Irina IGNĂTESCU-MANEA

A PRACTICAL STUDY ON THE SURFACES OCCUPIED BY SANITARY FIXTURES IN THE BATHROOM

Abstract: *In her extensive experience working in civil and industrial construction sites, the author has noticed frequent errors in adapting the sizes of the sanitary objects to the bathroom dimensions as well as the positioning of the sinks, bidets, bathtubs, or showers in the designated spaces. In this article, the author sought to utilize the functions available in AutoCAD software to present calculation formulas that could assist architects and users in making informed decisions when designing, constructing, or renovating a bathroom.*

Key words: *calculation of surfaces, dynamic blocks, AutoCAD, minimum surfaces of bathrooms, sanitary objects in the bathroom*

1. INTRODUCTION

The idea of writing this article came from the practical experience of the author who often encountered errors in the household bathrooms (individual houses or apartment blocks). At the same time, the author noticed a tendency to build smaller and smaller rooms, even smaller than the minimum areas envisaged by the Romanian legislation. The synergistic effect of these factors lead to increased discomfort in the use of the households which then translated into physical and mental illnesses and a decrease in productivity and well-being.

The first baths are attested as early as about 2800 B.C. in Pakistan at Mohejo-daro.

In 2500 B.C. this invention was in almost every household, as shown in Figure 1. These were made to work like simple toilets; they had a pipe from the bottom, and the pipe used as a sewage [1].

Figure 1 Ancient Flush Toilet System 2500 B.C. [1]

Both Greeks and Romans recognized the importance of baths in their lifestyle, constructing buildings with dedicated spaces, with separate hot and cold-water installations and sophisticated sewage systems (Figure 2). Although there was a separation between public and private baths, many Roman families having their own bathrooms, most of them routinely used the public baths system as a place for socializing, discussing and relaxing.

Figure 2 Vertical pipes in Pompeii's walls may once have lead to upstairs toilets [2]

The usage decline of public and private baths began immediately after the Roman period. Although in medieval times people did not wash regularly, the toilets were still needed (Figure 3). Some were fitted with sewage pipes, others used pots or buckets.

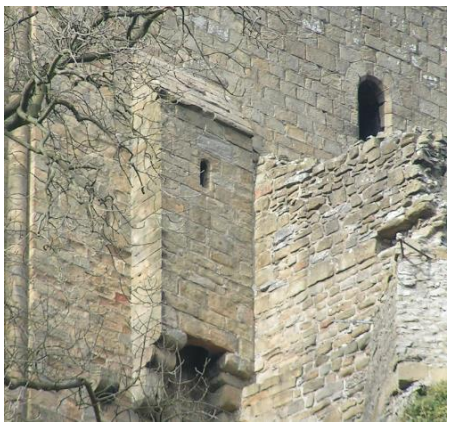

Figure 3 Medieval toilet, exterior, Peveril Castle [3]

In the following centuries, public baths usage decreased in interest, the emphasis being placed on private baths, which led to a certain lifestyle (Figure 4).

Figure 4 Romania, Prahova Country, Sinaia, Peles Castle, interior bath of neo-renaissance-castle, 1876 [4]

The first shower of the modern age was patented in 1767 by a London stove-maker (the user stand under a bucket of water and pulled a rope to use the shower). For a long time, at least in Europe, instead of a shower people took Rain Baths ("bain de pluie," in French), and later shampoo baths. It was seen as a novelty, and it took until the late 1800s for the idea to catch on. Big things have humble beginnings: but not the first patented shower design. The first real modern shower, the English Regency Shower— a 12-foot tall contraption that caught and recycled water– began to appear in wealthy households after 1810. A picture of one is as shown in Figure 5.

Figure 5 The first real modern shower [5]

2. ROMANIAN SPECIFIC CONTEXT TODAY

Today, bathrooms are associated not only with functionality but also with aesthetics, playing a significant role in both the design and cost of a building. The type of household (house or apartment), the number of rooms and the number of inhabitants is influencing the number of bathrooms and their layout.

The way bathrooms are used has led to the appearance of specific types of rooms, with a certain need for sanitary objects. Thus, the Romanian law distinguishes three types of bathrooms found in households, depending on the nature of the users: the service bathroom (for guests), the normal bathroom and matrimonial bathroom.

In the Romanian specialized Law 114 from 1996, the service bathroom is called a toilet, the normal bathroom is called a shower and the matrimonial bathroom is called simply - bathroom.

In this article, the author did not take into consideration the bathrooms of industrial buildings (bathrooms at the shopping malls, gas stations, factories, etc.) nor the bathrooms with several cabins like in schools, libraries, restaurants, theaters, etc. The article is aimed to provide an aid to the users of households in general.

According to Law no. 114 of 11 October 1996 (*republished*) on housings [6] there are a series of minimum requirements regarding the rooms surfaces.

The authorization for the construction of new housing, regardless of the nature of the property or its location, is granted based on meeting the minimum requirements outlined in Annex no. 1 of Law 114/1996.

The Law 114/1996 also mentions that in the bathroom should be a designated space for the washing machine and the sanitary rooms should be ventilated directly or through a ventilation chimney.

