Scientific Research Publishing

Computational Water, Energy, and Environmental Engineering, 2025, 14(3), 119-149
https://www.scirp.org/journal/cweee
ISSN Online: 2168-1570
ISSN Print: 2168-1562

New Method for Analyzing and Estimating Water Demand and Sizing Drinking Water Distribution Networks

Lakhdari Hocine[*], **Georgescu Andrei-Mugur**

Sanitary Engineering and Environmental Protection, Department of Hydraulics, Faculty of Hydrotechnics, Technical University of Civil Engineering, Bucharest, Romania
Email: *lakhdari_hocine@hotmail.fr, andrei_georgescu2003@yahoo.com

How to cite this paper: Hocine, L. and Andrei-Mugur, G. (2025) New Method for Analyzing and Estimating Water Demand and Sizing Drinking Water Distribution Networks. *Computational Water, Energy, and Environmental Engineering*, **14**, 119-149.
https://doi.org/10.4236/cweee.2025.143007

Received: June 21, 2025
Accepted: July 28, 2025
Published: July 31, 2025

Abstract

In the context of drinking water network management, the accurate estimation of flow rates at various system nodes is a central concern. This assessment is critical to ensuring stable, reliable distribution that meets users' actual needs. However, the traditional methods used to date exhibit certain weaknesses when it comes to taking into account unpredictable variations in consumption or losses that can occur throughout the network. In light of these limitations, a new approach has been developed to provide a more appropriate response to these challenges. This method is based on more detailed modeling, integrating not only the physical and technical constraints related to network hydraulics, but also the uncertainties inherent in consumption behavior. By combining these elements, it allows for a more realistic and dynamic assessment of flow rates, facilitating optimal infrastructure design. To test the robustness of this method, a comparative hydraulic simulation was conducted on a model representing a real urban distribution network in real operation. The results obtained confirmed the value of this approach, highlighting a significant improvement in the accuracy of water flow estimation at different points in the network. This increased accuracy translates into better intervention planning, more precise adaptation to the needs of the areas served, and optimized resource management, particularly in urban environments where constraints are greater and demands are more fluctuating.

Keywords

Water Demand, Distribution Networks, Hydraulic Simulation, Optimization

1. Introduction

Sustainable water resource management is one of the major challenges of the 21st century, particularly in a context of population growth, rapid urbanization, and the environmental challenges of climate change [1]. Drinking water distribution networks play a crucial role in supplying and meeting the water needs of populations, but their design and sizing are often based on traditional methods that fail to account for spatio-temporal variability in demand and recent changes in usage. Given these limitations, it is essential to develop more precise and dynamic methods and approaches to estimate water demand and optimally size networks to ensure reliable and balanced water distribution, reduce losses, and optimize water resources [2].

Indeed, traditional methods for calculating distribution networks are based on peak flow, which is considered constant, while the water needs of populations are highly varied and are constantly increasing over time at the urban scale [3].

Currently, several conventional methods are used for calculating the flow rate in drinking water networks, including models based on continuity and energy conservation equations.

They require heavy iterative calculations that can be costly in terms of computing time. They are sensitive to the quality and accuracy of the input data (consumption, pressure, pressure losses, etc.) [4] [5].

Faced with these challenges, it is becoming relevant to explore new approaches for better, more efficient, and tailored optimization.

One of the fundamental aspects of this optimization relies on the accurate calculation of flow rate at network nodes, an essential parameter for hydraulic analysis, and operation and maintenance decision-making. This innovative approach also paves the way for more efficient and sustainable management of water distribution systems.

The main objective of this work is to propose a new method for analyzing and estimating drinking water demand, based on calculating the flow rate at nodes in a distribution network. Finally, the method itself also aims to improve the sizing of distribution networks to better meet current and future needs while reducing operating costs.

2. Literature Review

2.1. Brief Literature Review on Traditional Methods

Estimating specific flow rates in drinking water distribution networks is essential to ensure optimal design, efficient operation, and sustainable infrastructure management. Several methods are used to determine these flow rates based on the demographic and urban characteristics of the service area. Among these methods, the most commonly adopted are the linear method, the area method, and the density method.

2.2. Linear Method

The linear method is based on the assumption that water demand is proportional to the length of pipes serving a given node. It is often used when detailed consumption data are not available. It is expressed as:

$$q_{sp} = \frac{Q_{p\,\text{domestic}}}{\sum_1^n L_i} \tag{1}$$

- The flow rate on the route is produced between the specific flow rate and the length of the section considered. We can write:

$$Q_{ri} = q_{sp} \times L_i \tag{2}$$

- The flow rate at the node is given by the following formula:

$$Q_{ni} = \frac{\sum_{i=1}^{n=n} Q_{ri}}{2} + \sum Q_{\text{equipment}} \tag{3}$$

where:

- q_{sp} : Specific flow rate (ℓ/s/m or km)
- $Q_{p\,\text{domestic}}$: domestic peak flow rate (ℓ/s)
- $\sum_1^n L_i$: the total length of the network (m) or (km)
- Q_{ni} : Flow rate at the node considered (ℓ/s),
- $\sum Q_{\text{eq}}$: the sum of the flow rates of the equipment concentrated at the node considered (ℓ/s).

This method is not precise because we can have a long pipe that serves only a few subscribers; therefore, the resulting flow rate is very high. It is recommended that the equivalent length method be used instead of the geometric length. We associate a coefficient called the equivalent coefficient C with the geometric length [6] [7].

2.3. Area Method

The area method allocates demand based on the area served by a node. It is useful in residential areas where population density is relatively constant.

The method is based on dividing the total surface area into subsurface areas surrounded by nodes.

- The specific flow rate is the ratio between the domestic peak flow rate and the total sum of the subsurface areas of the network. It is given by the following formula:

$$q_{sp} = \frac{Q_{p\,\text{domestic}}}{\sum_1^n S_i} \tag{4}$$

- The flow rate on the road is produced between the specific flow rate and the surface area served by the section considered. We can write:

$$Q_{ri} = q_{sp} \times S_i \tag{5}$$

where:

$$S = \sum_1^n S_i$$

- The flow rate at the node is given by the following formula:

$$Q_{ni} = \frac{\sum_{i=1}^{n=n} Q_{ri}}{2} + \sum Q_{\text{equipment}} \tag{6}$$

Among the disadvantages of this method is that it does not take into account the density of inhabitants per surface area [6].

2.4. Density Method

The density method is based on the population or activity density in a given area. It is particularly used in urban and metropolitan areas where the population varies from one sector to another.

This is the most accurate method that provides the actual flow rate served by the section in question.

- The specific flow rate is the ratio between the domestic peak flow rate and the total number of inhabitants. It is given by the following formula:

$$q_{sp} = \frac{Q_{p_{\text{domestic}}}}{\sum_1^n N_{pi}} \tag{7}$$

The flow rate on the road is produced between the specific flow rate and the number of inhabitants served by the section considered. We can write:

$$Q_{ri} = q_{sp} \times N_{pi} \tag{8}$$

The flow rate at the node is given by the following relation:

$$Q_{ni} = \frac{\sum_{i=1}^{n=n} Q_{ri}}{2} + \sum Q_{\text{equipment}} \tag{9}$$

N_{pi}: Number of inhabitants served by the section considered (inhabitants).

$\sum_1^n N_{pi}$: Number of inhabitants (inhab).

This method allows a more precise estimation of the specific flow rate by taking into account variations in population density and consumption habits [6] [8].

The choice of method depends on the geographical and urban context of the area under study. The linear method is suitable for rural areas; the surface method is suitable for cities with homogeneous development, while the density method is preferred for dense urban centers. A combination of these approaches is sometimes necessary for a more reliable estimate and better management of water resources.

Although these methods remain useful, they face several challenges and obstacles, including:

- Linear method: This does not take into account spatial and temporal variations in water needs, which can lead to overestimation or underestimation of flow rates.
- Area method: This assumes a uniform distribution of consumption over a given area, ignoring differences in population density and economic activities.
- Density method: This relies on statistical averages that do not capture demographic trends and changes in usage, sometimes rendering forecasts obsolete.

These methods lack flexibility and adaptability to actual consumption dynamics.

In the face of these problems and limitations, we propose a new method that allows them to be considered and addressed.

This method takes into account the density of population or activities (commercial, industrial, etc.) in the area under study. It is more accurate than previous methods because it incorporates demographic or socioeconomic data to estimate water demand according to well-studied criteria. It is often used for urban areas where population density varies significantly.

3. Field of Study

This work of ours falls within the framework of achieving a comparison between one of the classical methods, represented by the linear method, and the method that we will propose on a real example of the city of Massinissa in Algeria, as shown in (**Figure 1**), and concluding the comparison thereof.

