Romanian Journal of Civil Engineering, Volume 17 (2026), Number 2 © Matrix Rom

Adaptation of the pressure-based algorithm used by EPANET 2.2 to the provisions in force for different situations

Adaptarea algoritmului bazat pe presiune utilizat de EPANET 2.2 la prevederile în vigoare pentru diferite situații

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DOI: 10.37789/rjce.2026.17.2.4

Abstract. *This paper adapts the pressure-based algorithm of EPANET 2.2 to comply with national plumbing standards under different operating contexts. The study focuses on calibrating the discharge coefficient (C) and pressure exponent (γ), which govern flow behavior in pressure-driven conditions. Case studies in Algeria and Romania demonstrate how regulatory provisions influence these parameters, with γ converging around 0.6 and C varying according to building typologies. Results highlight the advantages of Pressure Driven Analysis (PDA) over Demand Driven Analysis (DDA), offering more realistic simulations for water distribution networks.*

Key words: *water distribution system, calibration, simulation, demand driven analysis, pressure driven analysis, EPANET*

1. Introducere

Water distribution networks are vital infrastructure systems that ensure the efficient and reliable delivery of drinking water to users. To achieve optimal design, operation, and management, analyzing and simulating these networks is crucial. One of the most commonly used tools for this purpose is EPANET, open-source software created by the U.S. Environmental Protection Agency (EPA) [1]. EPANET enables extended period simulations to analyze the hydraulic and water quality performance of pressurized pipe networks. It provides valuable information on factors such as flow rates, head losses in pipes, nodal pressures, and tank water levels. Thanks to its intuitive interface, open-source adaptability, and compatibility with numerous

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The article was received on 27.01.2026, accepted on 27.05.2026 and published on 12.06.2026

extensions, it has become a widely used tool in academic studies as well as in real-world water system design and management.

In hydraulic simulations, two main methods are used to model demand: Demand-Driven Analysis (DDA) and Pressure-Driven Analysis (PDA). The DDA approach assumes that the required water demand at each node is completely satisfied, independent of the actual pressure conditions in the network. Although this method is computationally efficient and has long been the default in EPANET's engine, it fails to account for pressure shortfalls, which can result in overly optimistic predictions when the system is under st ress [2], [3]. In contrast, the PDA method modifies water distribution according to the pressure at each node, providing a more accurate depiction of how the system responds under unusual or emergency situations, including pipe failures, periods of high demand, or firefighting operations. [4].

Although the benefits of PDA are increasingly acknowledged, many legacy simulations and even newer studies still rely mainly on DDA models. This persistence is due in part to default configurations in software such as EPANET and in part to the limited number of comparative analyses conducted under consistent conditions. Consequently, pressure-deficient scenarios often crucial for assessing resilience and reliability remain underrepresented in system evaluations and planning. The omission of PDA in standard modeling can lead to misleading insights for operators and engineers, potentially affecting system reliability, emergency readiness, and long-term investment decisions [5].This study seeks to fill this gap by performing a controlled comparison between DDA and PDA simulations under the same network conditions.

Using EPANET along with suitable pressure-driven extensions, it examines how accurately and reliably each approach represents different demand and pressure situations. The findings will highlight how the selected modeling framework affects performance evaluation and will help practitioners adopt more informed simulation practices, particularly in relation to aging infrastructure and growing urban water challenges.

2. Calibration of the coefficients

2.1. Problematic

Studies in hydro informatics and water distribution network simulation show that pressure-based algorithms do not treat consumption flows at nodes as fixed values. Instead, the flow at demand nodes varies depending on the pressure available at those nodes. To represent this relationship, a mathematical function is needed to describe how flow changes with pressure, controlled by certain parameters.However, these parameters are not universal. They differ depending on factors such as consumer type and the regulatory standards in force, which vary across countries, regions, and applications. Because there is no standardized way to define these parameters, hydraulic simulations may be prone to inaccuracies, which can affect the planning, design, and management of water supply systems. For this reason, a reliable calibration procedure is required to connect regulatory pressure and flow requirements for different categories of consumers to the correct pressure–flow parameters. The main aim of this paper is therefore to determine these parameters as precisely as possible based on relevant regulations. Once a suitable method for their determination is developed, numerical models will be constructed for several case studies, and their outcomes will be evaluated.

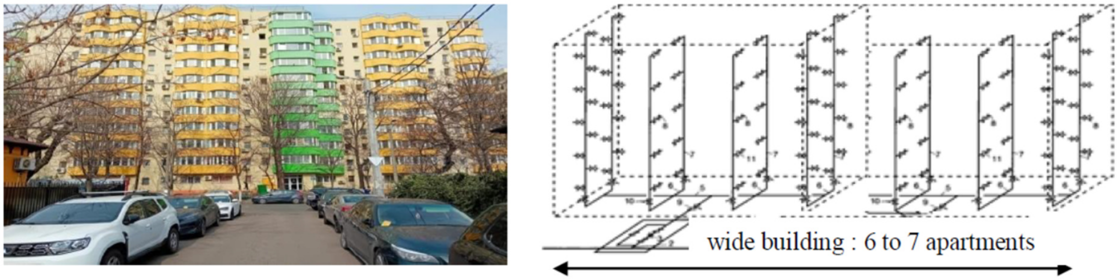
2.2. Determining Coefficients for Different Cases

Based on the emitter flow rate equation expressed as a function of pressure, and given the following formula:

$$q = C.P^{\gamma} \quad (1)$$

Where q: is the flow (ℓ/s), p: the pressure, C: the discharge coefficient, and γ: the pressure exponent, depending on the urban water distribution network.

The calculation of distribution networks under load has become increasingly complex, and traditional algorithms are no longer sufficient to address it. The challenge lies in the fact that pressure-based algorithms assume fixed consumption flows at nodes, whereas in reality these flows vary according to the pressure available at the most restrictive node. Therefore, it is essential to establish and accurately define the relationship between consumption flow and pressure, in line with applicable standards for the various categories of consumers. Concerning the determination of coefficients in accordance with the applicable standards in different countries, we will focus on two specific countries: Algeria and Romania.We will primarily rely on the data provided in (DTU 60.11 P1-1) for the Algerian case and on the information from the Official journal of Romania, (Monitorul Oficial al României, Part I, No. 1167 bis/6.XII.2022), for the Romanian case. Several cases were analyzed under the assumption that each floor accommodated the maximum possible number of dwellings. The buildings considered were characterized by their considerable height, typically comprising six to seven apartments per floor and extending over ten or more levels (R+ 10 floors). This building typology is exemplified by structures in the Tei-Colentina District of Bucharest, Romania, as depicted in (Fig.1).



a) Apartment block in Romania Source: Photo: H - Lakhdari on: 22/02/2024

b) Isometric plan of the internal water (Tei-Colentina District in Bucuresti Supply system of buildings. [6]

Fig. 1. Residential building pattern in Romania (Tei-Colentina District - Romania).

As for Algeria, the building and the apartment block are composed of (2 to 4 apartments) on each floor with a height of (R + 4 floors). Like the city of N'gaous in the Wilaya of Batna in Algeria, as shown in (Figure 2).

a) Apartment block in N'gaous - Algeria. Source: Photo: H - Lakhdari on: 22/02/2024

b) Plan of the internal water Supply system of buildings. [7]

Fig. 2. Residential building pattern in Algeria (city of N’gaous- Algeria).

