related buildings and similar buildings
	$I_{6,4}$	27	Technology	ratio of number of modern valves to the total number of valves	Relative	Total number of valves number of modern valves
	$I_{6,5}$	28	climate-population	ratio of amount of annual total water consumption to the number of users divided by the amount of renewable water in the same year of the region	Relative	Water balance number of users Water meter numbers per month Precipitation evaporation and transpiration runoff river Lake Dam Groundwater Well Spring
	$I_{6,6}$	29	population	ratio of total consuming water to the number of users per month divided by Average of several similar buildings	Relative	Census Water meter number
	$I_{6,7}$	30	climate	ratio of water provided by modern rain management	Relative	Precipitation volume of annual or monthly storage water annual Water meter number

$I_{6,8}$	31	facilities	pressure drop in pipes to pipeline system length	Relative	Pipeline Map Pipeline Length and Number of Connections
$I_{6,9}$	32	valves	discharge of building pipes per minute	absolute	pipe diameter nozzle diameter nozzle type discharge outlet
$I_{6,10}$	33	pressure drop	pressure drop in pipes and counters to total provided pressure	Relative	pipeline map Pipeline Length and Number of Connections counter drop total pressure
$I_{6,11}$	34	pressure drop	ratio of adjacent street water pressure to pressure drop in mentioned building	Relative	Pipeline Map Pipeline Length and Number of Connections
$I_{6,12}$	35	water consumption	ratio of air to water volume in under pressure tank	Relative	tank volume water volume air volume …
$I_{6,13}$	36	water consumption	under pressure tank capacity to amount of water consumption per day	Relative	tank volume counter number
$I_{6,14}$	37	water pressure	the longest sanitary instrument distance to gravity tank	absolute	Volume of water and volume of air and volume of reservoir
$I_{6,15}$	38	water pressure	ratio of the number of stories using gravity water to total stories	relative	Water meter number volume of reservoir
$I_{6,16}$	27	Technology	ratio of number of modern valves to the total number of valves	Relative	total number of valves number of modern valves
$I_{6,17}$	28	climate-population	ratio of amount of annual total water consumption to the number of users divided by the amount of renewable water in the same year of the region	Relative	Water balance number of users Water meter numbers per month- precipitation evaporation and transpiration runoff river Lake Dam Groundwater – Well Spring
$I_{6,17}$	29	population	ratio of total consuming water to the number of users per month divided by Average of several similar buildings	Relative	Census Water meter number
$I_{6,18}$	30	climate	ratio of water provided by modern rain management	Relative	Precipitation volume of annual or monthly storage water annual Water meter number
$I_{6,19}$	31	facilities	pressure drop in pipes to pipeline system length	Relative	Pipeline Map Pipeline Length and Number of Connections
$I_{6,20}$	32	valves	discharge of building pipes per minute	absolute	pipe diameter nozzle diameter nozzle type discharge outlet
$I_{6,21}$	33	pressure drop	pressure drop in pipes and counters to total provided pressure	Relative	pipeline map Pipeline Length and Number of Connections counter drop total pressure
$I_{6,22}$	34	pressure drop	ratio of adjacent street water pressure to pressure drop in mentioned building	Relative	Pipeline Map Pipeline Length and Number of Connections
$I_{6,23}$	35	water consumption	ratio of air to water volume in under pressure tank	Relative	tank volume water volume air volume …
$I_{6,24}$	36	water consumption	under pressure tank capacity to amount of water consumption per day	Relative	tank volume counter number
$I_{6,25}$	37	water pressure	the longest sanitary instrument distance to gravity tank	absolute	Volume of water and volume of air and volume of reservoir
$I_{6,26}$	38	water pressure	ratio of the number of stories using gravity water to total stories	relative	Water meter number volume of reservoir