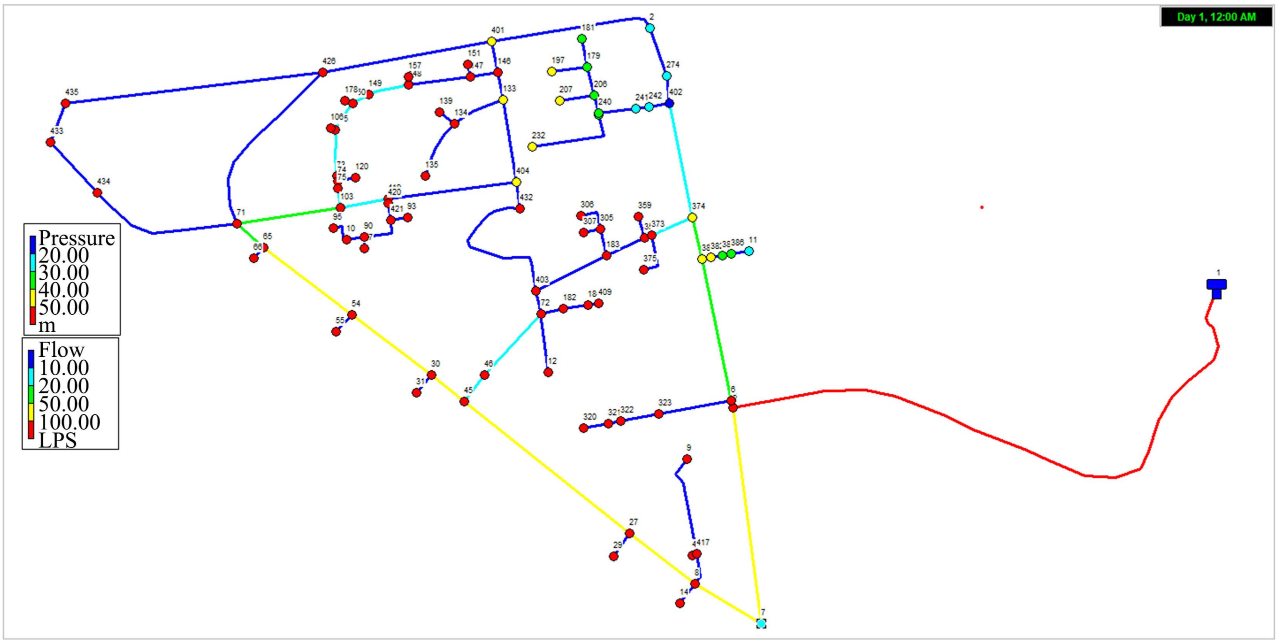

Figure 1. Distribution network, simulation: Pressure-flow.

3.1. Principle of Calculating the Water Distribution Network by the Linear Method

The linear method consists of establishing the flow rate at nodes using the following procedure: First, the peak flow rate is calculated, then the total network length is calculated, which will be used to calculate the specific flow rate. Finally, the flow rate calculation phase at nodes using the linear method is carried out as follows:

To calculate the peak flow rate, the current and future population numbers must be estimated according to the projection horizon, the allocation (ℓ/d/inhab), the average daily flow rate must be calculated, the maximum daily flow rate must be calculated, the increase coefficients must be calculated, and finally, the peak flow rate is calculated:

$$Q_p = Q_{avd} \cdot K_p$$

where:

$$K_p = K_h \cdot K_d$$

K_h: hourly coefficient, which expresses the irregularity of the population. It is given by: $K_h = \alpha_{\max} \times \beta_{\max}$ during the hours of the day.

$\alpha_{\max}$: coefficient that depends on the population's comfort level and the work schedule.

With: $1.2 < \alpha_{\max} < 1.4$

$\beta_{\max}$: coefficient that depends on the number of inhabitants. It varies between 0.2 and 1.15 for a population of less than 1000 to more than 50,000 inhabitants.

- Calculates the specific flow rate
- Calculates the transit flow rate
- Finally, calculates the flow rate at the nodes [9] [10].
- **Specific flow rate**

$$Q_{sp} = \frac{Q_p}{L}$$

where:

Q_{sp} : Specific flow rate.

Q_p : Peak flow rate.

L : Sum of all the lengths constituting the network.

The nodal flow rate is expressed by the following formula:

So, the flow rate of nodes:

- **Node flow rate:**

$$q_n = \frac{\sum L_i}{2} \times q_s$$

where:

q_n : Node flow rate.

$\sum L_i$: Sum of the lengths of the adjacent segments of this node.

q_{sp} : Specific flow rate [11] [12].

- The results obtained from the linear method

Number of inhabitants	32,180 inhabitant
Allocation in (ℓ/Day/Inhabitant)	100 (ℓ/day/inhabitant)
The average daily flow rate Qavg d	32318.00 (m^3/day)
Equipment 15% of the average daily flow rate	482.70 (m^3/day)
Total average daily flow rate Qavg d t	3700.71 (m^3/day)
K_d	1.2
K_h	1.53
K_p	1.836
Peak flow rate (Q_p)	6794.49 (m^3/day)
	78.64 (ℓ/s)
L	11746.6 (m)
q_{sp}	0.0066947 (ℓ/s/inhabitant)

3.2. Result Obtained from the Linear Method

These results are summarized in "Table 1" and "Table 2", respectively. These are the nodes results table and the arcs results table, after performing hydraulic simulation on a water distribution network model using EPANET software in both the linear method and the collective buildings method. These two tables are essential elements resulting from hydraulic simulation.

Table 1. Results of the node structures from the linear method.

Node ID	Elevation	Base Demand	Demand
	m	LPS	LPS
Junc 5	673	5.6715	5.66
Junc 6	674	1.7953	1.78
Junc 7	655	2.1735	2.16
Junc 8	637	1.5108	1.50
Junc 9	650	0.7260	0.73
Junc 14	635	0.7674	0.77
Junc 27	632	2.0118	2.01
Junc 29	630	0.7074	0.71
Junc 30	662	1.9124	1.90
Junc 31	660	1.0410	1.04
Junc 45	658	2.2673	2.25
Junc 46	661	0.7632	0.76
Junc 54	647	1.9883	1.99
Junc 55	648	1.1674	1.17
Junc 65	643	1.1526	1.14
Junc 66	638	0.937	0.94
Junc 71	642	4.6138	7.60
Junc 72	658	1.2932	1.28
Junc 87	653	0.837	0.84
Junc 90	655	0.4831	0.47
Junc 93	663	0.7138	0.71
Junc 73	656	0.3749	0.37
Junc 74	656	0.2254	0.21
Junc 75	658	0.1975	0.20
Junc 103	656	1.1861	1.17
Junc 105	654	0.6070	0.59

Continued

Junc 106	653	1.167	1.17
Junc 120	661	0.7105	0.71
Junc 133	679	2.2564	2.24
Junc 134	671	0.9618	0.95
Junc 135	667	0.7184	0.72
Junc 139	669	0.7072	0.71
Junc 146	678	0.7275	1.71
Junc 147	673	1.0609	0.72
Junc 148	662	0.9406	0.94
Junc 149	655	0.5624	0.56
Junc 150	653	0.4262	0.41
Junc 151	672	0.971	0.97
Junc 157	661	1.636	1.64
Junc 178	649	0.736	0.74
Junc 179	696	0.6940	0.68
Junc 181	694	0.7242	0.72
Junc 197	688	0.7141	0.71
Junc 206	696	0.5568	0.54
Junc 207	692	0.7074	0.71
Junc 222	699	0.7063	0.71
Junc 232	685	0.7262	0.73
Junc 240	699	0.4128	0.40
Junc 241	710	0.3682	0.37
Junc 242	711	0.2276	0.23
Junc 274	713	0.6594	0.66
Junc 182	654	0.3213	0.32
Junc 184	657	0.2477	0.25
Junc 320	641	0.7073	0.71
Junc 321	646	0.6343	0.63
Junc 322	648	0.3180	0.32
Junc 323	656	0.7029	0.70
Junc 183	665	3.8670	3.87

Continued

Junc 305	671	0.5434	0.21
Junc 306	671	1.7089	1.71
Junc 307	667	0.7938	0.79
Junc 358	673	0.4854	0.49
Junc 359	680	0.7206	0.72
Junc 373	676	0.7308	0.72
Junc 374	690	1.5275	1.51
Junc 375	675	0.7082	0.71
Junc 381	691	1.6647	1.65
Junc 382	693	0.1473	0.15
Junc 385	700	0.1473	0.15
Junc 386	703	0.1473	0.15
Junc 401	677	6.6478	6.65
Junc 402	717	1.2932	1.28
Junc 403	660	8.9955	8.98
Junc 404	681	1.6882	1.67
Junc 409	658	0.736	0.74
Junc 416	637	0.801	0.80
Junc 417	638	0.8748	0.86
Junc 419	662	1.2017	1.20
Junc 420	662	0.1406	0.14
Junc 421	660	0.5066	0.49
Junc 426	648	5.5131	5.51
Junc 95	653	0.7140	0.71
Junc 432	678	3.9590	3.96
Junc 433	625	0.8647	0.85
Junc 434	629	1.6212	1.61
Junc 435	623	2.0698	2.06
Junc 10	652	0.2946	0.29
Junc 11	707	0.904	0.90
Junc 12	646	0.7352	0.74
Junc 2	711	2.2212	2.22
Tank 1	734	#N/A	78.64

Table 2. Results of the arcs from the linear method.