Flow rates required to supply buildings ranging from 1 to 10 apartments per floor, and up to 10 floors in height, were estimated using standard calculation methods. For each configuration, the coefficients (C) and (γ) were determined and then used to produce graphs showing how flow rate varies with available pressure.

The choice of this method is mainly intended to enable direct comparison and highlight differences between national standards in each country. The 1-10 range ensures consistency when comparing the Algerian standard (DTU 60) with the Romanian standard (Monitorul Oficial 1167 bis/2022), and it also allows the development of coherent comparative curves for both.More generally, focusing on buildings with 1 to 10 apartments per floor offers a representative framework: it mirrors the most common urban layouts, facilitates the determination of C and γ for each case, and provides a uniform basis for cross-country and cross-standard analyses.

2.2.1. Proposed calculation methodology

The proposed methodology applies to collective residential buildings designed with between 1 and 10 apartments per floor, and up to a maximum of 10 floors. It defines the estimated flow rate requirements for each apartment, taking into account standard sanitary installations as prescribed by national regulations. In the case of Algeria, French standards [8] were referenced and adapted to local conditions, while Romania applies its own national standards [9].

Drawing on our knowledge of typical housing configurations in both countries, we observed that Romanian high-rise buildings often comprise 6 to 7 apartments per floor and generally extend up to 10 stories. In contrast, Algerian residential buildings tend to include 2 to 4 apartments per floor and are of moderate height, usually reaching around 4 stories depending on the location.

The methodology follows a series of calculation steps:

1. Specify the number of devices per building:

This section consists of determining the number of devices used per dwelling on one side and the estimated flow rate reserved for each type of device on one side using the data in (Table 01).

2. Calculating the total flow rate required for a home, called the base flow rate q_b:

In this section, we will calculate the base flow rate (q_b), which represents the sum of the base flow rates of each device present in a home using the calculation formula following the conditions of the DTU-60 standard (Table 02)

3. Calculation of the probable flow q_p:

The probable flow rate of a dwelling is defined by the formula:

$$q_P = \Sigma q \ x \ k$$

or $\sum$q: represents the basic flow rate in (ℓ/s), k: coefficient of simultaneity: $K = \frac{0{,}8}{\sqrt{x-1}}$ and x the number of devices per dwelling. For the case of several dwellings we have $q_p = N\Sigma q_b \ x \ k$ Where N is the number of dwellings.

4. Formatting a Data Table:

In this section, we will develop a table that includes all the calculation data, such as the flow rate of the devices, the pressure on each floor, and the simultaneity coefficient for each case, from 1 to 10 units / floor up to 10 floors.

5. Formatting the graphs of the variation of the flow rate as a function of the pressure q = *f* (p): In this step consists of mastering the format of the variation of the probable flow rate as a function of the pressure necessary at each level of a building which varies from 1 to 10 dwellings / floor up to 10 floors. First of all we worked with the directives of DTU60.

6. Formatting a Data Summary Table

This step involves formatting a data summary table, which primarily encompasses the form of the equation q = *f* (p) and the coefficients associated with this equation.

7. Processing and analysis of the data in the table from step 6:

In this step, we will analyze the processing and analysis aimed at defining coefficients

(a) and (b) that are unique for all cases, to the extent possible, and at least for the pressure exponent (b).

8. Data correction with the new value of the pressure exponent coefficient (b):

After processing and analyzing the data in the summary table, we were able to arrive at a single pressure exponent coefficient (b) for all cases processed, from 1 to 10 dwellings / floor up to 10 floors. We will apply this coefficient to all cases.

9. Correction of coefficient (a) unloading coefficient:

In this section, we will establish a relationship between the number of dwellings per floor and the variation of coefficient (a) to arrive at the final form of the equation: q = *f* (*p*).

For Romania case, we used the same methodology to structure the procedures. However, the determination of basic flow is carried out differently, since Romania applies its own standards and methods, distinct from those in NF DTU 60.11 P1-1. A major difference comes from the approach defined in the Romanian standard No. 1167 bis / 6.XII.2022.

- The coefficient of simultaneity for cold water is calculated with the following formula:

$$f_{AR} = \frac{0,83}{\sqrt{N-1}} \qquad (2)$$

According to the Roman Standard, two different formulas are used to calculate simultaneity coefficients one for cold water and another for hot water whereas the French standard relies on a single formula. Among the notable differences is that.

- The B-2 method was chosen, since the consumption unit Ui is applied when the reinforcement factor U ≥ 15 [9].

Consequently, the following flow rate calculation relations are used:

$$Q_{C,AR} = Q_{S,tot,AR} \; x \; f_{AR} \qquad (2)$$

With:
$Q_{c,\,AR}$: Design flow rates for cold water distribution (ℓ/s) ;
$Q_{s,tot,\,AR}$: Total specific cold water flow for a section (ℓ/s) ;
fAR: The coefficient of simultaneity for cold water.

3. Cases selected in the study

- Estimating of probable flows according to housing units and floors:
This study focuses s the estimation of probable flow rates based on the number of apartments per building and the total number of floors, in line with recognized national standards. In Algeria, the French DTU 60 standards were adjusted for local use, while in Romania the reference was the official standards (Monitorul Oficial al României, partea I, Nr. 1167 bis /6.XII.2022). The analysis covers buildings ranging from 1 to 10 apartments per floor, with a maximum of 10 floors. The methodology is illustrated in detail through two case studies: buildings with 4 apartments per floor in three Algerian cities, and buildings with 7 apartments per floor in the Tei– Colentina District of Romania. This same procedure is then extended to the other configurations.

3.1. Algerian Case

The procedure is illustrated using a reference building consisting of 10 floors, with 4 apartments per floor.

Tabelul 1

Estimated probable flow for a building with 10 floors and 4 apartments per floor.

Floor		Gf	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-9	F-10
designation		pressure demand per floor in (m)										
		5	8	11	14	17	20	23	26	29	32	35
Device Type in apartment	Flow (ℓ/s)	Basic Flow of devices according to the type and number of apartments in (ℓ/s)										
Sink	0,2	0,8	1,6	2,4	3,2	4	4,8	5,6	6,4	7,2	8	8,8
Wash basin	0,2	0,8	1,6	2,4	3,2	4	4,8	5,6	6,4	7,2	8	8,8
Shower	0,2	0,8	1,6	2,4	3,2	4	4,8	5,6	6,4	7,2	8	8,8
Bathtub	0,33	1,32	2,64	3,96	5,28	6,6	7,92	9,24	10,56	11,88	13,2	14,52
Basin hand wash	0,1	0,4	0,8	1,2	1,6	2	2,4	2,8	3,2	3,6	4	4,4
Washing machine	0,2	0,8	1,6	2,4	3,2	4	4,8	5,6	6,4	7,2	8	8,8
WC with flush tank	0,12	0,48	0,96	1,44	1,92	2,4	2,88	3,36	3,84	4,32	4,8	5,28
TOTAL	1,35	5,4	10,8	16,2	21,6	27	32,4	37,8	43,2	48,6	54	59,4
Number of apartments		4	8	12	16	20	24	28	32	36	40	44
Number of devices		28	56	84	112	140	168	196	224	252	280	308
Coefficient of simultaneity		0,154	0,108	0,088	0,076	0,068	0,062	0,057	0,054	0,050	0,048	0,046
Q probable in (ℓ/s)		0,831	1,165	1,423	1,640	1,832	2,006	2,166	2,314	2,454	2,586	2,712

- Graphical representation

The graphical representation in Fig.3 shows how the probable flow (qp) changes in relation to the requested pressure for the Algerian case (4 apartments per floor).

