# Real and Virtual Water in Civil Construction

Marta Denise Silva, André Montenegro Duarte and
Marco Valerio de Albuquerque Vinagre



March 3, 2021

# Real and virtual water in civil construction

**Silva ,M .D .N [1] ;Duarte, André Montenegro[2] ; Vinagre,M.V.A[3]**

**1 University of Amazonia (UNAMA), Belém, Pa, Brasil**
**md.silva@uepa.br**
**2 Federal University of Pará (UFPA), Belém, Pa, Brasil**
**amonte@ufpa.br**
**3 University of Amazonia (UNAMA), Belém, Pa, Brasil**
**valeriovinagre@gmail.com**

**ABSTRACT**

Water is an abundant natural resource in some regions such as the Amazon, but is finite and limited. The growing demand for various social and economic actors, there may be situations of water scarcity. This study evaluates the importance of water in the construction industry, as a real or virtual element. We intend to quantify the water in monetary or financial calculated based on rational principles, specifically in construction sites, introducing the budgeting of water as raw material in construction. The case study methodology is real, the value calculated of water was slightly more than 0.5% of the total cost of the work. This percentage is apparently little, but is not covering all elements inherent to the principles of sustainability (economic, social and environmental), which could not be worked out in this article, especially the fact that studies on this subject and approach are new, incipient, with little theoretical.

Keywords: water resources, virtual water, construction, sustainability, water budgeting.

## INTRODUCTION

Brazil has one of the largest surface water reservoirs. However, due to the inadequate use of water resources, associated with an increased demand for several social and economic aspects, some Brazilian areas face situations of water scarcity.

For mankind, water has always been essential and irreplaceable, since there are no other inputs that can be used in its replacement, such as what happens to oil and rice, for example, which can be replaced by solar energy and wheat, respectively. However, the fact that it is essential and irreplaceable, even for the life of all beings, makes the right of access to water transcend the individual issue, becoming diffuse and collective, as already stated by PETRELLA (2004).

In building construction, water is an important element for the composition of materials and also for the development of the services required by the construction, but its connection with sustainability at the construction site is still a highly discussed issue. Alternatives have been discovered to make materials and components more sustainable, such as the use and reuse of water in construction sites and in the operation of the project.

Professor Vahan Agopyan from USP (2016), in his academic research, states that: Concrete itself loses only to water in the table of most consumed products. In addition, the production chain needed to obtain cement consumes one third of the planet's natural resources. Besides, according to Agopyan, 40% to 75% of the consumption of materials in society happen in the construction industry.

According to GOMES (2015), the amount of real and virtual water present in the concrete varies according to its strength. For a material with 25 Mpa (Mega Pascal), used for conventional or small structures, 12,664 m3 of water (12,474 virtual and 0,190 real) are incorporated, while for a concrete with 45 Mpa (large structures), 13,860 m3 of water (13,670 virtual and 0,190 real). It appears that, according to this author, the variation in the amount of water is in the virtual context.

According to Barbosa et al. (2008), the other way of seeing water is to consider it as a natural, essential and liable to adding economic, political, social and ecological value. This vision is increasingly present considering, for example, its unequal distribution, which makes it an extremely valuable resource in regions of scarcity, which has been discussed in national and international meetings, such as World Water Forums and the Social Forum of Waters.

The introduction of the term “virtual water” was made by Tony Allan1[1]. This idea was brought to the public by this author for almost a decade until he got recognition for the theme, which involves issues related to the environment, food engineering, agricultural production engineering, international trade and so many other areas that relate to water. (RISOMAS,2021)
As part of the composition of civil construction inputs, water is present in almost all materials used, whether in the condition of “virtual water” or as part of the construction site production process, however, economic value is not attributed, unlike other materials or inputs, which are considered in the construction budget, such as concrete and steel. This means that water is not accounted for, financially, economically or environmentally, in the composition of unit costs, which contains the inputs of services with their respective indexes and values.
When used to produce a good or service, water, as an input, is often not visible or tangible, being incorporated into the final product. In this condition, the concept of “virtual water” emerges.
Water, a natural resource with multiple purposes, including the maintenance of life, has become scarce due to problems of increased demand and climate change, which has already become a global consensus.
Although water is a very important element and used on a large scale in civil construction, it is not budgeted, that is, its importance in economic and financial terms is not quantified.
It is possible to study water as an input in civil construction, incorporating it into the budget, as a component of the composition of construction services, so that the budget will incorporate sustainability principles. Such principles and approaches related to sustainability require that this natural resource has its appropriate economic value, that is, that it be valued.
The Sustainable Development Goals (SDGs, 2021) have already been working on the implementation of indicators, plans and targets that can make cities and communities more sustainable, as well as providing responsible consumption and production. Within this scenario, the sustainable use of water becomes present.
Water should be considered as one of the most important resources, among the many existing, holding an enormous economic value, especially in the construction stages where there is a variety of water-dependent services.