Link ID	Length	Diameter	Roughness	Flow	Velocity	Unit Head loss
	m	mm	mm	LPS	m/s	m/km
Pipe 1	64	53.6	0.01	−1.71	0.76	12.29
Pipe 17	60	63.8	0.01	−2.72	0.85	12.19
Pipe 18	42	42.6	0.01	0.72	0.51	7.97
Pipe 31	110	42.6	0.01	0.71	0.50	7.73
Pipe 37	17	42.6	0.01	1.35	0.94	24.25
Pipe 38	17	42.6	0.01	1.05	0.74	15.58
Pipe 42	27	42.6	0.01	1.20	0.84	19.70
Pipe 79	63	96.8	0.01	−6.37	0.87	7.56
Pipe 80	273	141	0.01	−13.44	0.86	4.74
Pipe 81	88	141	0.01	10.36	0.66	2.96
Pipe 82	16	110.2	0.01	8.94	0.94	7.45
Pipe 83	87	110.2	0.01	7.73	0.81	5.73
Pipe 84	155	53.6	0.01	−1.15	0.51	6.04
Pipe 85	45	110.2	0.01	−8.64	0.91	7.01
Pipe 86	91	220.4	0.01	−25.32	0.66	1.72
Pipe 88	186	63.8	0.01	3.30	1.03	17.34
Pipe 89	64	42.6	0.01	0.72	0.51	8.04
Pipe 98	55	42.6	0.01	0.71	0.50	7.84
Pipe 107	25	79.2	0.01	−3.37	0.68	6.32
Pipe 108	6	53.6	0.01	1.43	0.63	8.95
Pipe 109	88	96.8	0.01	−5.20	0.71	5.24
Pipe 119	53	42.6	0.01	0.71	0.50	7.71
Pipe 155	22	96.8	0.01	−5.57	0.76	5.93
Pipe 156	46	96.8	0.01	−5.79	0.79	6.37
Pipe 183	205	42.6	0.01	−0.73	0.51	8.08
Pipe 184	88	53.6	0.01	−3.23	1.43	38.71
Pipe 185	65	53.6	0.01	1.31	0.58	7.65
Pipe 186	44	42.6	0.01	1.31	0.92	22.94
Pipe 187	52	42.6	0.01	0.98	0.69	13.84
Pipe 188	22	42.6	0.01	0.74	0.52	8.27
Pipe 204	72	53.6	0.01	1.66	0.74	11.66
Pipe 205	23	42.6	0.01	1.34	0.94	24.11

Continued

Pipe 206	47	42.6	0.01	0.71	0.50	7.71
Pipe 235	9	42.6	0.01	−0.80	0.56	9.62
Pipe 236	58	63.8	0.01	−2.39	0.75	9.66
Pipe 237	190	42.6	0.01	0.73	0.51	8.08
Pipe 251	50	42.6	0.01	−0.71	0.50	7.71
Pipe 253	455	352.6	0.01	80.86	0.83	1.47
Pipe 254	190	352.6	0.01	78.70	0.81	1.40
Pipe 255	149	352.6	0.01	74.05	0.76	1.25
Pipe 256	402	352.6	0.01	71.33	0.73	1.17
Pipe 257	138	63.8	0.01	−2.36	0.74	9.48
Pipe 258	9	220.4	0.01	32.46	0.85	2.71
Pipe 270	206	277.6	0.01	56.35	0.93	2.42
Pipe 271	50	42.6	0.01	1.04	0.73	15.31
Pipe 292	65	141	0.01	12.72	0.81	4.29
Pipe 293	163	141	0.01	11.96	0.77	3.84
Pipe 294	311	277.6	0.01	−53.41	0.88	2.20
Pipe 295	50	42.6	0.01	1.17	0.82	18.79
Pipe 305	233	277.6	0.01	−50.26	0.83	1.96
Pipe 311	79	277.6	0.01	48.18	0.80	1.82
Pipe 312	210	220.4	0.01	29.64	0.78	2.30
Pipe 313	95	141	0.01	12.99	0.83	4.46
Pipe 314	6	79.2	0.01	3.66	0.74	7.33
Pipe 315	36	79.2	0.01	3.52	0.71	6.84
Pipe 316	80	63.8	0.01	2.31	0.72	9.14
Pipe 319	31	42.6	0.01	0.71	0.50	7.84
Pipe 332	25	42.6	0.01	0.84	0.59	10.39
Pipe 347	45	141	0.01	15.48	0.99	6.13
Pipe 348	14	141	0.01	−15.28	0.98	5.99
Pipe 349	10	141	0.01	14.36	0.92	5.34
Pipe 360	102	141	0.01	13.99	0.90	5.09
Pipe 361	5	42.6	0.01	1.17	0.82	18.77
Pipe 371	767	63.8	0.01	−1.76	0.55	5.62
Pipe 372	39	42.6	0.01	0.71	0.50	7.77
Pipe 380	22	42.6	0.01	0.74	0.52	8.27

Continued

Pipe 389	70	141	0.01	−12.23	0.78	3.99
Pipe 390	31	110.2	0.01	11.08	1.16	11.01
Pipe 397	137	110.2	0.01	10.52	1.10	10.02
Pipe 398	19	42.6	0.01	1.64	1.15	34.46
Pipe 405	125	96.8	0.01	7.94	1.08	11.27
Pipe 406	29	42.6	0.01	0.97	0.68	13.53
Pipe 412	60	96.8	0.01	6.25	0.85	7.31
Pipe 413	358	42.6	0.01	0.91	0.64	12.15
Pipe 414	120	63.8	0.01	2.37	0.74	9.56
Pipe 415	38	42.6	0.01	0.71	0.50	7.71
Pipe 426	258	110.2	0.01	8.13	0.85	6.28
Pipe 431	385	220.4	0.01	28.32	0.74	2.11
Pipe 428	34	42.6	0.01	−0.79	0.56	9.46
Pipe 434	56	79.2	0.01	3.15	0.64	5.61
Pipe 437	350	42.6	0.01	−0.81	0.57	9.72
Pipe 438	318	141	0.01	9.18	0.59	2.38
Pipe 439	162	110.2	0.01	7.57	0.79	5.52
Pipe 440	92	110.2	0.01	6.72	0.70	4.45
Pipe 441	522	96.8	0.01	4.66	0.63	4.31
Pipe 87	28	42.6	0.01	0.94	0.66	12.70
Pipe 96	84	53.6	0.01	2.12	0.94	18.06
Pipe 40	125	42.6	0.01	0.72	0.50	7.93
Pipe 55	50	42.6	0.01	0.77	0.54	8.91
Pipe 2	35	42.6	0.01	−1.01	0.71	14.47
Pipe 3	49	42.6	0.01	0.71	0.50	7.84
Pipe 4	27	42.6	0.01	0.90	0.63	11.91
Pipe 5	130	42.6	0.01	0.74	0.52	8.26
Pipe 6	1226	440.6	0.01	118.97	0.78	1.01
Pipe 7	345	53.6	0.01	−2.51	1.11	24.45
Pipe 8	134	96.8	0.01	−5.71	0.78	6.21

3.2.1. Node Results Table

The node results in "Table 1" provide essential information on the hydraulic conditions at each network junction point, including pressure, water demand, and elevation. It allows for the evaluation of the system's performance in terms of user service and compliance with regulatory pressure thresholds. These data are crucial for diagnosing hydraulic imbalances and guiding network improvements.

3.2.2. Arc Results Table

This table provides important information about the flow, including: (flow rate, speed, diameter, head loss)

The arc results "Table 2" report the flow characteristics in each pipe segment, such as discharge, water velocity, and head loss. They allow for the analysis of the efficiency of water transport between nodes and the identification of critical sections likely to cause malfunctions. These results are used to optimize pipeline design and operation.

- For the pressure-flow simulation as shown in "Figure 1".
- For the pressure-flow simulation as shown in "Figure 2".

