Productivity in building sanitary branch drains implementation

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Abstract

The study of the productivity of labor in construction services has been increasingly valued considering the rising need to better understand the production to improve efficiency through rationalizing actions in the organization of production, project design and even the creation of new products.

In the case of building systems, either because of the difficulty of understanding the effort required for labor or the traditional subcontracted posture, there is even less knowledge of productivity when compared to other building services.

This paper presents the Factor Model as a way of studying the labor productivity in this service, as well as an application of it in the case of building sanitary drains, showing the productivity values existing in the building construction of Brazil, based on an extensive survey data. Such data are treated statistically in order to generate more reliable indicators for building systems.

Keywords

Productivity, factor model, building sanitary branch drain

1 Introduction

The concern about productivity and quality improvement, mainly industrial, has been a constant in developed countries and it is intensifying in developing countries. This happens by the consciousness gained by the companies in which increased productivity results in better usage of resources in the production of goods and services, and consequently a higher margin profit.

In the Construction Industry, there are many factors that induce the need to improve productivity, including the fierce competition among builders, sharply due to the opening of the domestic market to the foreign capital in the 90s (PICCHI, 1993 apud PALIARI, 2008). In addition, the Code of Consumer Protection has provided legal means for consumers to claim their rights, giving the possibility to demand quality for the products offered as well as respect to the period of the works. Thus, the consumer market has become more demanding, contributing to increase competition among construction companies and developers.

For the company to improve its productivity, it must first know its current performance, in other words, defining methods of collection and analysis of information that support consistent proposals through reliable, representative data and take into account the current level of technological development and managerial in existing companies (PALIARI, 1999).

Accordingly, several studies on labor productivity and consumption of materials were developed, however, primarily directed to the implementation structure, sealing and coating. As to building systems, there is lack of information on productivity and consumption of materials allowing managers to conduct an efficient planning and scheduling, as well as dimension their work teams and assign tasks with greater accuracy.

This paper discusses a way to increase productivity and understanding of building sanitary sewer system, specifically for branch drains, part of the subsystem and transport of sewage. The work fits within a larger survey to gauge the units cost estimation of SINAPI from the Caixa Economica Federal, a reference cost system for public works executed with federal funds.

2 Labor Productivity: general concepts

Productivity is the efficiency in converting resources (inputs, or efforts) into products (outputs, or outcomes) (SOUZA, 2001).

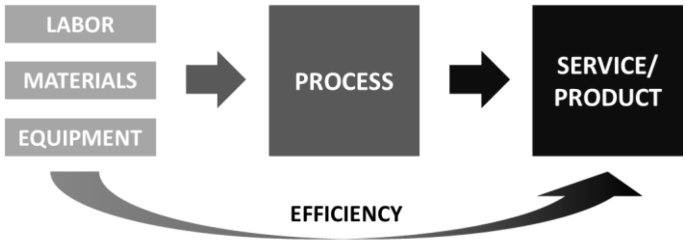


Figure 1 - Productivity definition (SOUZA, 2001)

In the Construction Industry it is common to discuss about productivity studies concerning the mainly physical resources: labor, materials and equipments. Therefore, the possibilities of resources efficient usage studies appear, like labor productivity, unit consumption of materials and efficiency of equipment, (SOUZA, 2001)

In general, input and outputs are related in the productivity measurement indicators:

$$PI = \frac{input}{output}$$, where:

PI = Productivity indicator

This indicator may have specific characteristics for each rated feature. Another general concept is the one related to the perception that the efficiency measured by an indicator can show both a cumulative performance (resulting from the aggregation of days more and less efficiency) and a potential, therefore, representing a challenging but doable efficiency; the knowledge of these performances is often extremely useful in delimiting the assembly team workers, or equipment, marking out the delivery of the correct amount of materials or to understand the cost of the work as a whole.

2.1 Labor Productivity

2.1.1 Unit Rate Productivity

The adopted indicator for measuring workforce productivity is nominated as unit rate production (URP), and it is defined as (SOUZA, 1996):

$$URP = \frac{Mh}{SA}$$, onde:

Mh = Man-hour;

SA = Services Amount.