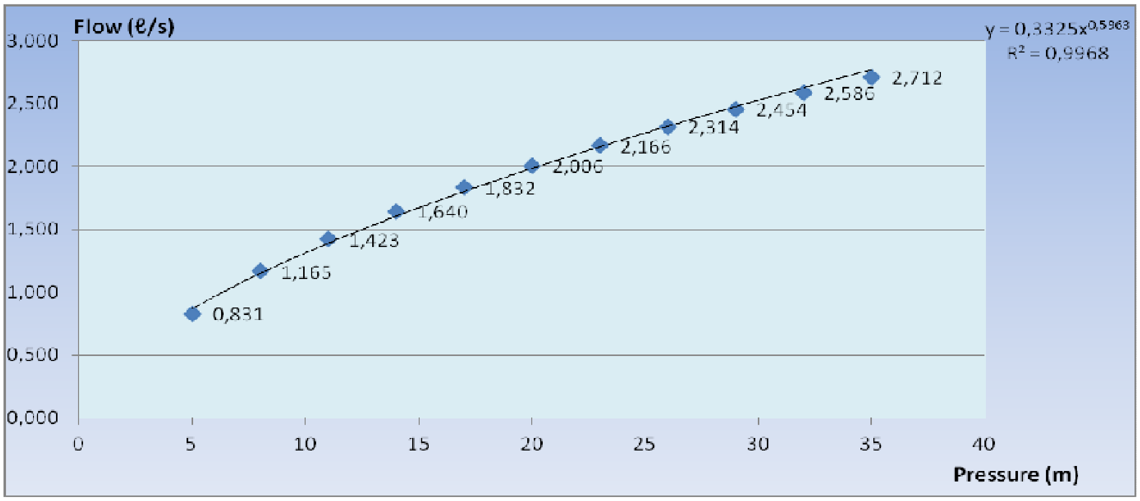


Fig. 3. Graph representing the variation in probable flow (qp) as a function of the requested pressure.

3.2. Romanian Case

This section describes the methodology applied to a building comprising 10 floors, each containing 7 apartments.

Tabelul 2

Estimated probable flow rates for this configuration of 7 apartments per floor across 10 floors

Floor			**Gf**	**F-1**	**F-2**	**F-3**	**F-4**	**F-5**	**F-6**	**F-7**	**F-8**	**F-9**	**F-10**
DESIGNATION			pressure demand per floor in (m)										
			5	**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**	**32**	**35**
Device Type/ apartment	**Flow (ℓ/s)**	**Unité (Ui)**	Basic flow rate of devices according to the type and number of dwellings (*Q*s, tot) in (ℓ/s)										
Sink	0,2	2	1,4	2,8	4,2	5,6	7	8,4	9,8	11,2	12,6	14	15,4
Wash basin	0,15	1,5	1,05	2,1	3,15	4,2	5,25	6,3	7,35	8,4	9,45	10,5	11,55
Shower	0,2	2	1,4	2,8	4,2	5,6	7	8,4	9,8	11,2	12,6	14	15,4
Bathtub	0,25	3	1,75	3,5	5,25	7	8,75	10,5	12,25	14	15,75	17,5	19,25
Toilet sink	0,1	1	0,7	1,4	2,1	2,8	3,5	4,2	4,9	5,6	6,3	7	7,7
WC with wash tank	0,12	1	0,84	1,68	2,52	3,36	4,2	5,04	5,88	6,72	7,56	8,4	9,24

Floor			**Gf**	**F-1**	**F-2**	**F-3**	**F-4**	**F-5**	**F-6**	**F-7**	**F-8**	**F-9**	**F-10**
DESIGNATION			pressure demand per floor in (m)										
			5	**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**	**32**	**35**
Device Type/ apartment	**Flow (ℓ/s)**	**Unité (Ui)**	Basic flow rate of devices according to the type and number of dwellings (*Q*s, tot) in (ℓ/s)										
Washing machine	0, 2	2	1,4	2,8	4,2	5,6	7	8,4	9,8	11,2	12,6	14	15,4
Dishwasher machine	0,2	2	1,4	2,8	4,2	5,6	7	8,4	9,8	11,2	12,6	14	15,4
TOTAL	1,42	14,5	9,94	19,88	29,82	39,76	49,7	59,64	69,58	79,52	89,46	99,4	109,34
Number of apartments			7	14	21	28	35	42	49	56	63	70	77
Number of devices/ apartment			56	112	168	224	280	336	392	448	504	560	616
Coefficient of simultaneity			0,112	0,079	0,064	0,056	0,050	0,045	0,042	0,039	0,037	0,035	0,033
Q probable in (ℓ/s)			1,112	1,566	1,915	2,210	2,470	2,705	2,921	3,122	3,311	3,489	3,659

- Graphical representation

Figure 4 shows the relation between probable flow (q_p) and the required pressure. It also illustrates the variation of probable flow according to Romanian standards (7 apartments per floor), confirming the increasing demand on higher floors.

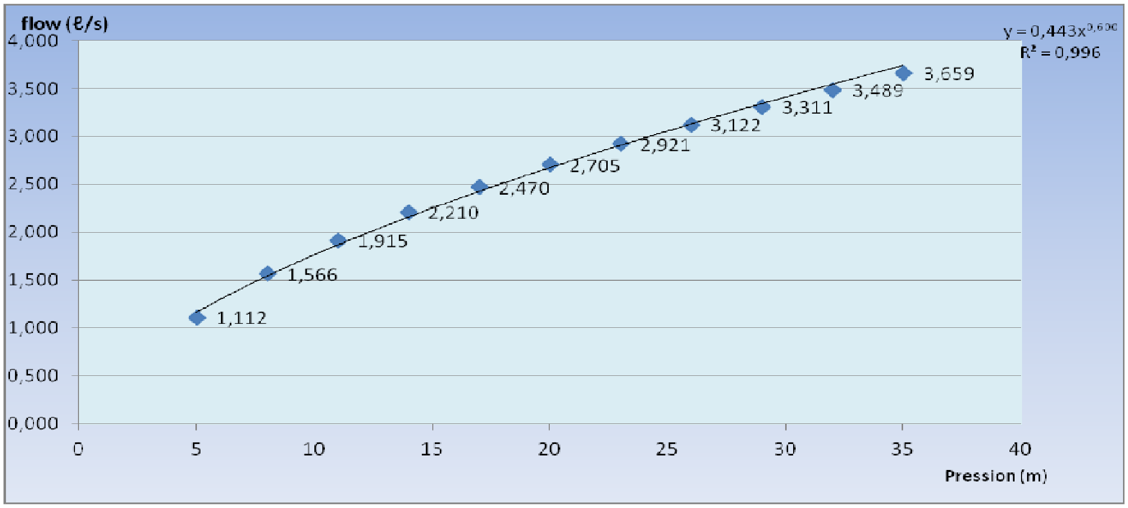


Fig. 4. Graphical representation of the probable flow variation (qp) as a function of the requested pressure.

4. Result and discussion

In the context of searching for the discharge coefficient (C) and the pressure coefficient (γ) related to the emitter formula (1)

After conducting a study on two cases, namely Algeria and Romania, the results obtained through the following two tables (3) and (4) were:

4.1 Case of Algeria

The coefficients determined for Algeria are presented in Table 3, showing the variation of discharge coefficient C with the number of apartments per floor.