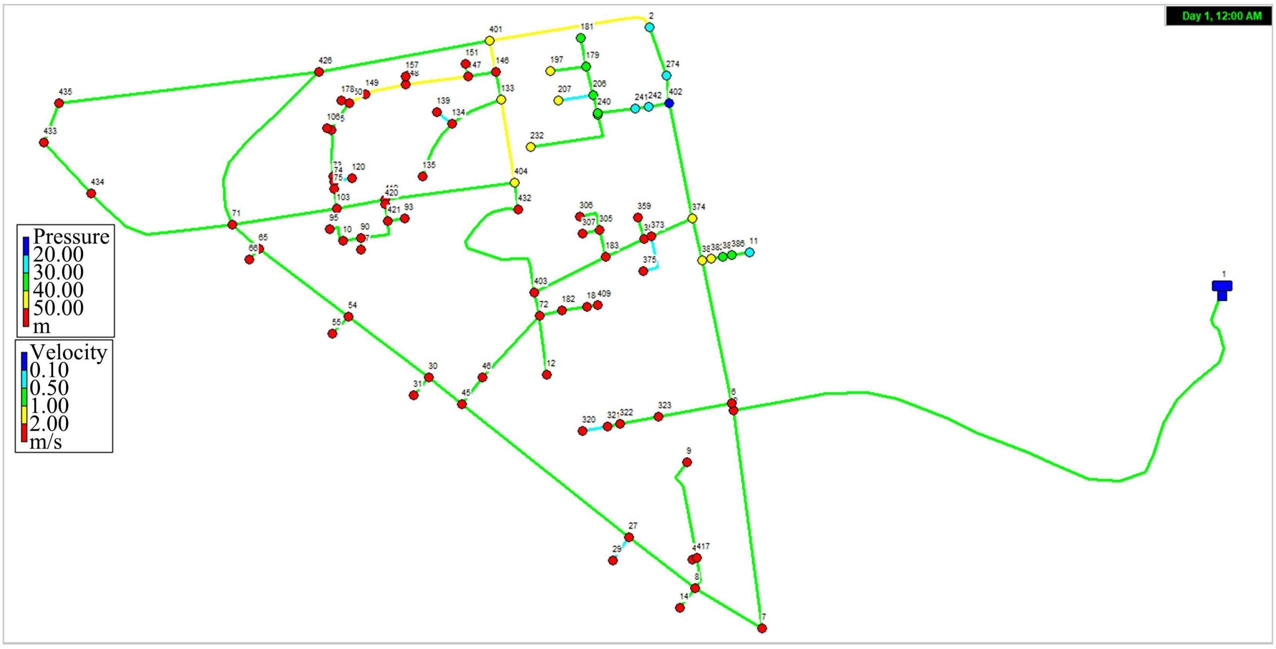

Figure 2. Distribution network, simulation: Pressure-velocity.

3.3. Concerning the Collective Buildings Method

3.3.1. Calculation Methodologies

The objective of this example is to explain the methodology applied to calculate flow rates at nodes and to compare the results obtained using this method with those obtained using the conventional method (linear method) used to calculate the Massinissa city network in Algeria.

The methodology consists of:

1) Dividing the study area into sectors based on the type and number of floors of the buildings.

2) Calculating the flow rate for each sector of the study area using the formula above, taking into account the number of dwellings per floor and the associated heights.

3) Calculate the total flow rate by summing the flow rates for each sector.

4) Calculating the total number of dwellings in the study area.

5) Calculating the specific flow rate for the study area in ℓ/s/apartment.

For the application case, our study area is divided into four sectors as follows:

Sector 4th floor with 2, 3, and 5 apartments on each floor.

Sector 5th floor with 3, 4, and 6 apartments on each floor.

Sector 9th floor with four apartments on each floor.

Sector 11th floor with four apartments on each floor.

Therefore, the calculation results are summarized in tables in the order indicated in the methodology.

While the use of simultaneity coefficients (Ks) and demand estimation based on sanitary fixtures and equipment, as well as the sanitary equipment present in apartments, are common in the design of building-scale plumbing systems, the novelty of our approach lies in the extension of these principles to urban water distribution modeling.

Specifically, the method innovatively sectorizes the study area based on building type and height, incorporates localized apartment data based on standards, and applies these values to node-level simulations within EPANET. By accounting for vertical density and occupancy patterns, this method allows for a more accurate and realistic spatial assignment of demand across the network.

- Summary of calculation results in **Table 3** in the order indicated in the methodology.

Table 3. Calculation of specific flow rate.

Section	Number of floors	Height (m)	Number of apartments/floor	Probable flow rate (ℓ/s)	Total number of apartments	Specific flow rate (ℓ/s/apart)
1	4	17	164	10.163	820	0.0068263
2	5	20	945	25.164	5670	
3	9	32	120	12.858	1200	
4	11	38	16	5.619	192	
		Total		53.805125	7882	

1) Calculation of flow rates at nodes

The flow rate for each node is calculated using the formula:

$$q_n = q_{sp} \cdot N_a$$

q_n : flow rate at the node in (ℓ/s)

q_{sp} : specific flow rate in (ℓ/s/apart)

N_a : number of apartments connected to this node (**Table 4**).

Table 4. Nodal flow rates.

N°	Node	Number of apartments	flow rate (ℓ/S)
I-1	14	256	1.7475

Continued

I-2	31	400	2.7305
I-3	46	168	1.1468
I-4	55	304	2.0752
I-5	66	160	1.0922
I-6	87	312	2.1298
I-7	29	192	1.3106
I-8	416	72	0.4915
I-9	9	96	0.6553
I-10	420	80	0.5461
I-11	93	240	1.6383
I-12	95	200	1.3653
I-13	75	200	1.3653
I-14	73	120	0.8192
I-15	106	228	1.5564
I-16	120	168	1.1468
I-17	139	384	2.6213
I-18	135	80	0.5461
I-19	178	120	0.8192
I-20	149	78	0.5325
I-21	157	168	1.1468
I-22	151	114	0.7782
I-23	181	288	1.9660
I-24	197	192	1.3106
I-25	207	140	0.9557
I-26	222	90	0.6144
I-27	241	210	1.4335
I-28	242	150	1.0239
I-29	274	504	3.4405
I-30	359	130	0.8874
I-31	307	120	0.8192
I-32	306	192	1.3106
I-33	375	120	0.8192
I-34	409	72	0.4915
I-35	184	192	1.3106

Continued

I-36	321	192	1.3106
I-37	322	144	0.9830
I-38	382	48	0.3277
I-39	385	144	0.9830
I-40	386	192	1.3106
I-41	232	70	0.4778
I-42	323	288	1.9660
I-43	182	96	0.6553
I-44	320	168	1.1468
TOTAL		7882	53.805

2) Equipment flow rate

For equipment flow rates, we have classified this equipment into two types as follows:

Equipment attached to buildings (commercial and service).

Equipment not attached to buildings (administration, primary schools, and middle school).

For equipment attached to buildings, the corresponding flow rates are already calculated and supported in the nodes that serve the buildings. See "Tables 5-8".

Table 5. Equipment not attached to buildings.

Equipment designation	Number of students	allocation (ℓ/student/day)	flow rate in (ℓ/s)	Attached node	Node flow rate (ℓ/s)
middle school BASE 5	600	100	0.6944	27	1.0417
Primary school A4-300	300	100	0.3472	27	
middle school BASE 5	600	100	0.6944	432	0.6944
middle school BASE 5	600	100	0.6944	12	0.6944
Primary school A4-300	300	100	0.3472	10	0.3472
Primary school A4-300	300	100	0.3472	11	0.3472
Primary school A4-300	300	100	0.3472	358	0.3472
		Total			3.4722

Table 6. Total flow rate for network sizing (peak flow rate Q_p).

Total flow rate		
N°	Designation	Flow rate (ℓ/s)
1	Total flow of buildings	53.81
2	Flow rate of equipment not attached to buildings	3.47
	Total	57.28

Table 7. Node status according to the collective buildings method.