Table 1

Minimum areas according to Law 114/1996, Annex 1

Persons/ Family	Rooms/ House	Living room room	Bed room	Dining room	Kitchen	Bath room	Storage Space	Useful Surface	Built Surface
No.	No.	Sm	Sm	Sm	Sm	Sm	Sm	Sm	Sm
1	1	18.00	-	2.50	5.00	4.50	2.00	37.00	58.00
2	2	18.00	12.00	3.00	5.00	4.50	2.00	52.00	81.00
3	3	18.00	22.00	3.00	5.50	6.50	2.50	66.00	102.00
4	3	19.00	24.00	3.50	5.50	6.50	3.50	74.00	115.00
5	4	20.00	34.00	3.50	6.00	7.50	4.00	87.00	135.00
6	4	21.00	36.00	4.50	6.00	7.50	4.50	93.00	144.00
7	5	22.00	46.00	5.00	6.50	9.00	5.00	107.00	166.00
8	5	22.00	48.00	6.00	6.50	9.00	5.50	110.00	171.00

Table 2

Sanitary rooms according to the number of rooms per dwelling according to Law 114/1996

	Number of rooms / house				
	1	**2**	**3**	**4**	**5**
Bathroom	1	1	1	1	2
Shower	-	-	-	1	-
TOILET	-	-	1	-	-

The Law 114/1996 also specifies the minimum equipment of each type of bathroom as we can see in the table below *Table 3*.

Table 3

Minimum endowment of sanitary rooms according to Law 114/1996

		Bathroom	**Shower**	**TOILET**
Bathtub		1	-	-
TOILET		1	1	1
Sink	Large	1	-	-
	Small	-	1	1
Shower		-	1	-
Shelf	Large	1	-	-
	Small	-	1	1
Mirror	Large	1	-	-
	Small	-	1	1
Towel rack		1	1	1
Soap dispenser		1	1	1
Toilet paper holder		1	1	1
Hanger		1	1	-
Floor drain		1	1	-

In all the examples used in this article, the author considered the entrance door to the bathroom room with an opening of 90 cm to allow access to a wheelchair. The author did not refer in this article specifically to bathrooms for people with disabilities, but only considered ensuring the size in case it would be necessary to access a wheelchair.

2.1 Equipping the service bathroom (WC)

According to Law 114/1996 in the service bathroom (for guests) should include: a toilet, a simple small sink, a small shelf, a small mirror, a towel rail, a soap dispenser and a toilet paper holder.

The surface of this room should be at least 2 m² i.e. 20000 cm² as shown in Figure 6.

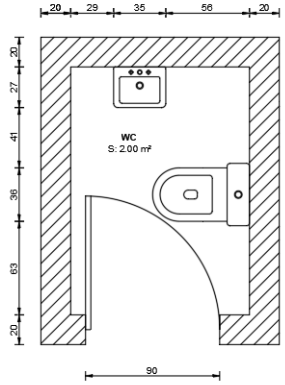

Figure 6 Minimum equipment of the toilet room with an area of 2.00 m²

2.2 Equipping the regular bathroom (shower)

According to Law 114/1996 the regular bathroom (shower) should include: a toilet, a shower cabin, a simple small sink, a small shelf, a small mirror, a towel rack, a soap dispenser, a toilet paper holder, a hanger and a floor trap. The minimum recommended area is 3 m² as shown in Figure 7.

This type of bathroom is usually located near the bedrooms.

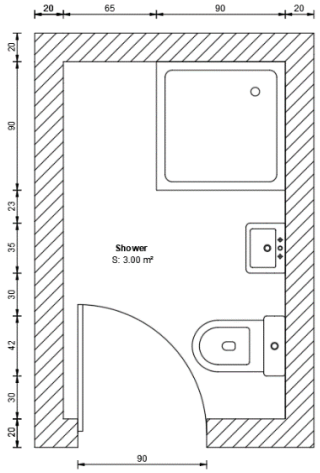

Figure 7 Minimum shower room with an area of 3.00 m²

2.3 Equipping the bathroom

According to the above mentioned law, in the bathroom someone should find: a toilet, a bathtub, a simple large sink, a large shelf, a large mirror, a towel rack, a soap dispenser, a toilet paper holder, a hanger and a floor drain. The surface of this room should be at least 4.5 m² i.e. 45000 cm² as shown in Figure 8.

This bathroom serves the master bedroom or, if it is the only bathroom in the household, the equipment should be adapted to all resident's needs.

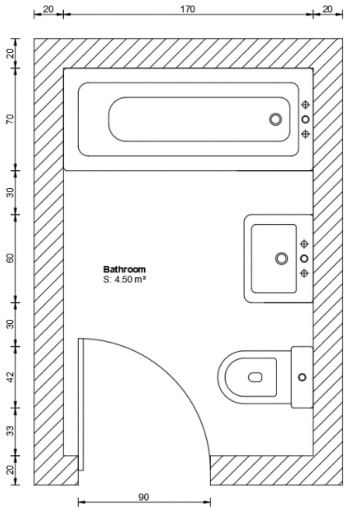

Figure 8 Minimum endowment of the bathroom with an area of 4.50 m²

Taking into account the author's experience in the field of civil constructions of individual dwellings, he noticed that currently, most of the users request to have in the bathroom also an bidet, a tumble dryer and a double sink.