Tabelul 3

The coefficients adopted (Case of Algeria)

Designation	Form of the equation	Coefficients	
	$q = c.\ p^{\gamma}$	c	γ
1 apartment / floor on 10 floors	$q = 0{,}176\ p^{0{,}6}$	0,176	0,6
2 apartment / floor on 10 floors	$q = 0{,}242\ p^{0{,}6}$	0,242	0,6
3 apartment / floor on 10 floors	$q = 0{,}292\ p^{0{,}6}$	0,292	0,6
4 apartment / floor on 10 floors	$q = 0{,}334\ p^{0{,}6}$	0,334	0,6
5 apartment / floor on 10 floors	$q = 0{,}370\ p^{0{,}6}$	0,370	0,6
6 apartment / floor on 10 floors	$q = 0{,}403\ p^{0{,}6}$	0,403	0,6
7 apartment / floor on 10 floors	$q = 0{,}432\ p^{0{,}6}$	0,432	0,6
8 apartment / floor on 10 floors	$q = 0{,}460\ p^{0{,}6}$	0,460	0,6
9 apartment / floor on 10 floors	$q = 0{,}486\ p^{0{,}6}$	0,486	0,6
10 apartment / floor on 10 floors	$q = 0{,}510\ p^{0{,}6}$	0,510	0,6

The relation between coefficient C and the number of apartments is depicted in Figure 5 (Case of Algeria).

- Graphical representation: C = *f* (N)

This curve represents the variation of the coefficient C as a function of the number of apartments per floor.

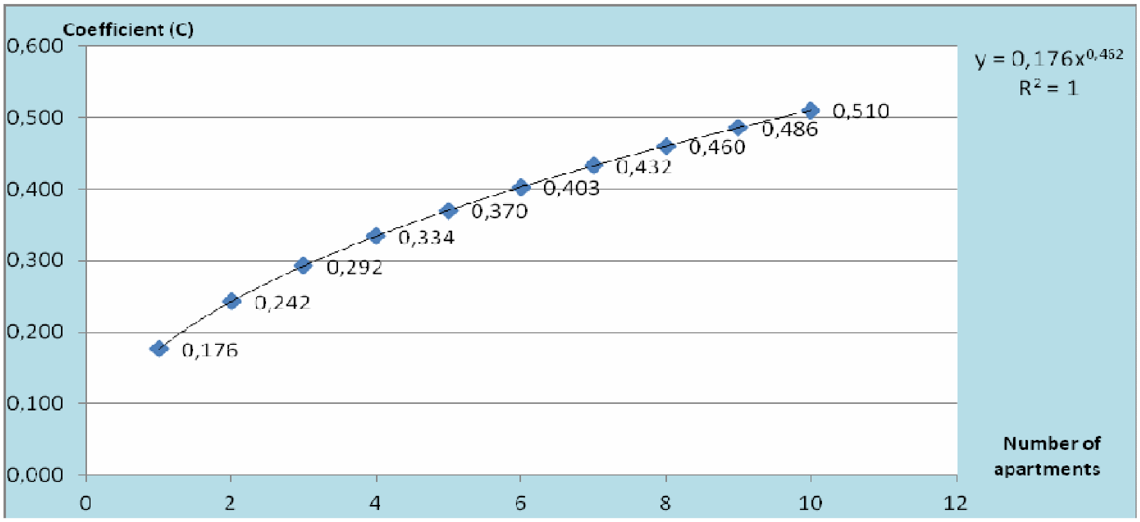


Fig. 5. Curve of the variation of the coefficient C as a function of the number of dwellings per floor
Curve of the equation: $y = 0.176\,x^{0.462}$.

4.2. Case of Romania

As shown in Table 4, Romania's adopted coefficients similarly indicate consistent pressure exponent values, with slight differences in C compared to Algeria.

Tabelul 4

The coefficients adopted (Case of Romania)

Designation	Form of the equation	Coefficients	
	$q = c.\ p^{\gamma}$	c	γ
1 apartment / floor on 10 floors	$q = 0{,}178\ p^{0{,}6}$	0,178	0,6
2 apartment / floor on 10 floors	$q = 0{,}246\ p^{0{,}6}$	0, 246	0,6
3 apartment / floor on 10 floors	$q = 0{,}297 p^{0{,}6}$	0,297	0,6
4 apartment / floor on 10 floors	$q = 0{,}340\ p^{0{,}6}$	0,340	0,6
5 apartment / floor on 10 floors	$q = 0{,}377\ p^{0{,}6}$	0,377	0,6
6 apartment / floor on 10 floors	$q = 0{,}411\ p^{0{,}6}$	0,411	0,6
7 apartment / floor on 10 floors	$q = 0{,}442\ p^{0{,}6}$	0,442	0,6
8 apartment / floor on 10 floors	$q = 0{,}470\ p^{0{,}6}$	0,470	0,6
9 apartment / floor on 10 floors	$q = 0{,}497\ p^{0{,}6}$	0,497	0,6
10 apartment / floor on 10 floors	$q = 0{,}522\ p^{0{,}6}$	0,522	0,6

The relationship between coefficient C and the number of apartments is depicted in Figure 7 (Case of Romania).

- Graphical representation C = *f* (N)

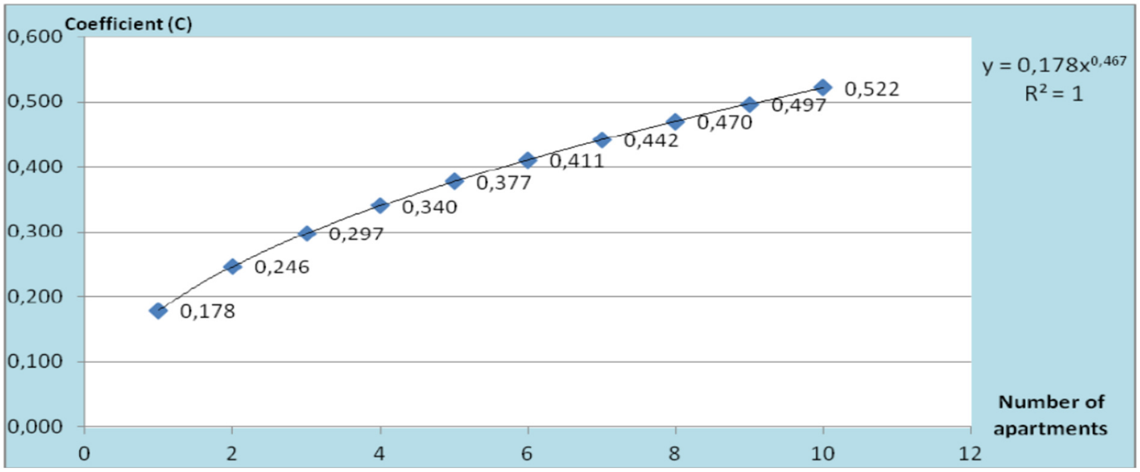


Fig. 6. Curve of the variation of the coefficient (C) as a function of the number of apartments per floor Curve of the equation: $y = 0.178\, x^{0.467}$.