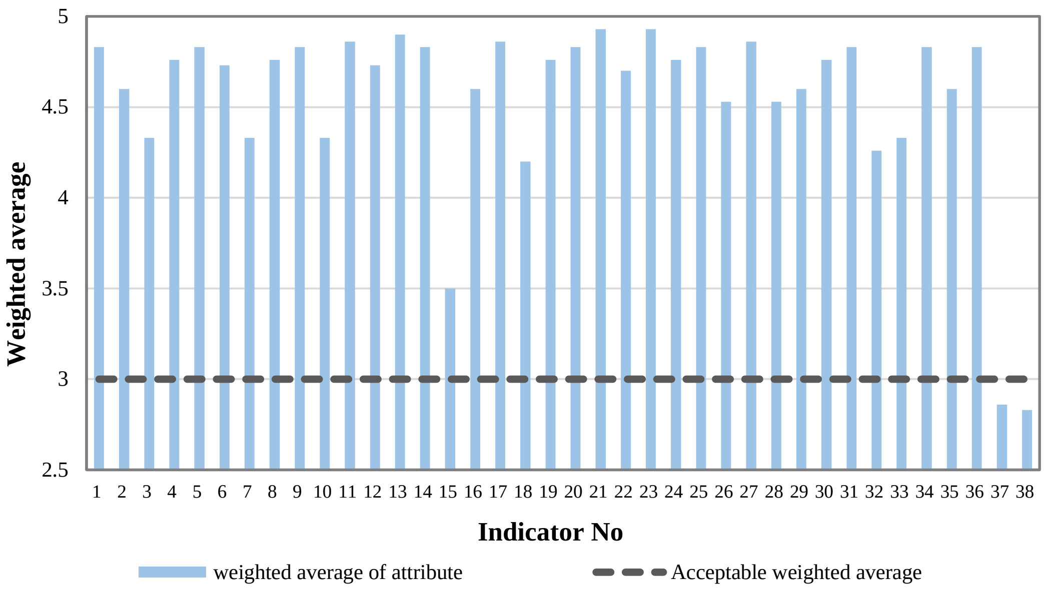
The weighted average of response to each indicator is its state of being illative and stable for its final design. As the accepted indicators are required to have an average of higher than 3 to be considered in the validity and reliability examinations, the presented indicators in Table 7 and Figure 5(a) with an average of less than 3 are omitted, and their reliability and validity will not be evaluated.

Table 7. Deleted indicators with a weighted average of less than 3

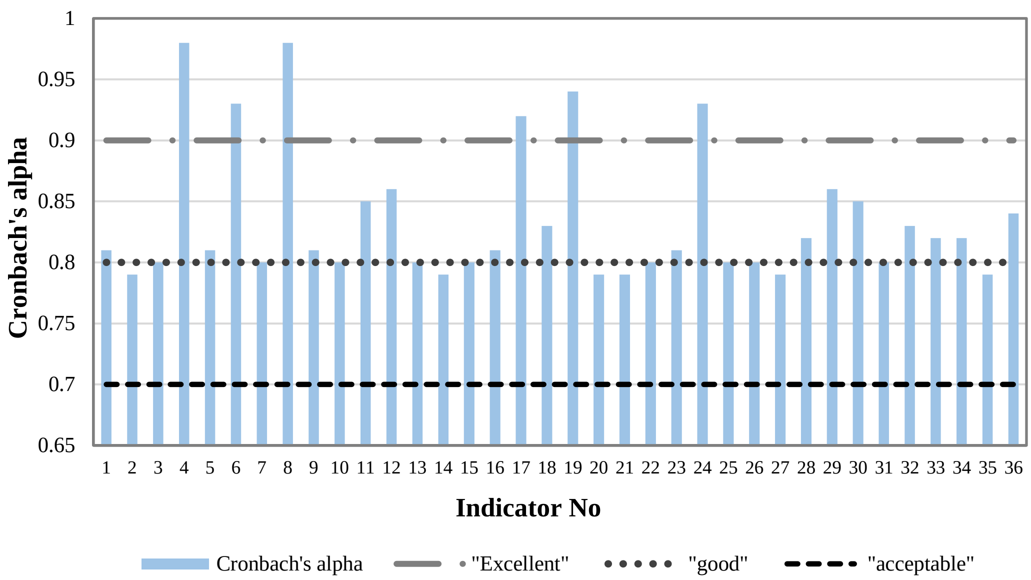
Indicator No.	Indicators with a weighted average of less than 3	Weighted average
37	highest sanitary instrument distance to gravity tank	2.86
38	ratio of number of stories using gravity water to total stories	2.83