Node ID	Elevation	Base Demand	Demand
	m	LPS	LPS
Junc 5	673	0	0.00
Junc 6	674	0	0.00
Junc 7	655	0	0.00
Junc 8	637	0	0.00
Junc 9	650	0.7260	0.73
Junc 14	635	1.7475	1.75
Junc 27	632	1.0417	1.04
Junc 29	630	1.3106	1.31
Junc 30	662	0	0.00
Junc 31	660	2.7305	2.73
Junc 45	658	0	0.00
Junc 46	661	1.1468	1.15
Junc 54	647	0	0.00
Junc 55	648	2.0752	2.08
Junc 65	643	0	0.00
Junc 66	638	1.0922	1.09
Junc 71	642	0	0.00
Junc 72	658	0	0.00
Junc 87	653	2.1298	2.13
Junc 90	655	0	0.00
Junc 93	663	1.6383	1.64
Junc 73	656	0.8191	0.82
Junc 74	656	0	0.00
Junc 75	658	1.3652	1.37
Junc 103	656	0	0.00
Junc 105	654	0	0.00
Junc 106	653	1.5564	1.56
Junc 120	661	1.1468	1.15
Junc 133	679	0	0.00
Junc 134	671	0	0.00
Junc 135	667	0.7184	0.72
Junc 139	669	2.6213	2.62

Continued

Junc 146	678	0	0.00
Junc 147	673	0	0.00
Junc 148	662	0.94	0.94
Junc 149	655	0	0.00
Junc 150	653	0	0.00
Junc 151	672	0.9782	0.98
Junc 157	661	1.1468	1.15
Junc 178	649	0.8191	0.82
Junc 179	696	0	0.00
Junc 181	694	1.966	1.97
Junc 197	688	1.31065	1.31
Junc 206	696	0	0.00
Junc 207	692	0.9556	0.96
Junc 222	699	0.7063	0.71
Junc 232	685	0.7278	0.73
Junc 240	699	0	0.00
Junc 241	710	1.4335	1.43
Junc 242	711	1.0239	1.02
Junc 274	713	3.44	3.44
Junc 182	654	0.6553	0.66
Junc 184	657	1.3106	1.31
Junc 320	641	1.1458	1.15
Junc 321	646	1.3106	1.31
Junc 322	648	0.9893	0.99
Junc 323	656	1.9659	1.97
Junc 183	665	3.8670	3.87
Junc 305	671	0	0.00
Junc 306	671	1.3106	1.31
Junc 307	667	0.819	0.82
Junc 358	673	0.4872	0.49
Junc 359	680	0.8872	0.89
Junc 373	676	0	0.00
Junc 374	690	0	0.00
Junc 375	675	0.819	0.82

Continued

Junc 381	691	0	0.00
Junc 382	693	0.3276	0.33
Junc 385	700	0.9893	0.99
Junc 386	703	1.3106	1.31
Junc 401	677	1.6478	1.65
Junc 402	717	0	0.00
Junc 403	660	0	0.00
Junc 404	681	0	0.00
Junc 409	658	0.7360	0.74
Junc 416	637	0.8603	0.86
Junc 417	638	0	0.00
Junc 419	662	3.8901	3.89
Junc 420	662	0.5461	0.55
Junc 421	660	0	0.00
Junc 426	648	5.5131	5.51
Junc 95	653	1.3652	1.37
Junc 432	678	0.6944	0.69
Junc 433	625	0	0.00
Junc 434	629	0	0.00
Junc 435	623	0	0.00
Junc 10	652	0.3472	0.35
Junc 11	707	0.904	0.90
Junc 12	646	0.7352	0.74
Junc 2	711	0	0.00
Tank 1	734	#N/A	−74.75

Table 8. Arcs status according to the collective buildings' method.

Link ID	Length	Diameter	Roughness	Flow	Velocity	Unit Headloss
	m	mm	mm	LPS	m/s	m/km
Pipe 1	64	53.6	0.01	−1.31	0.58	7.65
Pipe 17	60	63.8	0.01	−2.13	0.67	7.87
Pipe 18	42	42.6	0.01	0.89	0.62	11.52
Pipe 31	110	42.6	0.01	0.82	0.57	10.00
Pipe 37	17	63.8	0.01	3.53	1.10	19.56
Pipe 38	17	53.6	0.01	2.21	0.98	19.57

Continued

Pipe 42	27	63.8	0.01	3.20	1.00	16.40
Pipe 79	63	96.8	0.01	−6.22	0.85	7.24
Pipe 80	273	141	0.01	−14.34	0.92	5.33
Pipe 81	88	79.2	0.01	6.49	1.32	20.67
Pipe 82	16	79.2	0.01	5.67	1.15	16.17
Pipe 83	87	63.8	0.01	4.29	1.34	27.89
Pipe 84	155	53.6	0.01	1.70	0.75	12.21
Pipe 85	45	110.2	0.01	−10.15	1.06	9.39
Pipe 86	91	176.2	0.01	−20.83	0.85	3.57
Pipe 88	186	96.8	0.01	6.78	0.92	8.46
Pipe 89	64	53.6	0.01	1.97	0.87	15.80
Pipe 98	55	53.6	0.01	1.31	0.58	7.65
Pipe 107	25	79.2	0.01	−4.23	0.86	9.53
Pipe 108	6	53.6	0.01	1.43	0.64	8.98
Pipe 109	88	96.8	0.01	−5.67	0.77	6.12
Pipe 119	53	42.6	0.01	0.96	0.67	13.15
Pipe 155	22	96.8	0.01	−7.10	0.96	9.20
Pipe 156	46	96.8	0.01	−8.12	1.10	11.75
Pipe 183	205	42.6	0.01	−0.73	0.51	8.11
Pipe 184	88	53.6	0.01	−1.24	0.55	6.88
Pipe 185	65	79.2	0.01	−3.44	0.70	6.55
Pipe 186	44	53.6	0.01	2.70	1.20	28.03
Pipe 187	52	53.6	0.01	2.05	0.91	16.98
Pipe 188	22	42.6	0.01	0.74	0.52	8.27
Pipe 204	72	63.8	0.01	3.45	1.08	18.71
Pipe 205	23	53.6	0.01	2.46	1.09	23.60
Pipe 206	47	42.6	0.01	1.15	0.80	18.17
Pipe 235	9	42.6	0.01	−0.86	0.60	10.91
Pipe 236	58	53.6	0.01	−1.59	0.70	10.75
Pipe 237	190	42.6	0.01	0.73	0.51	8.08
Pipe 251	50	42.6	0.01	−1.31	0.92	23.12
Pipe 253	455	277.6	0.01	44.97	0.74	1.60
Pipe 254	190	277.6	0.01	44.97	0.74	1.60
Pipe 255	149	220.4	0.01	41.64	1.09	4.27
Pipe 256	402	220.4	0.01	39.29	1.03	3.84
Pipe 257	138	79.2	0.01	−5.41	1.10	14.87
Pipe 258	9	220.4	0.01	29.77	0.78	2.32

Continued

Pipe 270	206	176.2	0.01	24.56	1.01	4.82
Pipe 271	50	63.8	0.01	2.73	0.85	12.30
Pipe 292	65	141	0.01	14.73	0.94	5.60
Pipe 293	163	141	0.01	13.58	0.87	4.83
Pipe 294	311	141	0.01	−21.83	1.40	11.47
Pipe 295	50	53.6	0.01	2.08	0.92	17.41
Pipe 305	233	141	0.01	−19.75	1.26	9.56
Pipe 311	79	141	0.01	18.66	1.20	8.61
Pipe 312	210	141	0.01	15.51	0.99	6.15
Pipe 313	95	96.8	0.01	8.94	1.22	14.00
Pipe 314	6	79.2	0.01	6.03	1.22	18.08
Pipe 315	36	79.2	0.01	5.48	1.11	15.21
Pipe 316	80	79.2	0.01	3.84	0.78	8.01
Pipe 319	31	53.6	0.01	1.64	0.73	11.39
Pipe 332	25	53.6	0.01	2.13	0.94	18.24
Pipe 347	45	110.2	0.01	6.57	0.69	4.27
Pipe 348	14	110.2	0.01	−5.20	0.55	2.81
Pipe 349	10	96.8	0.01	4.06	0.55	3.36
Pipe 360	102	79.2	0.01	3.24	0.66	5.89
Pipe 361	5	53.6	0.01	1.56	0.69	10.39
Pipe 371	767	53.6	0.01	−1.73	0.77	12.55
Pipe 372	39	42.6	0.01	1.15	0.80	18.20
Pipe 380	22	42.6	0.01	0.82	0.57	10.00
Pipe 389	70	53.6	0.01	−1.68	0.75	11.94
Pipe 390	31	42.6	0.01	0.86	0.61	10.97
Pipe 397	137	42.6	0.01	0.86	0.61	10.97
Pipe 398	19	42.6	0.01	1.15	0.80	18.20
Pipe 405	125	42.6	0.01	−1.22	0.86	20.44
Pipe 406	29	42.6	0.01	0.98	0.69	13.71
Pipe 412	60	53.6	0.01	−2.20	0.98	19.37
Pipe 413	358	53.6	0.01	−2.37	1.05	22.06
Pipe 414	120	53.6	0.01	3.34	1.48	41.18
Pipe 415	38	53.6	0.01	2.62	1.16	26.53
Pipe 426	258	42.6	0.01	−0.97	0.68	13.57
Pipe 431	385	176.2	0.01	24.36	1.00	4.75
Pipe 428	34	42.6	0.01	−0.82	0.57	10.00
Pipe 434	56	96.8	0.01	−7.75	1.05	10.78