## MATERIALS AND METHODS

In this research, a case study was carried out in 4,420 popular houses built in structural concrete and masonry walls in ceramic brick.
For the purpose of presenting and understanding the proposed budget mechanisms, a popular residential design project was used, which was financed by *Caixa Econômica Federal* (CEF, 2010). This project contains buildings with two floors, each comprising units of 35 m² of built area, with the following internal division: two bedrooms, living room, kitchen, circulation, toilet, bathroom and yard. Figure 01 and 02 demonstrate the layout of the residences.

[1] https://www.eni.com/en-IT/low-carbon/concept-of-virtual-water.html

Figure 01: Floor plan of the models of the houses

Figure 01 shows the layout of the compartments, the suggestion of furniture for the building and, at the background, the location of the yard with a division for four apartments in each block.

Figure 02: Perspective plan of the houses

In figure 02, there is a part of the number of houses that will be constructed, with paving around the building, access to each block and a landscaping that makes up the front of the buildings.

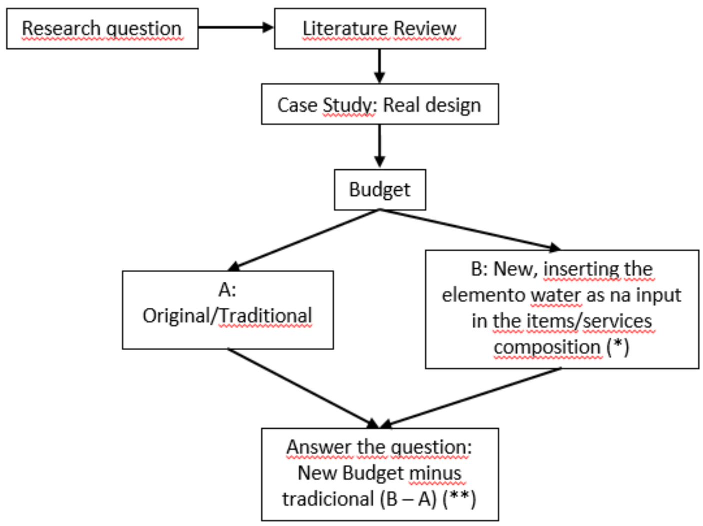
Each building reflects a different reality. However, when choosing materials, there is an indispensable input in construction, which is water. Such input can be analyzed in any building standard, sometimes with a higher or lower consumption, depending on how the construction was planned to be carried out.

After the budgetary and financial analysis, the most used materials in civil construction were selected, as a way to facilitate the data investigation. A comparative study was carried out with the data collected in the technical literature, by unit of measure, with the data from the budget spreadsheet (CEF). A comparative analysis was performed with the inputs of the budget spreadsheet, in which the consumption of both real and virtual water is present, however, this consumption is not inserted directly in the composition of the materials.

The data collection used for the development of the research occurred taking as a reference the composition of the inputs of two manuals: *Mãos à Obra* (ABCP, 2010) and Fiorito (1994), and the budget spreadsheet practiced by the Secretariat of public works of the state of Pará (SEDOP, 2019). All of these references provide information with technical understanding within the standards adopted in construction sites for civil construction.

Figure 3 presents the Methodology Workflow of the developed study:

Research question: What is the value (or cost) of the water, whether real or virtual, used in a civil construction?




(*) Quantifications of water required in each item / service, whether real or virtual. They were defined based on the technical literature, without measurements on site, and the unit prices were based on reliable institutions in the civil construction segment and in the water supply concessionaire.
(**) Only the "total service cost" was considered, which is approximately equivalent to the "values for direct water users and net benefits return flow", that is, the "total cost" or "total value", which contemplate the environmental, economic and social externalities and the opportunity cost, were not taken into account.

Figure 3: Methology Workflow

## RESULTS

Of the 4,420 popular houses built in structural concrete, which cost a total of 150,830,266.82 (one hundred and fifty million, eight hundred and thirty thousand, two hundred and sixty-six reais and eighty-two cents), it was elaborated a spreadsheet of budgetary values resulting from the research developed with the main inputs used in this work, with a total cost of R$ 49,547,227.16 (forty-nine million, five hundred and forty-seven thousand, two hundred and twenty-seven reais and sixteen cents), and with water tariff values of R$ 14,40 applied during the budget period, in the Belém-Pará market.
Table 01 shows the quantities and the amount of water used in each service, the total consumption in liters and m3, the price charged by the water supply concessionaire and the total price for services with and without the water input.