Thus, it can be seen that the minimum area proposed by the law maker is not sufficient to meet the current needs as shown in Figure 9.

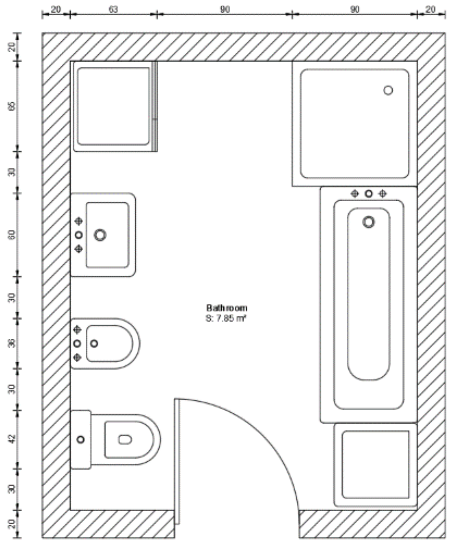

Figure 9 Endowment of a modern bathroom with toilet, bidet, sink, shower, bathtub, washing machine and dryer; the area is 7.85 m²

Today, in the modern bathroom, people have combined all the progressions of previous elements into the epitome of style and functionality. The bathroom is a hub of relaxation, with people no longer bathing just for hygiene, but because a bubble bath can cure a multitude of worries and stresses. People have created a space for ourselves to unwind and feel ultimate comfort. With even more technological and engineering progression, we are at a point where people can have underfloor heating, televisions and other digital aspects in their bathrooms. [7]

When everything is fast-paced and people predominantly live in the virtual world, many order everything from the internet. For the uninitiated, it is difficult to read all the dimensions and understand the real size of various sanitary objects.

Therefore an array of situations can be encountered with items ordered based on an shallow judgment, of which the author mentions a few:

- the sink is too small for the family's needs;
- the bathtub is too big and does not fit in the intended place;
- there is not enough space in the toilet or bidet so that it can be used efficiently;
- there is not enough space in front of the toilet or bidet or sink;
- the shower cabin is too large and covers the window;
- the shower cabin is too small and cannot be used by the users;
- faucets are too large or too small compared to the sink;
- the impossibility of carrying the bathtub into the bathroom because the household corridors are too narrow or have too many corners.

These inconsistencies in the choice of bathroom furniture came from the fact that the users based their choice exclusively on their design or the economic criteria. The author believes that the main criteria in choosing sanitary furniture should be flat and spatial dimensions. As secondary criteria, the design and cost of the products should also be used.

In conclusion, given the difficulty in shifting the customers mindset, the author thought that it would be easier to use some "recipes" for the users who wanted to shop online but also for the users constrained by various factors.

3. PRACTICAL AND TECHNICAL SOLUTIONS

It is noticed that, in all bathrooms since ancient times, the room intended for the bathroom had a large surface, that the distances between the sanitary objects were large enough for easy access and use without being hindered by another piece of furniture.

In the current study, the author examined the specific context of Romania where people asked to have functional bathrooms. What does a functional bathroom mean? It's simple: a bathroom in which the sanitary objects are correctly arranged, in order to efficiently use the space of the room but also to optimally meet the needs of the users.

The author considered that the space between the sanitary objects and in front of them was fundamental for a bathroom to be considered functional. Therefore, this space should be taken into account when calculating the surfaces necessary for a functional bathroom.

In order to help the users, so that they understand how important is to arrange the furniture so that there is space for ventilation, movement and storage, for the ultimate comfort of the bathrooms, the author proposed that before purchasing the sanitary objects, a simulation of their arrangement in the bathroom space should be made in AutoCAD software.

In case using AutoCAD is difficult, a simplified, tabular version of this calculation is also presented.

In the calculations for furnishing the functional sanitary room, the following requirements should be followed:

- the access door should be 90cm;
- the surface of the main sanitary room in the house should be designed so as to allow access to the bathtub of the people using a wheelchair;
- on the side of the toilet, both left and right, there should be a free space of 30 cm (minimum 25 cm);
- on the side of the bidet, both left and right, there should be a free space of 30 cm (minimum 25 cm);
- in front of the toilet there should be a free space of 50 cm;
- in front of the bidet there should be a free space of 50 cm;
- in front of the sink there should be a free space of 60 cm;
- In front of the washing machine and the dryer there should be a free space of 60 cm.

For the calculation of the surfaces of sanitary objects, the author used the AutoCAD software.

Since there are no closed contours, before calculating the surfaces the user should use one of the following commands:

- command **BPOLY** to create regions or a polylines from enclosed areas.
- Command **JOIN** to join the endpoints of linear and curved objects to create a single object. Valid objects include lines, arcs, elliptical arcs, polylines, 3D polylines, and splines.
- Command **PEDIT** to include joining 2D polylines, converting lines and arcs into 2D polylines, and converting polylines into curves that approximate B-splines (spline-fit polylines).