5. Comparison between flow and pressure-based analysis in water distribution systems serving a given population.

In this section, we will conduct a comparative case study of the two calculation algorithms currently used by EPANET 2.2. For the pressure-based analysis, the flow variation coefficients determined in the previous section will be used. The study will examine how results differ depending on the locality's geographical location across different countries.

5.1. Hydraulic simulation and analysis methods

There are two approaches that we normally use to run Hydraulic Modeling in EPANET, Demand Driven Analysis (DDA) and Pressure Driven Analysis (PDA).
The model-based distribution site identification methodology was tested in Two Algerian cities and one Romanian city under real-world distribution scenarios. The water distribution networks in these cities cover their entire urban areas, and the populations of the cities are listed in table 5 below.

Tabelul 5

Population number in each city

Cities	Total population
N’gaous	33619
Ras El Aioun	19850
Tei-Colentina	40 000

In these figures, the simulation process was carried out for two cases: Demand Driven Analysis (DDA) and Pressure Driven Analysis (PDA). The previously defined parameters were inserted into the numerical model for the PDA case at the nodes corresponding to the type of building they supply.

To our knowledge, the buildings in the studied Algerian cities each consist of five floors (ground floor + 4 upper floors) and contain four apartments per floor. In contrast, buildings in Tei-Colentina District, Romania, typically consist of eleven floors (ground floor + 10 upper floors) and contain seven apartments per floor, as previously explained.

Therefore, the parameters entered into the numerical models for each city are as follows:

- For the four cities in Algeria, the values were based on the equation obtained from Table 6.

Tabelul 6

The coefficients determined for the case of Algeria

Designation	Equation form	Coefficients	
4 apartment/ floor on 10 floors	$q=c.p^{\gamma}$	C	γ
	$q=0{,}334\ p^{0{,}6}$	0,334	0,6

For the city of Tei - Colentina District in Romania, the values were calculated based on the equation shown in Table 7.

Tabelul 7

The coefficients determined for the case of Romania

Designation	Equation form	Coefficients	
7 apartment/ floor on 10 floors	$q=c.p^{\gamma}$	C	γ
	$q=0{,}442\ p^{0{,}6}$	0,442	0,6

5.2. Simulation and analysis for cities

5.2.1. Analysis for the city of N'gaous

5.2.1.1. DDA (Demand-Driven Analysis)

As illustrated, the water distribution network of the city of N’gaous was simulated under demand driven analysis (DDA) conditions. Figure 7 shows the pressure distribution and the resulting flow, while Figure 8 shows the pressure and velocity results

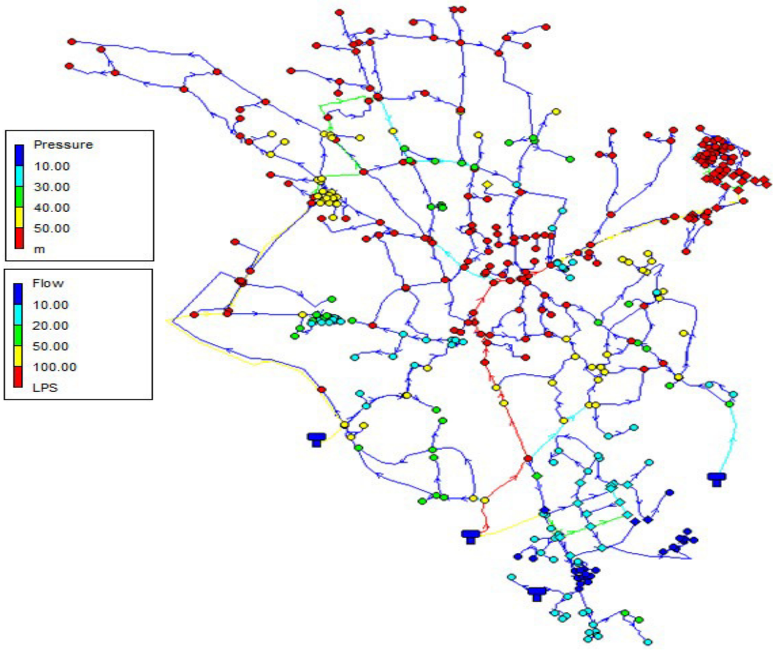


Fig.7. Water distribution network of the city N'gaous, simulation: Pressure – flow.

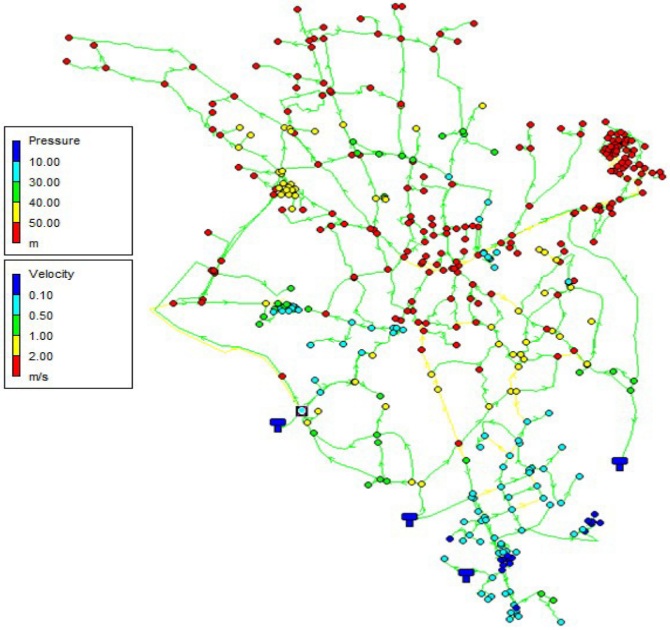


Fig.8. Water distribution network of the city N'gaous, simulation: Pressure – velocity.

5.2.1.2. PDA (Pressure Driven Analysis)

As illustrated, the water distribution network of the city of N'gaous was simulated under pressure driven analysis (PDA) conditions. Figure 9 shows the pressure distribution and the resulting flow, while figure 10 shows the pressure and velocity results.

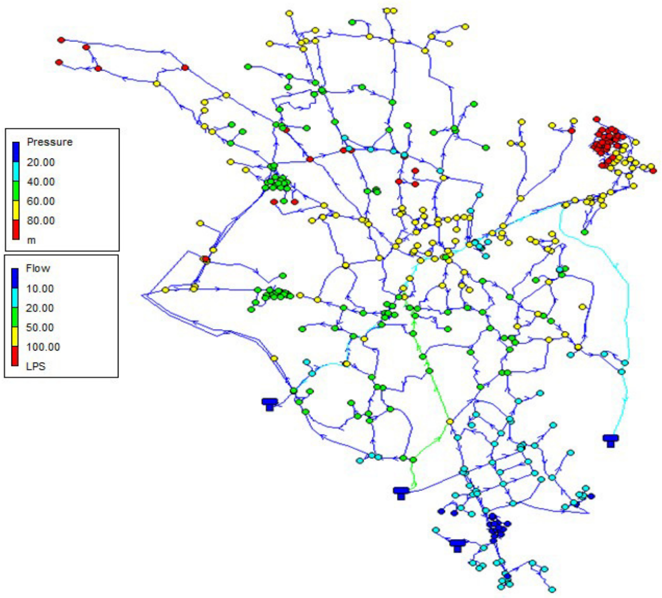


Fig. 9. Water distribution network of the city N'gaous, simulation: Pressure – flow.