Table 01 - **Budget spreadsheet with data and research results**

| | Services | Un | Service quantities | Water amount (liter) | Total consumption liter (un) | Total consumption ($m^3$) | Water price per $m^3$ (Cosanpa) | Water consumption's total price (R$) | Service's total price (R$) With water | Service's total price (R$) Without water |
|---|---|---|---|---|---|---|---|---|---|---|
| FOUNDATION | RUNNING SHOE AND BALDRAME | $m^2$ | 7,867.60 | 168.8 | 1,327,657.50 | 1,327.65 | 14.04 | 18,640.21 | 3,800,202.15 | 3,781,561.94 |
| | CONCRETE BALLAST | $m^3$ | 2,055.30 | 144 | 295,963.20 | 295.96 | 14.04 | 4,155.32 | 402,369.70 | 398,214.38 |
| | LEVELING LEVEL | $m^3$ | 10.574,85 | 144 | 1.522.778,40 | 1.522,77 | 14,04 | 21,379.69 | 3,679,114.56 | 3,657,734.87 |
| STRUCTURE | STRUCTURAL CONCRETE | $m^3$ | 5,768.10 | 160.7 | 926,991.35 | 926.99 | 14.04 | 13,014.94 | 1,676,477.30 | 1,663,462.36 |
| | PRE-MOLDED SLAB WITH CONCRETE | $m^3$ | 6,313.09 | 160,7 | 1.014.576,69 | 1,014.57 | 14.04 | 14,244.56 | 7,040,709.28 | 7,026,464.72 |
| WALLS AND PANELS | MASONRY SETTLEMENT | $m^2$ | 468,210.60 | 2.23 | 1,044,109.64 | 1,044.10 | 14.04 | 14,659.16 | 13,105,827.54 | 13,091,168.38 |
| | CONCRETE ROD | $m^3$ | 481.78 | 160.7 | 77,426.86 | 77.42 | 14.04 | 1,086.98 | 291,494.33 | 290,407.35 |
| COATINGS | ROUGHCAST | $m^2$ | 178,081.80 | 0.67 | 119,314.80 | 119.31 | 14.04 | 1,675.11 | 701,536.58 | 699,861.47 |
| | PLASTER | $m^2$ | 33,879.30 | 6.68 | 226,313.72 | 226.31 | 14.04 | 3,177.39 | 403,630.72 | 400,453.33 |
| | PLASTERING | $m^2$ | 1,006,478.20 | 6.68 | 6,723,274.38 | 6,723.27 | 14.04 | 94,394.71 | 13,523,582.15 | 13,429,187.44 |
| PAVING | SMOOTH FINISH | $m^2$ | 156,711.10 | 2.67 | 418,418.63 | 418.41 | 14.04 | 5,874.48 | 3,478,592.46 | 3,472,717.98 |
| | PROTECTION SIDEWALK | $m^2$ | 10,806.90 | 2.67 | 28,854.42 | 28.85 | 14.04 | 405.05 | 526,376.87 | 525,971.82 |
| | TINY FINISH | $m^2$ | 6,364.80 | 2.67 | 16,994.02 | 16.99 | 14.04 | 238.54 | 177,689.16 | 177,450.62 |
| | TOTAL | | | | **19,453,999.59** | **19,453.93** | | | **49,820,598.92** | **49,547,227.16** |

Source: Authors

## DISCUSSION

Based on the results obtained, as shown in table 01, there is a comparison of the cost of water as an input and without valorization as an input. Water as an input has a value of R $ 49,820,598.92 (forty-nine million, eight hundred and twenty thousand, five hundred and ninety-eight reais and ninety-two cents) and without accounting for inputs the value is R $ 49,547,227.16 (Forty-nine million, five hundred and forty-seven thousand two hundred and twenty-seven reais and sixteen cents). In the budgeted amount for water within the budget spreadsheet in table 01, the total water used in cubic meters is 19,453.93. Considering the value adopted by the concessionaire (COSANPA, 2019) is R $ 14.04 / m³. Table 2 below shows the relationship between the value of water as an input, the percentage in relation to the work and the value adopted for the cost of water.