First the author has checked that all the contours are closed, and then she found out the surface of each object using the **AREA** command.

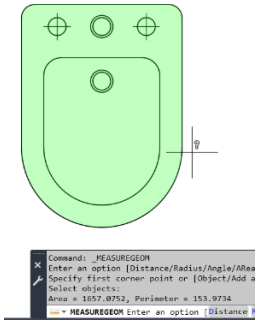

Figure 10 The actual bidet area is 1657.0752 cm²

Since it is very difficult for the users to calculate the areas so accurately (Figure 10) the user should make an additional approximation by framing the bidet in a rectangle and calculating the area again.

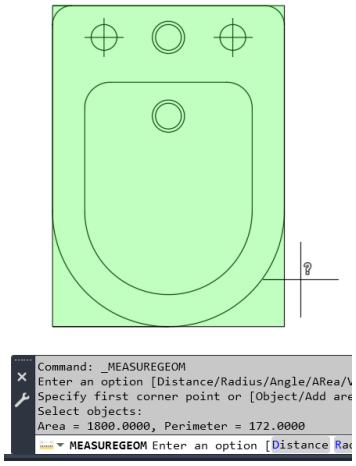

Figure 11 The approximate area of the bidet is 1800 cm²

The user should calculate the resulting error as the difference between the approximate area (Figure 11) and the actual area.

In the case of the bidet, the error resulting from this approximation was 1800 cm² – 1657.0752 cm² = 142.9248 cm² as shown in *Table 4.*

Table 4

The error is the difference between the actual surface and the approximate surface area of the bidet

Object	Actual Surface	Approximate surface area	Error (cm²)
Bidet	1657.0752	1800	142.9248

In the case of the toilet bowl (WC) where the user have two closed surfaces (toilet and water tank) the author should use the **AREA** command and choose the ***Add area*** option to sum the two surfaces as shown in Figure 12.

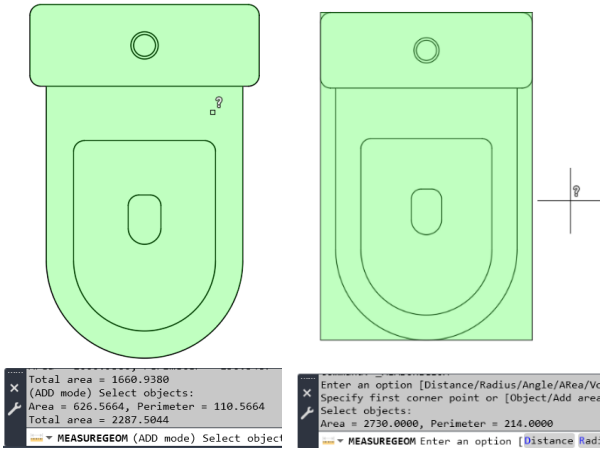

Figure 12 The WC area is 2287.5044 cm² and the approximate WC area is 2730.00 cm²

As in the case of the bidet, the user should make an additional approximation by framing the toilet in a rectangle and calculating again the surface as shown in *Table 5.*

Table 5

The error is the difference between the actual surface and the approximate surface of the toilet

Object	Actual Surface	Approximate surface area	Error (cm²)
TOILET	2287.5044	2730	442.4956

The calculation of the shower tray is simple and does not require approximations. The shower tub is a square with a side of 90 cm so the surface should be 8100 cm² as shown in Figure 13.

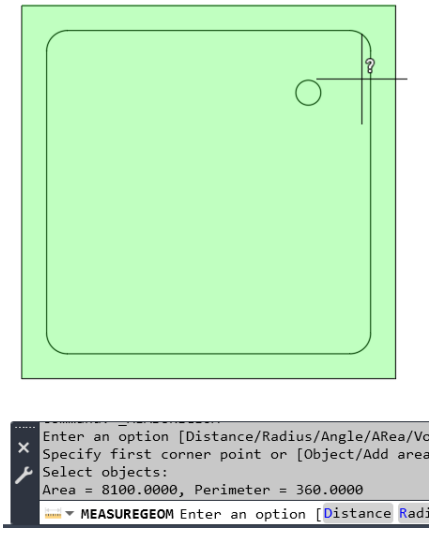

Figure 13 The area of the shower tub is 8100 cm²

The area occupied by the bathtub should be calculated with **the AREA** command and is 11894.6350 cm² as shown in Figure 14.

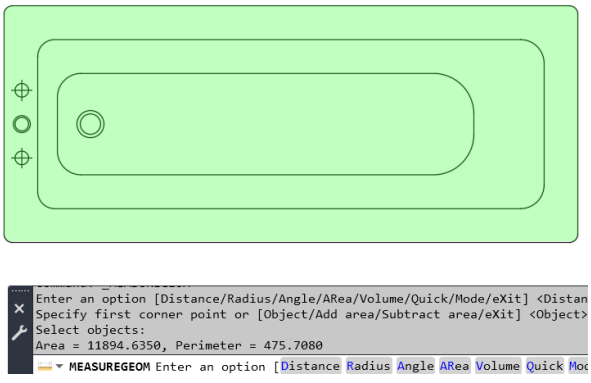

Figure 14 The actual area of the bathtub is 11894.6350 cm²

By approximating with a rectangle the user should obtain the area of 11900.00 cm² as shown in Figure 15.