2.1.2 URP d x URP cum x URP pot

Each input (Mh) and output (SA) data can be associated with different defined periods:

- a work day, when the URP is calculated using the daily measured inputs and outputs obtaining a daily URP (URPd);

- a cumulative period, when the quantities of inputs and outputs are those from the first day of the study until the date of their evaluation; designated as cumulative URP (URPcum);
- A service cycle, when the evaluated service happens in defined cycles, such as concrete forms for floor repetition; in this case, a cyclic URP (URPcyc) can be obtained.

Among the daily URP, the cumulative URP and the cyclic URP there is the potential URP (URPpot), which can be explained as a daily URP value associated to a challenging but doable performance when compared to all the daily URP detected.

Mathematically, the potential URP is calculated as the median value of the URPdaily inferior to the URPcum at the end of the evaluation. The Figure 1 shows the values of URPdaily, URPcum and URPpot graphically.

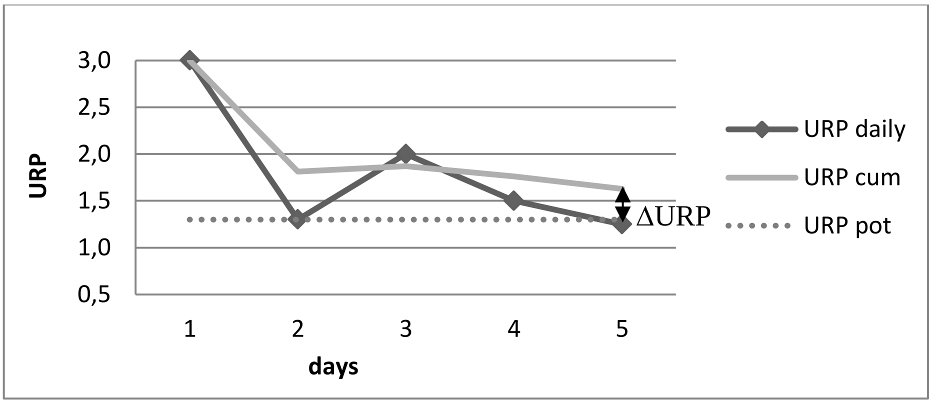


Figure 2 - Graphic showing the URP daily, cumulative and potencial.

Productivity that occurs in a certain process varies depending on the factors that must be identified, in order to interpret such changes in productivity of a service throughout the construction work.

2.1.3 Influencing Factors

The factors that influence labor force can be associated with:

- Content: related to physical components of the work, required specifications and design details among others - for example, the branch drain require more runtime than the soil stack due to the quantity and variety of parts and fittings;
- Context: related to the work environment and how it is organized and managed, management aspects, including also the adopted means to make available materials and equipment, work sequence etc. – Example: The existence of a mounting central of hydraulic kits to reduce the time of installation;
- Abnormalities often present in the production process: cover the occurrence of non-productive time due to changes in work front, localized shortages of materials and information, among others.

Content/Product	Context/Process
	
	

Figure 3 - Example of factors related to content (stack has better productivity than branch drains) and context (facilities with pre-assembled kits or piece by piece).

The labor productivity analysis will consider the mutual influence of the mentioned factors. The variation between the cumulative and potential value reflects the existence of abnormalities, the larger the Δ, greater variability occurred in the work.

2.1.4 The Factor Model

Proposed by Thomas and Yiakoumis (1987), the "Factor Model" is the variation in productivity through influencing factors. This model assumes the existence of a standard working condition, under which the daily output is the reference. Changes in content or context make the real productivity vary from the reference. (SOUZA, 1996)

The Model Factor (THOMAS, 1990) indicates that there are factors that determine the productivity variation and you can understand their influence. In other words, this model implies that one can understand the productivity variation once known the potentially influencing factors and the magnitude of this effect (Figure 4).