Continued

Pipe 437	350	96.8	0.01	−8.44	1.15	12.60
Pipe 438	318	53.6	0.01	1.42	0.63	8.80
Pipe 439	162	53.6	0.01	1.42	0.63	8.80
Pipe 440	92	53.6	0.01	1.42	0.63	8.80
Pipe 441	522	53.6	0.01	1.42	0.63	8.80
Pipe 87	28	42.6	0.01	1.09	0.77	16.68
Pipe 96	84	53.6	0.01	3.28	1.45	39.78
Pipe 40	125	42.6	0.01	0.72	0.50	7.93
Pipe 55	50	53.6	0.01	1.75	0.77	12.79
Pipe 2	35	53.6	0.01	−1.71	0.76	12.33
Pipe 3	49	53.6	0.01	1.37	0.61	8.23
Pipe 4	27	42.6	0.01	0.90	0.63	11.91
Pipe 5	130	42.6	0.01	0.74	0.52	8.26
Pipe 6	1226	352.6	0.01	74.75	0.77	1.27
Pipe 7	344	63.8	0.01	−2.78	0.87	12.70
Pipe 8	134	53.6	0.01	−2.78	1.23	29.50

For equipment not attached to buildings, their flow rates are calculated according to the characteristics of each type.

3.3.2. The Results Obtained by the Collective Buildings Method

- For the pressure-flow simulation, as shown in "**Figure 3**"

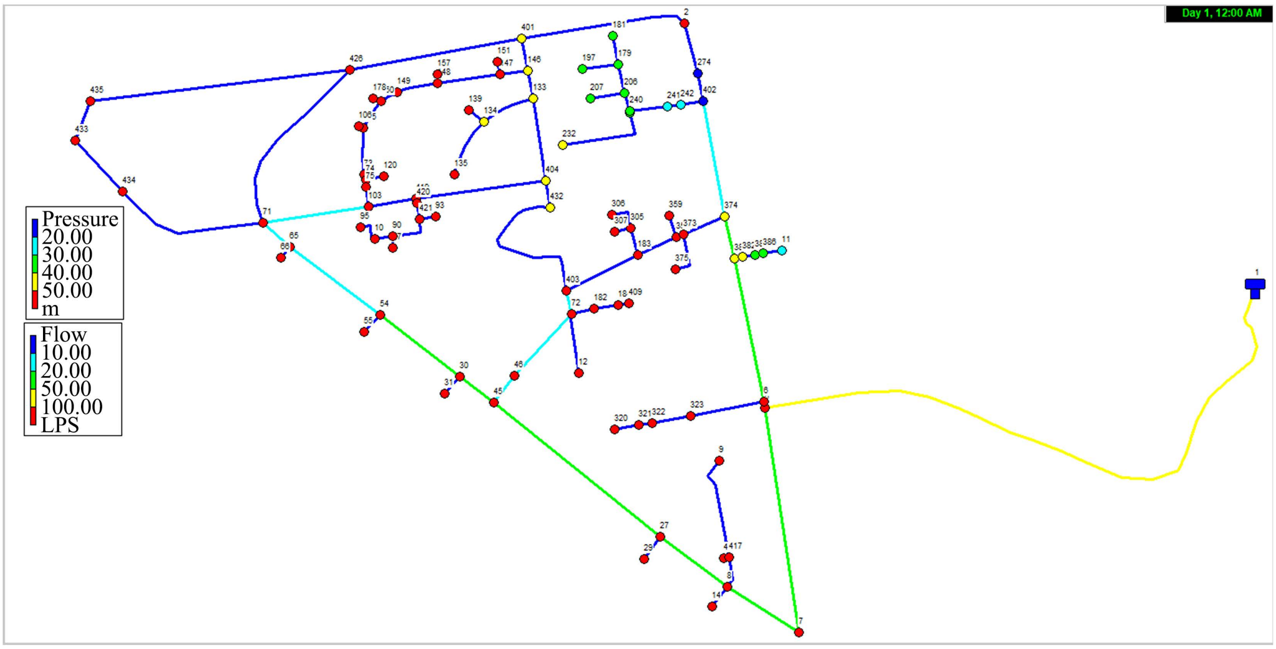

Figure 3. Distribution network, simulation: Pressure-flow.

- For the pressure-velocity simulation as shown in "**Figure 4**".

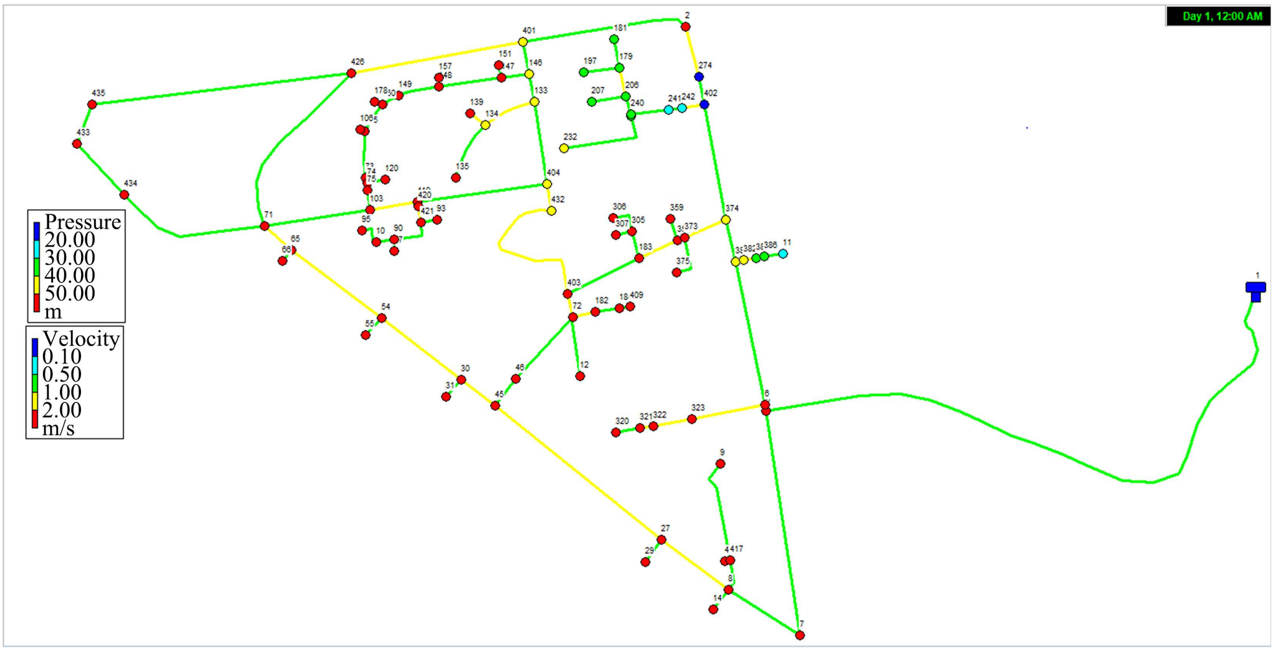

Figure 4. Distribution network, simulation: Pressure-velocity.

3.3.3. Analysis and Interpretation of the Results Obtained

This part of the work consists of analyzing and interpreting the results obtained by each method. The principle of analysis and interpretation will be based primarily and mainly on:

- Analysis of the flow chart of each method, as well as the difficulties encountered in each,
- The flow values at the nodes obtained by each method from the point of view of quantity and location, and comparing these values to the reality and characteristics of the study area.
- The diameters, velocities, and flow rates along the pipelines constituting the network.

1) Analysis of the flowchart of each method

- Both methods were calculated based on a flowchart corresponding to each unit.

Flowchart of the Linear Method (**Figure 5**)

Flowchart of the collective buildings (**Figure 6**)

2) Analysis of the flow values at the nodes obtained by each method

By comparing and analyzing "**Table 9**" and "**Table 10**" concerning the flow rates at the nodes in the two methods, we observe the following:

For the linear method, all nodes have a base water demand, while in the collective buildings method, there are 35 nodes that do not have a base water demand and are solely connection junctions.