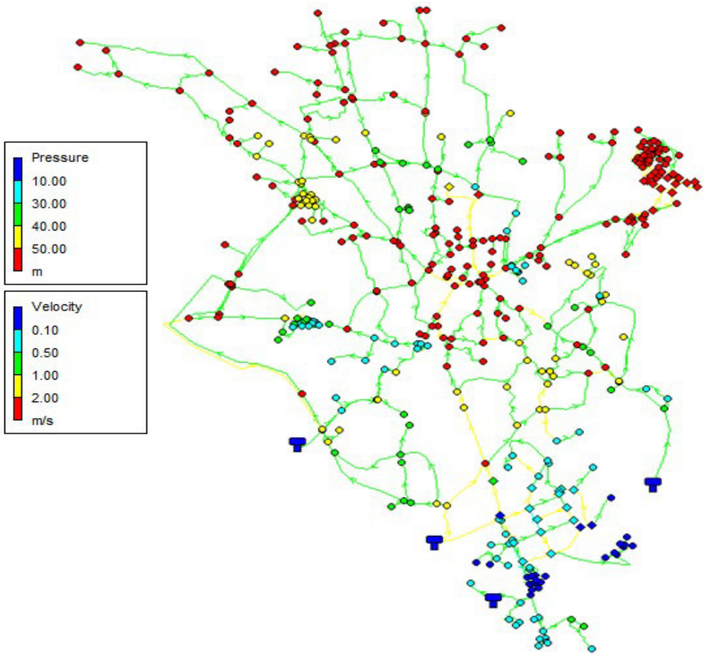


Fig. 10. Water distribution network of the city N'gaous, simulation: Pressure – velocity.

5.2.2. Analysis for the city of Ras El Aioun

5.2.2.1. DDA (Demand-Driven Analysis)

As illustrated, the water distribution network of the city of Ras ElAioun was simulated under demand driven analysis (DDA) conditions. Figure 11 shows the pressure distribution and the resulting flow, while Figure 12 shows the pressure and velocity results.

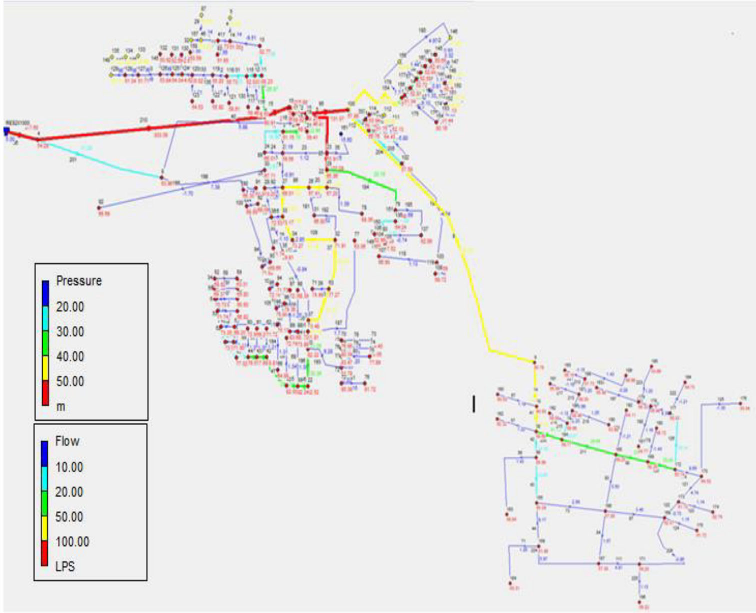


Fig. 11. Water distribution network of the city Ras El Aioun, simulation: Pressure – flow.

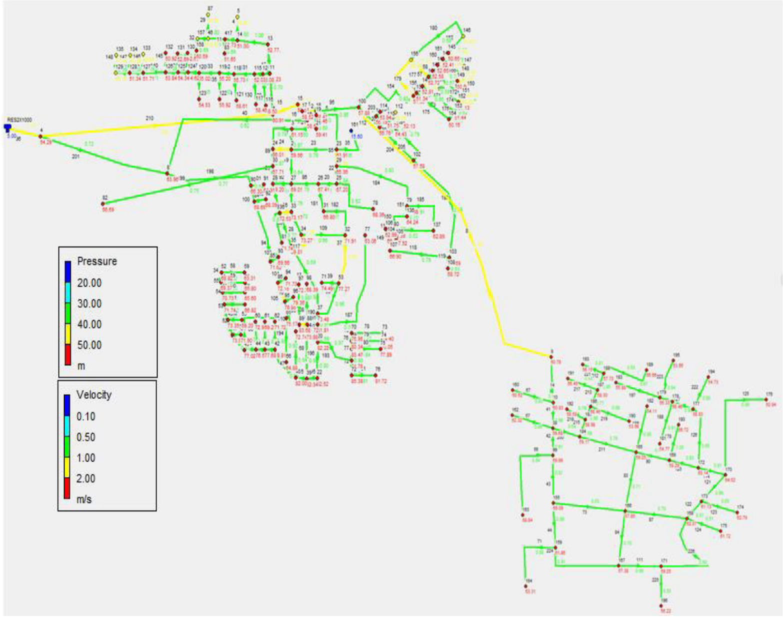


Fig. 12. Water distribution network of the city Ras El Aioun, simulation: Pressure – velocity.

5.2.2.2. PDA (Pressure Driven Analysis)

As illustrated, the water distribution network of the city of Ras El Aioun was simulated under pressure driven analysis (PDA) conditions. Figure 13 shows the pressure distribution and the resulting flow, while figure 14 shows the pressure and velocity results.

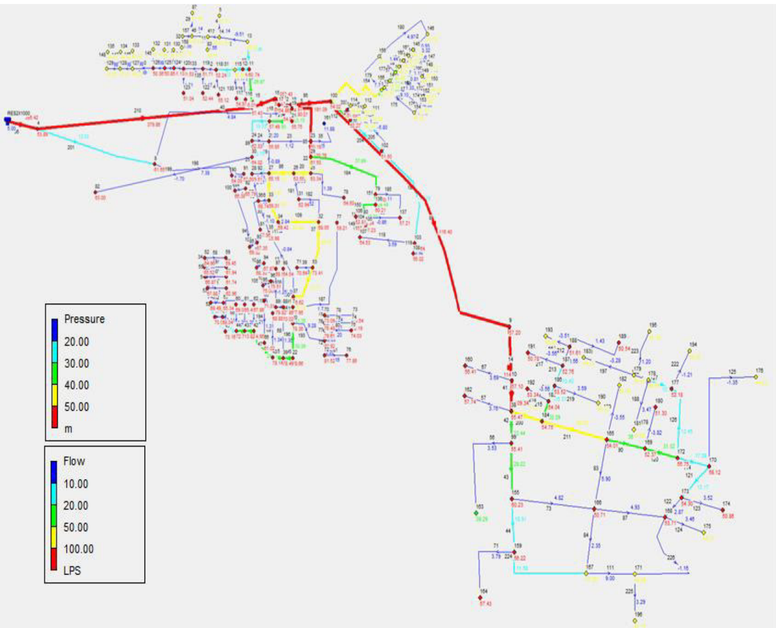


Fig.13. Water distribution network of the city Ras El Aioun, simulation: Pressure – flow.