Reaching a Cronbach's Alpha value of greater than 0.79 indicates that indicators with four designed questions have acceptable reliability (Figure 5(b)). As it was stated, reliability is the necessary condition for the evaluation of index validity. Therefore, the validity can be evaluated. The content validity can be qualitatively calculated regarding the opinions of technicians and according to the content validity, CVR, and its index, CVI. The minimum value of CVR in unilateral examinations of Lawshe is 0.33 for a statistical population of 30 users. The validity ratio of the content is higher than 0.33 (above 0.53) for all indicators, meeting the conditions of content validity (Figure 5(c)).

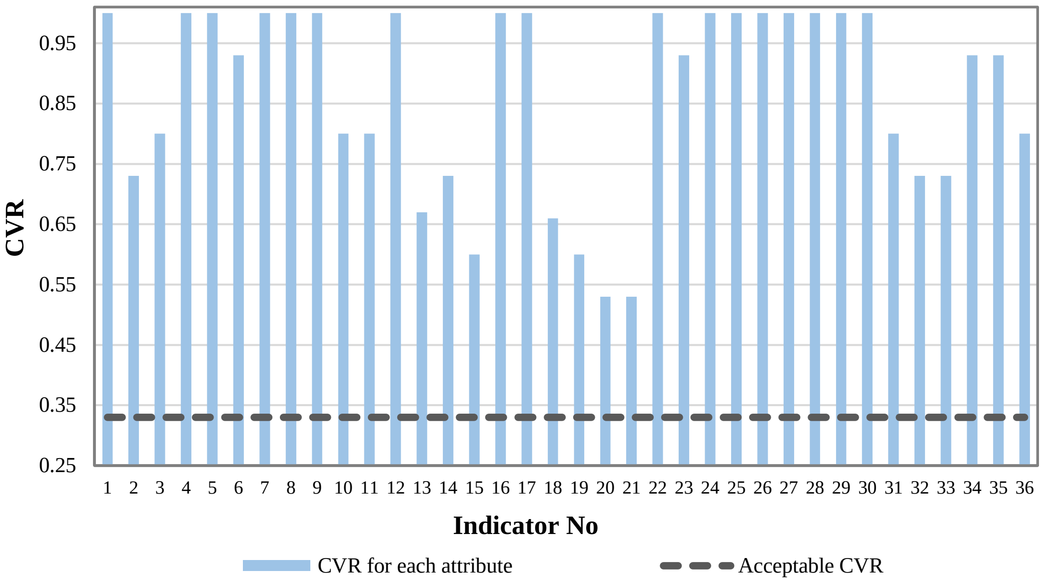
The validity indicator of the content is calculated for the final confirmation. CVI index can be calculated after the calculation of CVR. The minimum acceptable value of the CVI index is 0.79, and lower values must be dismissed. Results show that all indicators have a CVI value above 0.8, being in the acceptable range with a confirmed validity (Figure 5(d)). According to examinations (weighted average, validity, and reliability), eventually, 36 indicators with high credit results are selected with respect to water consumption in an office building among the total number of 38 prepared indicators.