From this, we can conclude the following:

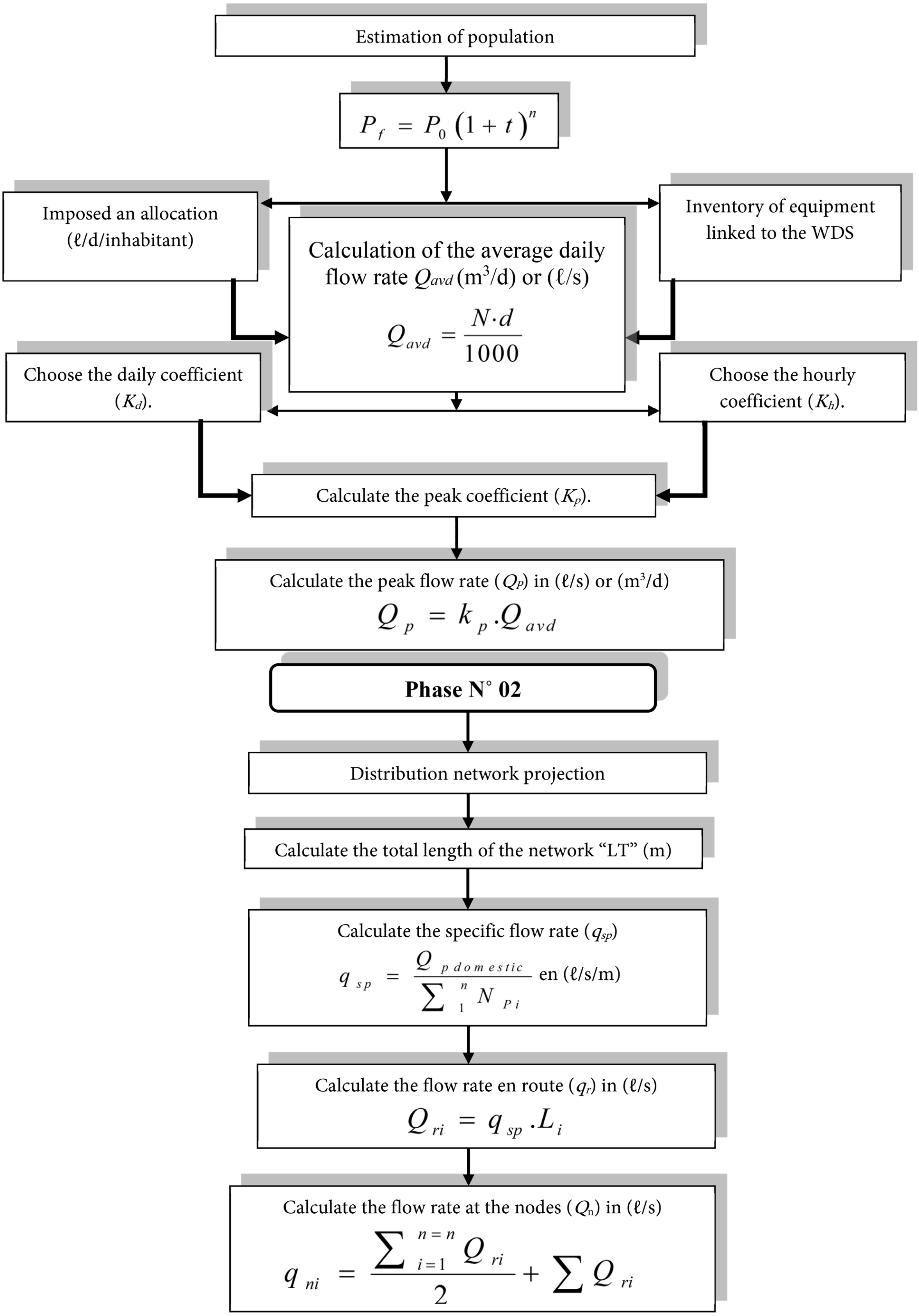

Figure 5. Flowchart of calculation by the linear method (summarized from the references: [3] [13]-[16]).

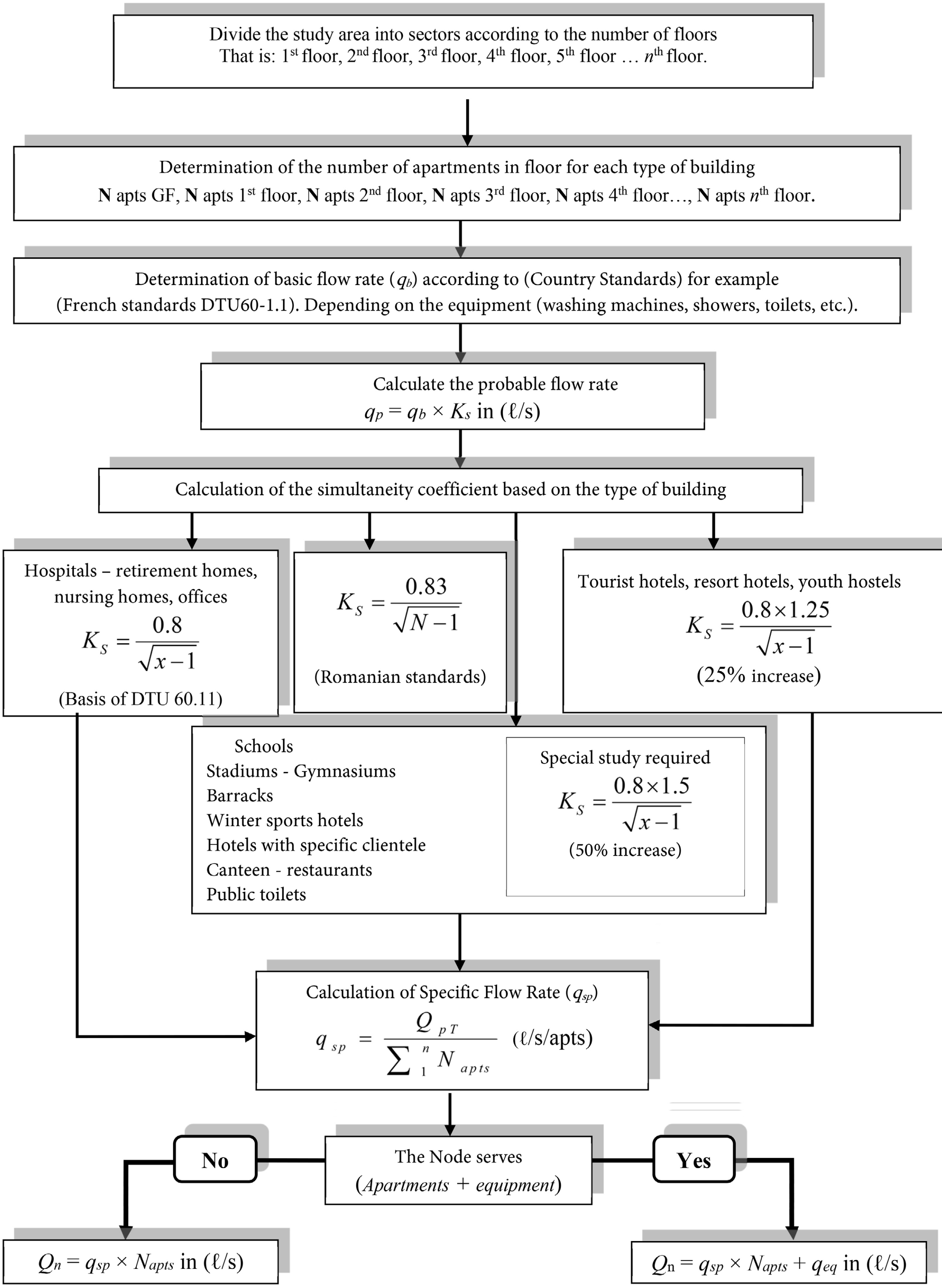

Figure 6. Flowchart of calculation by the collective buildings method (summarized from the references: [17]-[19]).

Table 9. Results of the node status according to the linear method.

Node ID	Elevation	Base Demand
	m	ℓ/s
Junc 5	673	5.6715
Junc 6	674	1.7953
Junc 7	655	2.1735
Junc 8	637	1.5108
Junc 30	662	1.9124
Junc 45	658	2.2673
Junc 54	647	1.9883
Junc 65	643	1.1526
Junc 71	642	4.6138
Junc 72	658	1.2932
Junc 90	655	0.4831
Junc 74	656	0.2254
Junc 103	656	1.1861
Junc 105	654	0.6070
Junc 133	679	2.2564
Junc 134	671	0.9618
Junc 146	678	0.7275
Junc 147	673	1.0609
Junc 150	653	0.4262
Junc 179	696	0.6940
Junc 206	696	0.5568
Junc 240	699	0.4128
Junc 305	671	0.5434
Junc 373	676	0.7308
Junc 374	690	1.5275
Junc 381	691	1.6647
Junc 402	717	1.2932
Junc 403	660	8.9955
Junc 404	681	1.6882
Junc 417	638	0.8748
Junc 421	660	0.5066
Junc 433	625	0.8647
Junc 434	629	1.6212
Junc 435	623	2.0698
Junc 2	711	2.2212
Total		58.57 ℓ/s

Table 10. Results of the node status according to the collective buildings method.