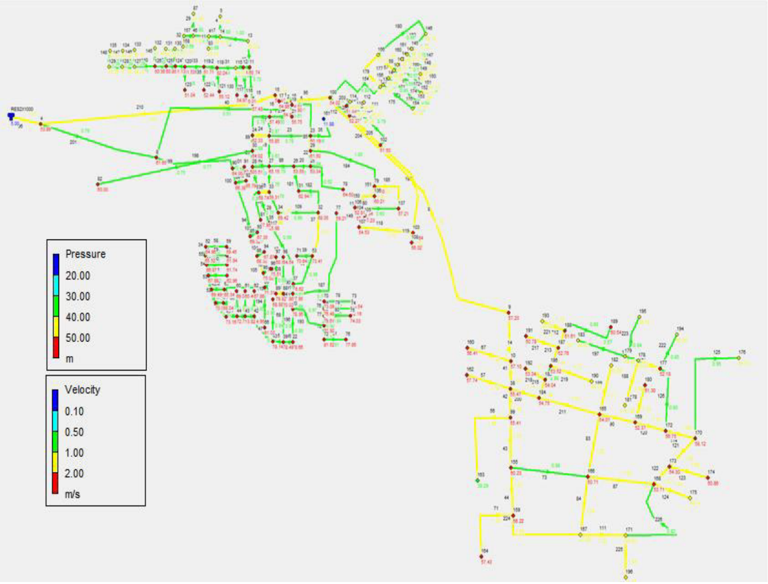


Fig.14. Water distribution network of the city Ras El Aioun, simulation: Pressure – velocity.

5.2.4. Analysis for the « Tei - Colentina District » (Bucarest)

5.2.4.1. DDA (Demand-Driven Analysis)

As illustrated, the water distribution network of the city of Tei - Colentina was simulated under demand driven analysis (DDA) conditions. Figure 15 shows the pressure distribution and the resulting flow, while Figure 16 shows the pressure and velocity results.

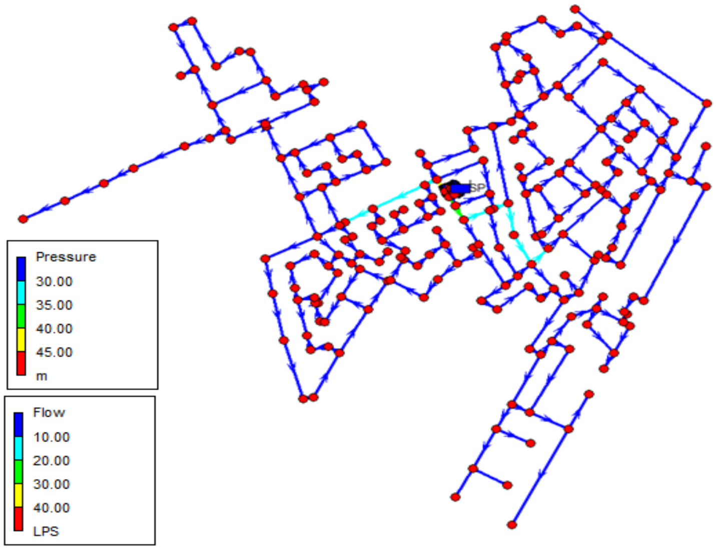


Fig. 15. Water distribution network of the city Tei-Colentina, simulation: Pressure – flow.

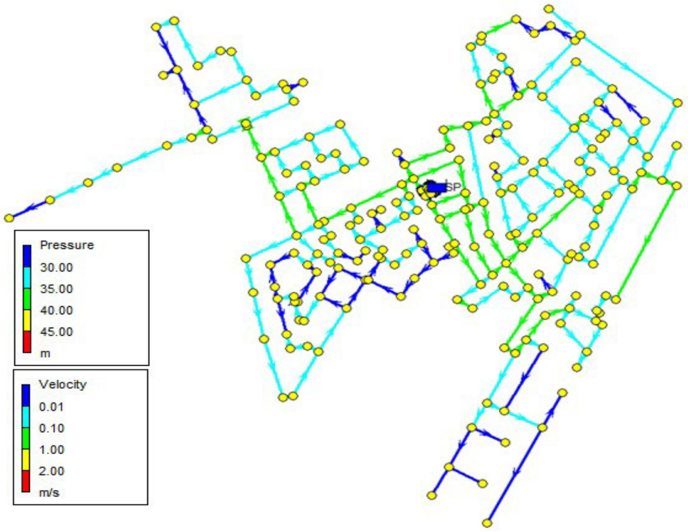


Fig.16. Water distribution network of the city Tei-Colentina, simulation: Pressure – velocity.

5.2.4.2. PDA (Pressure -Driven Analysis)

As illustrated, the water distribution network of the city of Tei - Colentina was simulated under pressure driven analysis (PDA) conditions. Figure 17 shows the pressure distribution and the resulting flow, while figure 18 shows the pressure and velocity results.

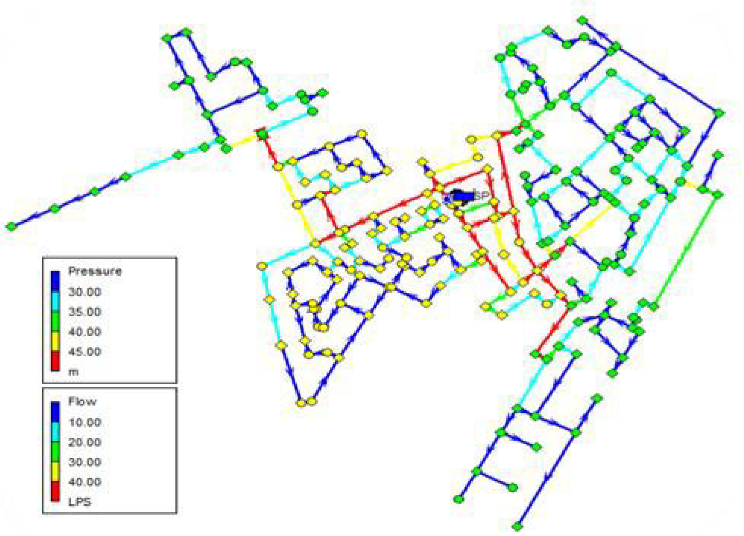


Fig. 17. Water distribution network of the city Tei-Colentina, simulation: Pressure – flow.

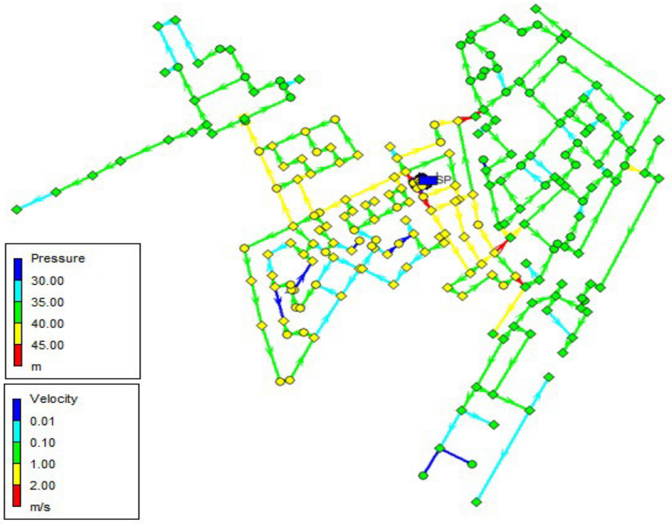


Fig. 18. Water distribution network of the city Tei - Colentina, simulation: Pressure – velocity.