Table 02: **Budgeted amount for water**

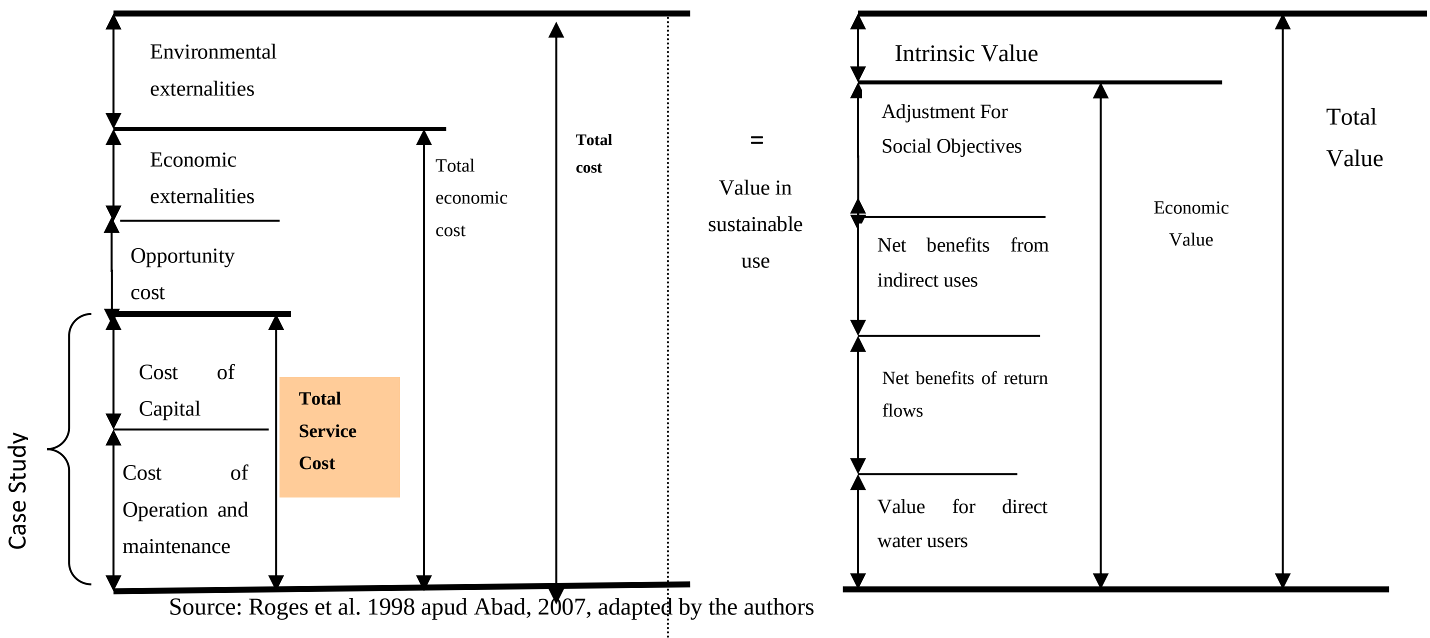
| Budgeted amount for water | % in relation to construction | Unit value adopted for water (R$/m$^3$) |
|---|---|---|
| **R$ 273.371** | **0,55%** | **14.04** |

Source: Authors

The amount of R$ 14,04/m³ used to budget water as an input in construction is not, in principle, very significant, increasing the cost by just over 0.50% of the total amount surveyed in the worksheet. This magnitude, which is insignificant in relative terms, may be due to the fact that the real value of water was not considered.

The volume of water calculated for budget purposes in this case study is restricted to the construction steps shown in table 01. Therefore, it is worth mentioning that other construction steps, such as cleaning the work and hydraulic tests, require a significant amount of water, but in the present research it was not possible to identify or even estimate this quantity. According to Roges et al (1998) apud Abad (2007), the real value or the value in sustainable use is the one shown at drawing 01.

Drawing 01– **General Principles for Water Cost and Value**




Source: Roges et al. 1998 apud Abad, 2007, adapted by the authors

From drawing 01, it can be inferred that the case study presented in this work was restricted to the **total cost of service**. However, the sustainable value of water in civil construction is not limited to what was calculated in this study. Therefore, it would also be necessary to quantify the environmental, economic, social externalities, which should constitute the collection cost (including the onerous grant) and the opportunity cost.