Node ID	Elevation	Base Demand
	m	ℓ/s
Junc 5	673	0
Junc 6	674	0
Junc 7	655	0
Junc 8	637	0
Junc 30	662	0
Junc 45	658	0
Junc 54	647	0
Junc 65	643	0
Junc 71	642	0
Junc 72	658	0
Junc 90	655	0
Junc 74	656	0
Junc 103	656	0
Junc 105	654	0
Junc 133	679	0
Junc 134	671	0
Junc 146	678	0
Junc 147	673	0
Junc 150	653	0
Junc 179	696	0
Junc 206	696	0
Junc 240	699	0
Junc 305	671	0
Junc 373	676	0
Junc 374	690	0
Junc 381	691	0
Junc 402	717	0
Junc 403	660	0
Junc 404	681	0
Junc 417	638	0
Junc 421	660	0
Junc 433	625	0
Junc 434	629	0
Junc 435	623	0
Junc 2	711	0
Total		0

1) For the collective buildings method

After locating the nodes that do not have basic flow demand values, as shown in the tables above, we note that these nodes are considered sharing or change-of-direction points and have no other role to play in the distribution network, which is why the basic demand value is zero.

In this method:

The flow rate is assigned only to nodes where a building (or group of buildings) is actually connected.

It more realistically represents the location of demand, especially in densely populated areas.

If a node is not connected to a building, then it has no demand of its own and therefore no assigned flow rate.

As a result, only nodes connected to buildings have a non-zero nodal flow rate.

2) For the linear method

By comparing "Table 9" and "Table 10", we note that in the collective buildings method, some nodes, which have base demand values in the linear method, do not take these values into account. It is worth noting that these nodes alone have a total base demand flow of 58.57 ℓ/s, out of a total of 78.64 ℓ/s, representing 74.5% of the total demand.

By comparing the two methods, we note a crucial point: the profitability of distributing baseline demand across the entire network.

In the linear method, the distribution does not take into account the actual location of demand points. Therefore, there will be a sudden increase in baseline demand in areas where it is not necessarily justified.

This highlights the main weakness of the linear method: its tendency to distribute demand proportionally to pipe length without taking into account the reality on the ground (population density, building availability, etc.). Conversely, the collective buildings method, which is based on more realistic data, allows for better distribution of demand, which can lead to a more economical design that is more accurate for the actual needs of the network.

3.3.4. Analysis of the Diameters, Velocity, and Flow Rates of the Pipelines Constituting the Network

1) Velocity analysis

We observe from methods, the linear method and the construction method, that the flow velocity in water distribution network pipes ranges from 0.50 m/s to 1.50 m/s, which is within the acceptable range.

2) Analysis of flows

Since flows are closely related to peak flows and flows at nodes, the difference between the flows of the two methods will necessarily be clear and logical.

We note that the network in the study area is well-dimensioned in relation to the flows carried by the different sections of the network, whether calculated by the linear method or the collective buildings method.

As for the diameters, they are proportional to the flow quantity, as evidenced by the fact that the velocity values are proportional to the optimal range.

4. Economic Impact of Pipe Sizing

From "Table 2" and "Table 8", we conducted a comparative analysis of pipe diameters used in the linear method and the collective buildings method, and the data shown in "Table 11" were derived. The analysis shows that the collective buildings method significantly reduces the use of large-diameter pipes (≥220 mm), while favoring smaller diameters (≤53.6 mm).

Table 11. Pipe length distribution by diameter.

Diameter (mm)	Linear Method (m)	Collective Method (m)	Difference (m)
≤53.6	3399	5328	−1929
63.8 - 96.8	2469	1574	895
110.2 - 176.2	2071	2120	−49
≥220.4	3946	2431	1515
Total	11,885	11,453	432

For example:

The total length of pipes with diameters ≥ 220 mm is reduced from 3946 m (linear method) to 2431 m (collective buildings), a reduction of 1515 m, which corresponds to a considerable cost saving, given the higher material, transport, and installation costs associated with large diameter pipes and valves, and the high price of valves with large diameters.

Conversely, the total length of small-diameter pipes (≤53.6 mm) increases by 1929 m, which is more economical in both material and labor costs.

This shift results in a better match between pipe diameter and actual demand flows, reducing overdesign and associated expenses. The overall pipe length is slightly reduced in the collective method (11,453 m vs. 11,885 m), contributing further to lower costs.

Hence, the collective method not only rationalizes the sizing but also optimizes the costs associated with construction and maintenance.

This confirms a clear trend: the collective method relies more heavily on smaller diameters and avoids oversized pipes.

5. Conclusion

This study introduced and validated a localized approach for estimating water demand and sizing drinking water distribution networks, based on the characteristics of collective buildings. Compared to the linear method, the proposed model more accurately reflects the spatial distribution of demand by assigning flow rates only to nodes with actual building connections. The simulation results revealed a reduction in peak flow from 78.64 ℓ/s to 57.28 ℓ/s, translating to a 27% decrease. This optimization results in more appropriate pipe diameters and material savings. A preliminary cost comparison showed a potential 20% - 25% reduction in pipeline costs, highlighting the method's economic feasibility. While simultaneity coefficients and apartment counts are not new, their application at the node level in a real urban layout contributes a practical and effective advancement in demand modeling. Future work could include extending this method to variable consumption patterns over time or integrating real-time data for dynamic planning.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] United Nations Educational, Scientific and Cultural Organization (UNESCO) (2020) Water and Climate Change. https://hdl.handle.net/20.500.12870/7402

[2] Dupont, A. (1979) Hydraulique urbaine, Ouvrages de transport, élévation et distribution des eaux. Tome 2, Edition Eyrolles.

[3] Walski, T.M., Chase, D.V., Savic, D.A., Grayman, W., Beckwith, S. and Koelle, E. (2003) Advanced Water Distribution Modeling and Management. Civil and Environmental Engineering and Engineering Mechanics Faculty Publications. Paper 18. http://ecommons.udayton.edu/cee_fac_pub/18

[4] Mays, L.W. (2000) Water Distribution System Handbook. 1st Edition, McGraw-Hill. https://www.accessengineeringlibrary.comcontent/book/9780071342131

[5] Whitman, B.E., Walski, T., Barnard, T.E., Durrans, S.R. and Lowry, S. (2021) Computer Applications in Hydraulic Engineering. Bentley Institute Press.

[6] Manescu, A.L., Sandu, M. and Ianculescu, O. (1994) Alimentari cu apa, Editura didactica si pedagogica.

[7] Абрамов, Н.Н. (1974) водоснабжение. https://aquaprom-sz.ru/images/blog/%D0%90%D0%B1%D1%80%D0%B0%D0%BC%D0%BE%D0%B2%20%D0%9D.%20%D0%9D.%20%D0%92%D0%BE%D0%B4%D0%BE%D1%81%D0%BD%D0%B0%D0%B1%D0%B6%D0%B5%D0%BD%D0%B8%D0%B5.pdf

[8] Абрамов, Н.Н. (1983) Расчет водопроводных сетей. https://mega.nz/file/TttTlaxT#p8lFDHgnRA0hRRuYlaSMiz-tpGMXybNcYcSAW8nQAhvk

[9] Сомов, М.А. and Квитка, Л.А. (2007) Водоснабжение: учеб.

[10] Ovidiu, I. and Gheorghe, I. (2002) Alimentari cu apa. Matrix Rom.

[11] Николадзе, Г.И. and Сомов, М.А. (1995) Водоснабжение. Стройиздат, 688, 75.

[12] Jalbă, R. (2007) Alimentation en eau et assainissement. Editura conspress.

[13] Brière, F.G. (2012) Distribution et collecte des eaux. Presses inter Polytechnique.

[14] Swamee, P.K. and Sharma, A.K. (2008) Design of Water Supply Pipe Networks. John Wiley & Sons. https://doi.org/10.1002/9780470225059

[15] Pîslărașu, I. (1964) Alimentări cu apă. Editura Tehnică.

[16] Alexandru, D. and Mircea, M. (2006) Rețele Edilitare. Matrix Rom.

[17] Dumitrescu, L.D. (1980) Instalații sanitare pentru ansambluri de clădiri. Editura Tehnica.

[18] Normes Français (2013) Travaux de bâtiment—Règles de calcul des installations de

plomberie sanitaire et d'eaux pluviales—Partie 1-1: Réseaux d'alimentation d'eau froide et chaude sanitaire.

[19] Dubreuil, G. and Giraud, A. (2008) Calculs pratiques de plomberie sanitaire. Editions Parisiennes.