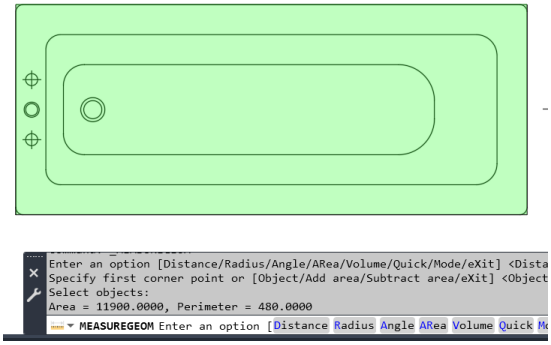

Figure 15 The approximate surface area of the bathtub is 11900 cm²

Table 6

The error is the difference between the actual surface and the approximate surface of the bathtub

Object	Actual Surface	Approximate surface area	Error (cm²)
Tub	11894.6350	11900.00	5.365

The actual area occupied by a small sink is 955.6758 cm² Figure 16.

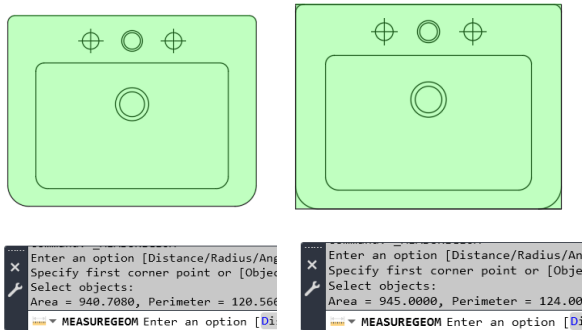

Figure 16 The actual surface area of the small sink is 940.7080 cm² and the estimated surface area of the small sink is 945.00 cm²

Table 7

The error is the difference between the actual surface and the approximate surface of the small sink

Object	Actual Surface	Approximate surface area	Error (cm²)
Small sink	940.7080	945	4.292

The actual area occupied by a sink should be 2807.5531 cm² as it is shown in the Figure 17.

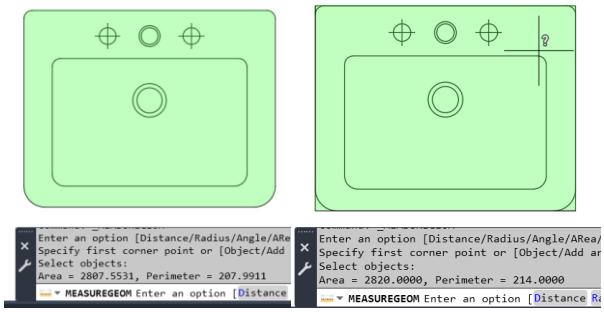

Figure 17 The sink area is 2807.5531 cm² and the estimated sink area is 2820.00 cm²

Table 8

The error is the difference between the actual surface and the approximate surface of the sink

Object	Actual Surface	Approximate surface area	Error (cm²)
Sink	2807.5531	2820	12.4469

The surface area of the washing machine has an area of 3898.2832 cm² and the approximate area is 3900 cm² Figure 18.

Figure 18 The area of the washing machine is 3898.2832 cm² and the approximate area of the washing machine is 3898.2832 cm²

Table 9

The error is the difference between the actual surface and the approximate surface of the washing machine

Object	Actual Surface	Approximate surface area	Error (cm²)
Washing machine	3898.2832	3900	1.7168

The author considered that the tumble dryer had the same dimensions as the washing machine.

Table 10

The error is the difference between the actual surface and the approximate surface of the tumble dryer

Object	Actual Surface	Approximate surface area	Error (cm²)
Tumble dryer	3898.2832	3900	1.7168

Other surfaces the user needs to consider are those that must remain unobstructed to ensure the proper use of the room.

1. The area required to open the door should be 6361.7251 cm². For the calculation the author used the **AREA command** from the AutoCAD software with the ***Add area option*** because there are two closed contours as in the Figure 19.

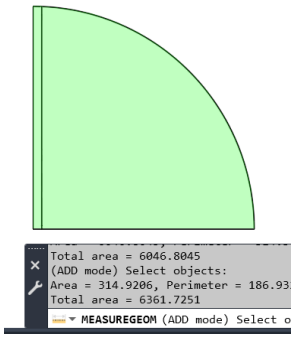

Figure 19 The area for opening the door is 3898.2832 cm²

2. The required surface area on the side of the toilet, both left and right, should be 2 x 30 x 65 = 3900 cm²
3. The required surface area on the side of the bidet, both left and right, should be 2 x 30 x 50 = 3000 cm²
4. The required area in front of the toilet should be 42 x 50 = 2100 cm²
5. The required area in front of the bidet should be 36 x 50 = 1800 cm²
6. The required surface in front of the sink should be 60 x 60 = 3600 cm²
7. The required area in front of the washing machine should be 65 x 60 = 3900 cm²
8. The required surface in front of the tumble dryer should be 65 x 60 = 3900 cm²

The user should work in the tabular mode, with the real and approximate surfaces to make the calculation easier.