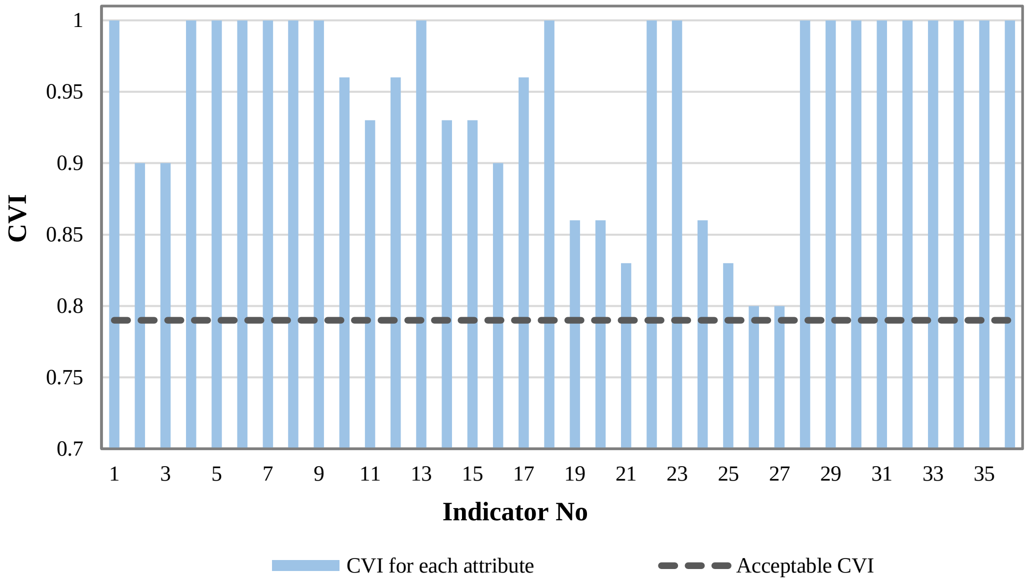
(a)



b)



c)



d)

Figure 5. validity and reliability of the indicators, a) indicators for evaluating, b) Calculation of the Cronbach's alpha, c) Calculation of the CVR, d) Calculation of the CVI.

As a practical- scientific conclusion of this article, we can mention the application of this article in arid regions of the world. For example, in Iran, in the top 5 largest cities (in terms of population), all of them (Tehran, Mashhad, Karaj, Isfahan, Shiraz) are in dry regions, and considering the indicators mentioned in this study, it is possible to reduce the needs for water consumption in those cities [24].

4. Conclusion

Introduction and control of indicators are of the proper methods for energy saving. Water consumption is not an exception, and by the preparation and design of proper indicators, not only can the consumption rate be controlled, but also it can be optimized. Previous studies indicate that the office buildings are among the most important water-consuming sections in a country. In this study, an office building is divided into different sections including units such as showers, bathrooms, kitchens, green space, and cooling/heating systems. The Delphi method is used to prepare effective indicators of water consumption for each section. In order to evaluate water consumption in an office building, 36 high credit indicators are presented as the results of this research. The main results of the present study include:

1. Due to the expert's opinions, four questions (which are mentioned in Table 3), are archived during the second stage of the Delphy method.
2. According to examinations (weighted average, validity, and reliability), eventually, 36 indicators with high credit results are selected among the total number of 38 prepared indicators (consist of 30 novel indicators).
3. Regarding to Cronbach's Alpha, $I_{1,4}$, $I_{2,2}$, $I_{3,2}$, $I_{4,5}$, $I_{4,7}$ and $I_{6,1}$ are the excellent accepted indicators.
4. Regarding to weighted average, $I_{1,3}$, $I_{3,1}$, $I_{3,4}$, $I_{4,3}$, $I_{4,6}$, $I_{6,9}$ and $I_{6,10}$ are the least important indicators in an office building.
5. For kitchens, taps and floor area have a large role in water consumption.
6. Factors, such as the amount of water consumption for each system, exposure of the cooling devices to sunlight, and insulation of pipelines strongly influence the water consumption in the cooling-heating systems.

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