6. Simulation results and discussion by city

6.1. City of N'gaous

•Analyse DDA (Demand Driven Analysis):
- Pressures are relatively high, ranging from 14 m to 66 m, with all demands fully met. as shown in Figures (7) and (8).
- This may seem ideal but does not reflect reality if the pressure were to drop or in the event of network overload.

•Analyse PDA (Pressure Driven Analysis):
- Results show more realistic pressure in high-altitude areas or at the end of the

network. as shown in Figures (9) and (10).
- In some nodes, demand is only partially met, and speeds vary more.
- We notice a progressive loss of pressure, revealing weak points in the network.

6.1.2. City of Ras El Aioun

• DDA (Demand Driven Analysis):
- Hypothesis: All demands are met regardless of pressure.
- Relatively high pressures, for example, from (54.29 m to 65.15 m) in the nodes. as shown in Figures (11) and (12).

• PDA (Pressure Driven Analysis):
- Slightly lower pressures than in DDA.
- Allows observation of areas where pressure is insufficient to meet demand. as shown in Figures (13) and (14).

6.1.3. Tei - Colentina

• DDA analysis:
- Provides optimistic results: demand is assumed to be fully supplied. As shown in the figure (15) and (16).

• PDA analysis:
- From Figure (17) and (18) highlights critical low pressure areas (e.g. pressures around 15 m).

The comparative analysis of the three urban networks shows that:
- Traditional methods (DDA) may overestimate the actual performance of the networks, especially under variable pressure conditions.
- The (PDA) approach allows for a better understanding of hydraulic behavior, taking into account the nonlinear relationship between flow and pressure. The data from the simulations clearly show that Algerian networks, although important, require technological updates and hydraulic optimization (better management of pressures, flows, water losses, etc.) to ensure efficient (good quality, waste-free, and cost-effective) and sustainable (long-term, even in the face of growing demand or limited resources) service.

In EPANET, when performing a Pressure Driven Analysis (PDA), the introduction of discharge coefficients and the emitter exponent has a direct impact on the modeling of flow rates at nodes based on the available pressure.

From what has been observed:
- Unlike Demand Driven Analysis (DDA), where demand at nodes is fixed, PDA adjusts flow rates at nodes based on available pressure.
- When the pressure drops below a certain threshold value, the delivered flow rate is reduced in accordance with the orifice emission equation (n°1): $q = C.P^{\gamma}$

Where: q: flow rate, c: discharge coefficient, It was determined with a variable value between: (0,176 - 0,510) in the case of Algeria. And between: (0,178 - 0,522) in the case of Romania. This coefficient varies according to the number of apartments on each floor of the building (see tables 3 and 4).

P : is the nodal pressure, γ: pressure exponent (generally between 0.5 and 0.6 for orifices), It was determined with a value of 0,6.

The formulas deduced for each of the two cities are:

- The 02 cities of Algeria: q = 0,334 . p 0,6
- Tei-Colentina: q = 0,442 . p 0,6

We observed that the difference between the two formulas is minimal, due to the type of equipment used by households either in Algeria or in Romania.

The same applies when we look at the basic flow rate tables, according to the French standard NF DTU 60.11P1-1. And the Roman standards (Monitorul Oficial al României, partea I, nr. 1167 bis/6.XII.2022) and standard (STAS 1478-90).

There is a slight difference in the estimated flow rates in buildings, for example, for (sinks French standards: 0.20 ℓ/s and Roman standards 0.15 ℓ/s while for bathtubs 0.33 ℓ/s vs 0.25 ℓ/s.(See Tables 1 and 2)

The same can be observed for the formula for calculating the simultaneity coefficient, given that in Romania, the formula is as follows: $f_{AR} = \frac{0,83}{\sqrt{N-1}}$; while those applied in Algeria are based on the French standards, which are: $K = \frac{0,8}{\sqrt{x-1}}$

This slight difference between the two constants (0, 8 in the French standards) and (0, 83 in the Roman standards) is:

- The difference between 0.83 and 0.8 comes from experimental data and analyses conducted in each country on how sanitary facilities are used.

- Romania adopted the coefficient of 0.83 based on local studies on the frequency of use and the distribution of water consumption.
- French standards adopted the coefficient of 0.8 following its own observations on the use of the facilities.

- Furthermore, the difference between these two constants is probably due to several factors:

- Building typology: In Romania and France, the use of sanitary facilities can vary depending on the building type (residential, hotel, industrial ....etc.).
- Consumption habits: Depending on lifestyle, the frequency and duration of use of water consumption points can differ between the two countries.
- Design safety: The slightly higher coefficient in Romania (0,83 versus 0,8) may indicate a more conservative approach, providing a greater safety margin for system design.

Ultimately, the difference between the two coefficients is relatively small (0.83 versus 0.8), but reflects national particularities in terms of water consumption and plumbing design philosophy. Romania adopts a slightly higher value, likely for safety reasons and to adapt to the specific requirements of local infrastructure.

•Regarding the analysis status :

- PDA allows for more accurate modeling of network pressure variability, which is essential for infrastructure design.
- PDA focuses on assessing network pressures, providing a more realistic representation of the service conditions offered to users.
- Regarding pressure and flow, in both analysis cases

•Flow-based analysis (DDA) and

•Pressure-based analysis (PDA), this must be done under two conditions:

$$\begin{cases}\text{Flow rate: } Q \text{ DDA} \neq Q \text{ PDA (Varies with pressure)} \\ \text{Pressure: P (DDA)} > \text{P (PDA).}\end{cases}$$

The flow-in state (DDA) is a theoretical state where all demands are met, but as soon as the pressure is insufficient, the analysis state moves to a pressure-based analysis state (PDA), where the flow is reduced based on the available pressure. This change allows for more realistic modeling of networks under hydraulic constraints.

7. Concluzii

This study presents a comprehensive methodology for simulating and calibrating water distribution networks using EPANET 2.2, with a particular focus on evaluating Demand Driven Analysis (DDA) and Pressure Driven Analysis (PDA) under realistic operating conditions. By deriving discharge coefficients (C) and pressure exponents (γ) based on national plumbing standards from Algeria and Romania, the research bridges theoretical hydraulic modeling with practical regulatory constraints and consumer behavior.

The calibration process yielded consistent values for the pressure exponent (γ =0.6), while the discharge coefficient (C) varied according to the number of apartments per floor ranging from 0.176 to 0.510 in Algeria and 0.178 to 0.522 in Romania. These parameters were essential in constructing pressure-dependent demand models that more accurately reflect flow conditions under variable pressure scenarios. Case studies from both gravity-fed and pumped systems (in Algeria and Romania, respectively) demonstrated that while DDA assumes ideal conditions with fully satisfied demands, PDA reveals actual network limitations, such as pressure deficiencies and unsatisfied demands during peak usage or infrastructure stress. PDA simulations enabled the identification of critical nodes, areas prone to underperformance, and design oversights that DDA tends to obscure.

This work contributes a novel framework by linking empirical regulatory data to hydraulic simulation parameters, thus improving the realism and transferability of network models across different urban contexts. It highlights the necessity of using PDA augmented by properly calibrated coefficients for informed decision-making in system design, infrastructure reinforcement, and operational management.

Ultimately, the study demonstrates that integrating country-specific standards into pressure-based simulation models not only enhances their accuracy but also fosters a more resilient and responsive approach to managing water distribution systems in diverse geographic and technical environments.

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