Table 11

Occupied surfaces in the toilet

Bathroom type – WC = 20000 cm²	Actual / approximate surface area	Occupied area %
TOILET	2287.5044 / 2730.00	11.44 / 13.65
Small sink	940.7080 / 945.00	4.70 / 4.72
Door clearance	3898.2832	19.49
Free space on the side of the toilet	3900	19.5
Free space in front of the toilet	2100	10.5
Free space in front of the sink	3600	
Total	16726.5 / 17173.3	83.63 / 85.87

It can be seen in this type of bathroom that if the user opted for a normal sink in terms of dimensions, they would have a total occupied area of 18593.34 cm², which represented 92.97% of the total area of the bathroom. In other words, an inappropriate choice of furniture does not allow the use of the bathroom.

Table 12

Surfaces occupied in the shower

Bathroom-shower type = 30000 cm²	Actual / approximate surface area	Occupied area %
TOILET	2287.5044 / 2730.00	7.62 / 9.1
Small sink	940.7080 / 945.00	3.14 / 3.15
Went	8100	27
Door clearance	3898.2832	12.99
Free space on the side of the toilet	3900	13
Free space in front of the toilet	2100	7
Free space in front of the small sink	3600	12
Total	24826.5 / 25273.3	82.75 / 84.24

Table 13

Occupied surfaces in the bathroom

Bathroom-bathroom type = 45000 cm²	Actual / approximate surface area	Occupied area %
TOILET	2287.5044 / 2730.00	5.08 / 6.07
Sink	2807.5531 / 2820	6.24 / 6.27
Bathtub	11894.6350 / 11900	26.43 / 26.44
Door clearance	3898.2832	8.66
Free space on the side of the toilet	3900	8.67
Free space in front of the toilet	2100	4.67
Free space in front of the sink	3600	8
Total	30487.98 / 30948.28	67.75 / 68.77

With this type of bathroom, it is noticed that the space is more generous and an more careful user could also find space for a washing machine in this room (*Table 13)*.

The washing machine had 3898.2832 cm² and will occupy 8.66% of the area. In front of the washing machine, a space of 3900 cm² is required, which leads to a total space required of 17.33%. In the end, summing 67.75% with 17.33% the author reached 85.08%. This bathroom occupancy area was similar to the other types of bathrooms.

Table 14

Differences between actual occupied areas and approximate areas

Bathroom type	Actual area occupied %	Approximate area occupied %	Difference
TOILET	83.63	85.87	2.24
Shower	82.75	84.24	1.49
Bathroom	67.75	68.77	1.02

Since Table 14 demonstrates that the discrepancies between actual and estimated surfaces were minimal, it can be concluded that using approximations for calculating the dimensions of sanitary fixtures when designing the bathroom is effective.

For users who do not have the AutoCAD software, the author recommends using the tables above.

For designers, the author recommends using the **BPOLY** command together with **AREA** command as can be seen in Figure 20, Figure 21, Figure 22, Figure 23.