## CONCLUSIONS

The world is in an environmental dilemma, including with regard to climate change, and the scientific community must seek to contribute so that natural resources are used correctly and sustainably.
This research seeks to contribute to the segments of civil construction and water resources management in the proposal to introduce water input into the worksheet of the construction.
Considering that water is an indispensable and irreplaceable natural resource in construction processes and that, so far, it is not considered as an input with a price in a construction’s budget, it is proposed, in this study, that its value should be budgeted.
In times of global warming, scarcity of water resources and society’s awareness of the importance of natural resources, the principles of sustainability and the consequent need to attribute these resources, such as water, economic values compatible with their importance, it can be considered that the value of water is much higher than what is currently budgeted, which can be observed when this value is compared to other natural inputs, such as sand and pebble, for example, which have costs of R $ 59.00 / m3 respectively and R $ 123.08.00 / m3 (SEDOP, 2019). This is probably due to the fact that not all stages of the life cycle of a building have been worked on, but only the implantation (construction site), with water not being priced at the project design and planning stage, nor in the later stages of implantation. Therefore, virtual water is not being budgeted as a whole, only virtual water or even real/physical water that is used at the construction site as an input. A natural resource, such as water, has real value that includes all sustainability requirements, that is, economic, social and environmental aspects.
In this research, only the economic aspect was considered, this being the budget for the water supply service by the concessionaire, with a unit value of R$ 14.04/m³ which, in the case study, has represented 0.55% of the total cost of construction. Certainly, this value, even when calculated only for the moment of implementation (execution of construction services), as in the present study, should be much higher if the other phases of a civil construction are considered (project, manufacture of materials such as steel, cement and masonry) and other aspects (externalities and opportunity cost), which can be analyzed in future works, which improve and expand the real and sustainable quantification of water, considering all the principles of sustainability, as well as in other stages or phases of the building life cycle that, in this research, was restricted to the implementation/execution.

## REFERÊNCIAS


1. BRAZILIAN CEMENT PORTLAN ASSOCIATION - ABCP - Concrete Sustainability. Available at: http://www.abcp.org.br/conteudo/sustentabilidade/sustentabilidade-do-concreto. Access on September 2010.

2. BARBOSA, Francisco; BARRETO;F César de Sá. **Angle of Water: Integration challenges**. In: BARBOSA, Francisco (Org.). Different Views of Water. Belo Horizonte: Federal University of Minas Gerais (UFMG), 2008.

3. ABAD, Eugenia Patrícia Garcés. **Proposed water pricing for irrigation in agriculture, using the methodology of positive mathematical programming**. 2007. Dissertation (Doctoral degree in Water Resources and Environmental Sanitation) - Hydraulic Research Institute, Federal University of Rio Grande do Sul. Porto Alegre, 2007.

4. CEF - CAIXA ECONÕMICA FEDERAL. **Discriminative Budget Worksheet of a Residential of popular houses**. Available at: https://www.caixa.gov.br/Paginas/home-caixa.aspx . Access on October 2020.

5. PARÁ SANITATION COMPANY - COSANPA. **Service tariff table**. Available at: http://www.cosanpa.pa.gov.br/wp-content/uploads/2018/05/Tarifas-Cosanpa-atual_dez2019-2.pdf. Access on December 8th, 2020.

6. FIORITO**,** Antonio J. S. I. **Mortar and coating manual: studies and execution procedures**. São Paulo. PINI, 1994.

7. GOMES, L. P. L. B. **The study of real and virtual water in machined concrete**. 2015. 51f. Master's Dissertation in Civil Engineering. Postgraduate Program in Civil Engineering. Federal University of Pará, Belém, Pará, 2015.

8. PETRELLA, Riccardo. **The water. The challenge of the common good**. Translation from Fabiola kochenborger. NEUTZLING, Inácio (Org.). Water: universal public good. Publishing company Unisinos, 2004.

9. Education and culture portal - RISOMAS. Rodrigo Travitzki, 2008. Available at: http://rizomas.net/quem-somos/o-que-e-um-rizoma.html. Access on January 9th, 2019.

10. ODS - Sustainable Development Goal - 2030 Agenda Platform. Available: http://www.agenda2030.org.br/. Access on January 26th, 2021.

11. Secretary of State for Urban Development and Public Works - SEDOP - Price Composition Worksheet. Available at: https://www.sedop.pa.gov.br/. Access on December 7th, 2020.

12. UNIVERSITY OF SÃO PAULO - USP - **Civil construction is the branch that consumes the most materials in the world**. Polytechnic School. Edition nº110 - Year 45 – Science and Technology, 2012. Available at: http://www.usp.br/aun/antigo/exibir?id=4848&ed=853&f=2. Access on January 7th, 2021.