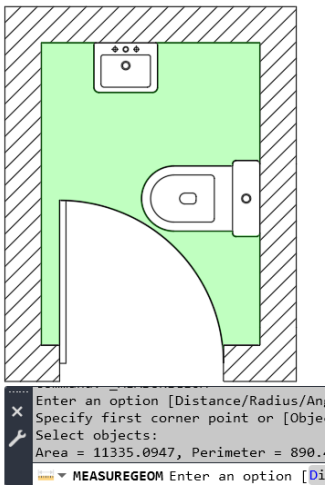

Figure 20 The free area for the WC is 11335.0947 cm²

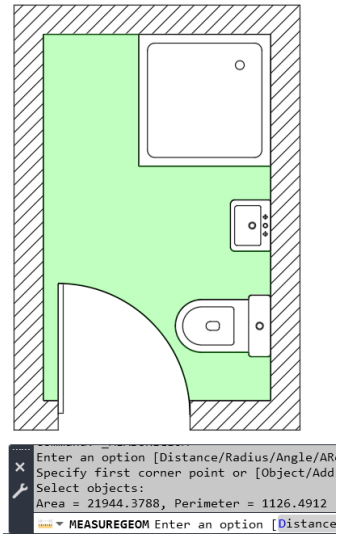

Figure 21 The free shower area is 21944.3788 cm²

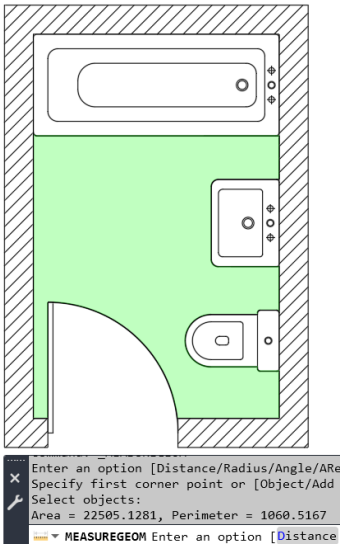

Figure 22 The free area for the bathroom was 22505.1281 cm²

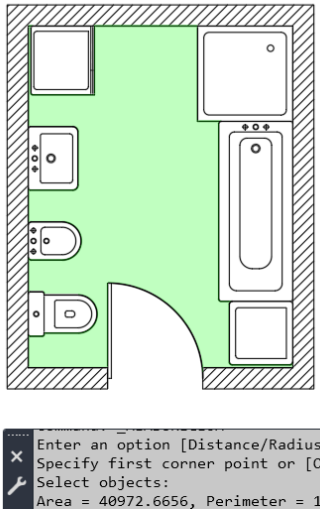

Figure 23 The free area in the bathroom was 40972.6656 cm²

These formulas are also recommended to be used in the design stage. The architect can indicate through the project the maximum sizes in which the sanitary objects can fit.

Analysis of the data revealed that the surface areas set by the legislator were at the minimum required for a functional bathroom. It would be beneficial for the planned surfaces to exceed these minimum legal requirements.

However, in practice it was observed that some households as well as some bathrooms in apartment buildings constructed during the communist period had meager surfaces. This fact lead to very small, impractical bathroom as well to a very cramped arrangement of the sanitary furniture. Fortunately, the market came the rescue by offering a wide variety of sinks, bathtubs and shower cabins.

4. SOLUTIONS FOR SPECIALISTS

Speaking especially to designers and specialists in the field of constructions, the author proposed a variant of representation of sanitary objects in a 2D CAD environment using dynamic blocks.

By analyzing the ratios between the dimensions of sanitary fixtures, the author concluded that they can be divided into two categories. One category is set to dimensions that can be varied in both ways of one direction and on the other direction to remain constant (bathtub). The second category refers to objects that have standardized size sets, the dimensions of these objects being interconnected by mathematical relations (sink).

4.1. Variable dimensions in one direction

Having different shapes and sizes for bathrooms, the bathtub size needs to be adapted for each case. As the readers already know, the market provides a wide range of models and sizes. For this shape the user should create a block called BATHTUB.

The user then should define parameters and actions for this block according to Figure 24 and Figure 25.

The first parameter should be *Linear*, the length of the bathtub, which is represented by *Distance 1*, the length of the bathtub that the author wants to vary from case to case.

The second parameter used should be *Alignment* because the user always should want to align the bathtub to the wall or another object in the bathroom as it is represented by *Flip state 2*.

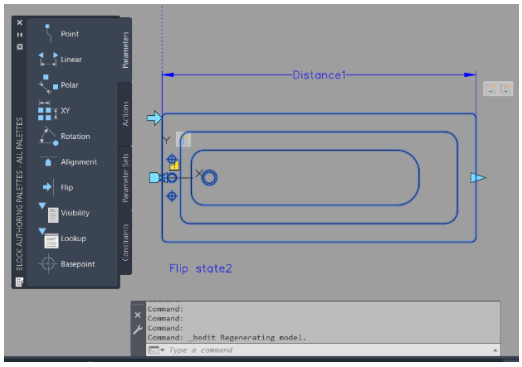

Figure 24 Block authoring palettes – Parameters – Linear and Alignment

As Actions the user should use *Strech* to adjust the bathtub size depending on the functionality of the bathroom.

The second action used should be *Flip* because the user wants to easily move the bathtub from one wall to another, after it has been aligned with the Alignment parameter.

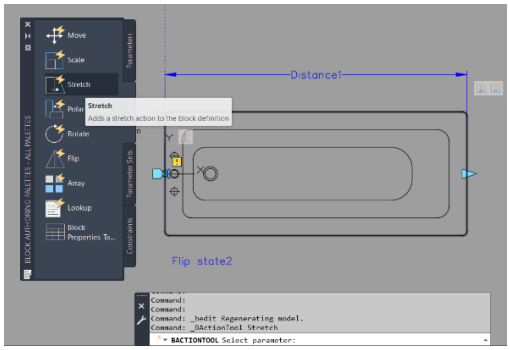

Figure 25 Block authoring palettes – Actions – Strech and Flip

Figure 26 shows how the dynamic block works.

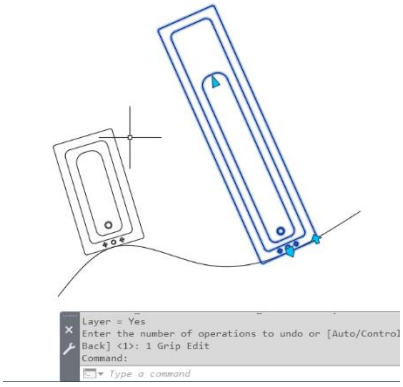

Figure 26 The CADA Block I Used Actions: Stretch, Alignment and Flip

4.2. Variable dimensions in both directions

Regarding objects that need to be modified in two directions, it is necessary to use another approach.

The user should use constraint settings and impose dimensions.

The use of constraints is a very challenging operation. Therefore the author proposed perpendicularity, concentricity and coincidence constraints as shown in Figure 26.

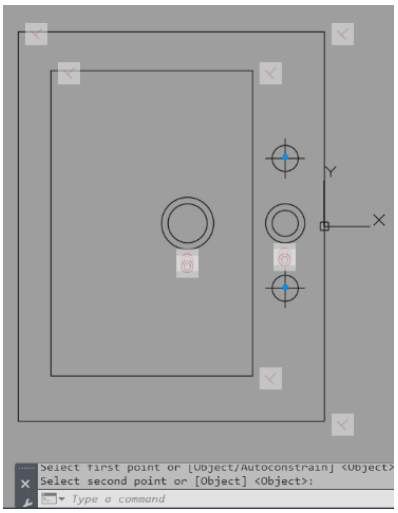

Figure 26 The SINK block to which the author has imposed CONSTRAINS: Coincident, Perpendicular, Concentric

To preserve the proportions the author used formulas in defining the dimensions as shown in Figure 27.

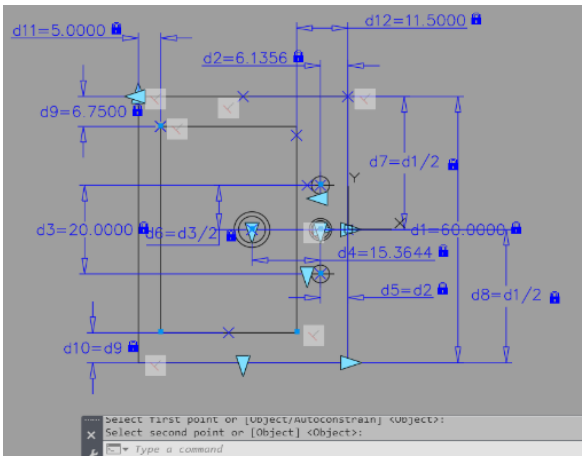

Figure 27 The SINK block to which the author has imposed DIMENSIONAL LINEAR

In the dynamic block the author has imposed several fixed parameters and other parameters that were dependent on the fixed ones, however in Figure 27 they did not all appear due to visibility conditions.

To change the dimensions as desired, the user can access from the menu the command *MANAGE – Parameters manager* and change the dimension parameter *d1* as shown in Figure 28. Then the user can notice the change in the dimensions of the element.

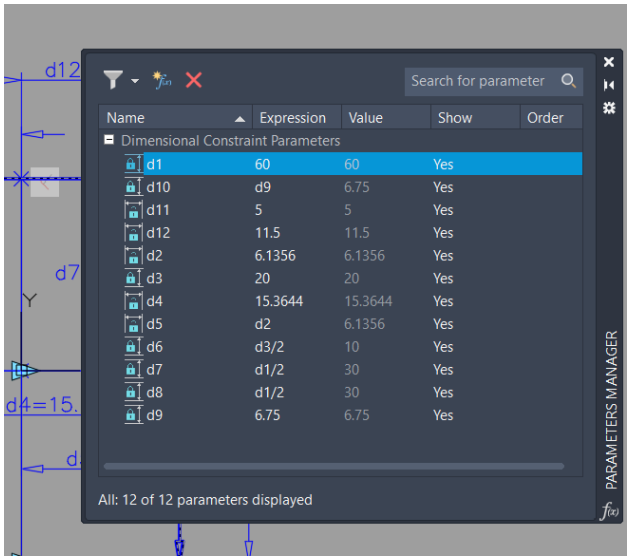

Figure 28 MANAGE Menu – *Parameters manager*

5. CONCLUSIONS

The paper provides solutions for quickly resolving common issues, such as frequent mistakes in adjusting the sizes of sanitary fixtures to fit bathroom dimensions and properly positioning sinks, bidets, bathtubs, or showers within their allocated spaces using the AutoCAD software.

For users, the author proposed a tabular model for approximating the calculation of sanitary fixture surfaces and the free spaces needed for their effective use. For architects, solutions were provided for calculations using commands in AutoCAD 2D software.

For more advanced AutoCAD users, the author recommended using dynamic blocks.

Depending on the direction in which the dimension of the sanitary fixture needs to be varied, two categories were identified: the first category refers to variation in a single direction, while the second category considers variation in both directions, not through scaling but by using mathematical functions to define the proportions between the two dimensions.

The author presented this conceptual model for selecting sanitary fixtures to 20 architects and users over the past few years. They all valued the time and cost savings it provided. Additionally, they noted that having precise figures assisted in decision-making and helped manage emotions that could lead to impulsive purchasing.

The recommendations in the article represent minimum requirements. Clearly, depending on the available space and user preferences, additional sanitary fixtures or furniture could be included in each type of bathroom. However, it is crucial to avoid overcrowding the room and to ensure that circulation areas are sufficient for wheelchair access to all elements in the bathroom.

Therefore, as engineer, the author felt compelled to come up with some solutions to enhance the quality of life.

In conclusion, the proposal was intended to serve both designers and users by improving efficiency and enhancing overall well-being in their homes.

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Author:

Assistant professor Irina IGNĂTESCU-MANEA, Ph. D., Gheorghe Asachi Technical University of Iasi, Faculty of Constructions and Installations, Department of Engineering Graphics, E-mail.: irina.ignatescu-manea@academic.tuiasi.ro