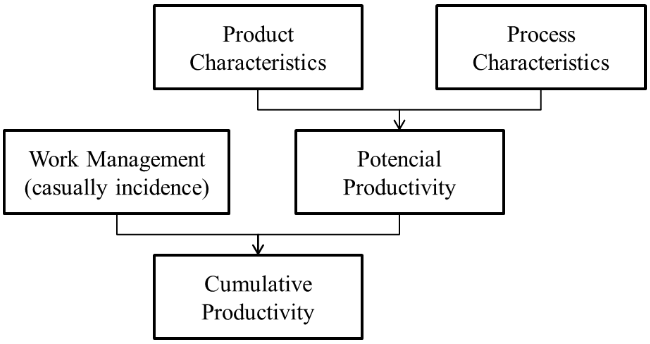


Figure 4 - Factor Model

3 Labor Productivity on Facility Sanitary Sewerage

Analyzing the national units cost reference manuals (TCPO and SINAPI) and the international one (RSMEANS), all treat the plumbing separating them according to the building system (cold water, hot water, sanitary sewerage, gas, fire, etc.) and the material used in (PVC, copper, cast iron, CPVC etc.) system.

Comparing the team composition for nationals manuals no matter what the element to be installed or the system itself, there is always a helper for each plumber. In the international manual this relationship varies according to the diameter of the pipe or connection, with only a plumber to diameters smaller than 2" and 1:1 for diameters smaller than 8".

Regarding the productivity, they vary with the diameter (larger is the diameter, worse is the productivity) and the type of connection. The Table 1 shows a comparison of productivity between the manuals.

Table 1 – Productivities on Reference Manuals

	TCPO	**SINAPI**	**RSMEANS**
PVC pipe, 40mm	0,24 Mh/m (without connections)	0,60 Mh/m (with connections)	0,25 Mh/m (without connections)
PVC pipe, 100mm	0,52 Mh/m (without conections)	1,09 Mh/m (with conections)	0,42 Mh/m (without conections)
PVC elbow 90°, 50mm	0,28 Mh/ea.	0,27 Mh/ea.	0,43 Mh/ea.
PVC tee, 50mm	0,29 Mh/ea.	0,28 Mh/ea.	0,66 Mh/ea.

The manuals have very different results in some compositions, but in order to affirm which result is correct and which one is consistent with reality, it shall depend on the criteria used for measurement. The data collection of plumbing productivity is difficult because frequently rooms can be not finalized, can be done more than a system can be done on a day, each element is quickly done and is a service with great idleness. Also, by doing a soil stack with a 100mm pipe and a brainch drain with the same pipe, the installation time of a meter is different due to the number of pipe fittings present.

Considering these difficulties, Paliari (2008) analyzes the building facilities systems by Factor Model, adopting as influencing factors of productivity of labor-intensive types of component materials, the number of pipe fittings per meter of pipe, the pipe diameter, interference with other subsystems, the composition of the team and the organization of production, reaching a result of productivity per installation.

4 Research Methodology

In order to obtain productivity indicators for the various components of the branch drains, the analysis was based on the presence and influence of certain factors. Thus the reliability of the results depends on the adequate planning and preparation of instruments for data collection, in order to consider the potentially influencing factors.

Based on the “Factor Model”, a spreadsheet was prepared to collect necessary data for the productivity and material consumption analysis. Therefore, the following was raised:

- Execution time per stretches;
- Execution time per subsystem (extension of sewer extension ventilation, plumb, collectors etc.).
- Number of pipe fittings per stretches;
- Characteristics of each pipe or fitting installed (diameter, material, length of pipe or connection type);
- Consumption of materials (pipes cuts losses and consumption of materials for the connections of the parties).

Once a significant database is gathered, it is processed into a statistical basis (see the main steps in Figure 5), seeking at understanding the characteristics of the product and process (Factor Model) to analyze the potential productivities and search for possible abnormalities in order to analyze the cumulative productivities. After this, it passes by a processes of dispersion graphs, analysis of variance and linear regression to select and quantify the effects of that influenced factors and generate productivity indicators.

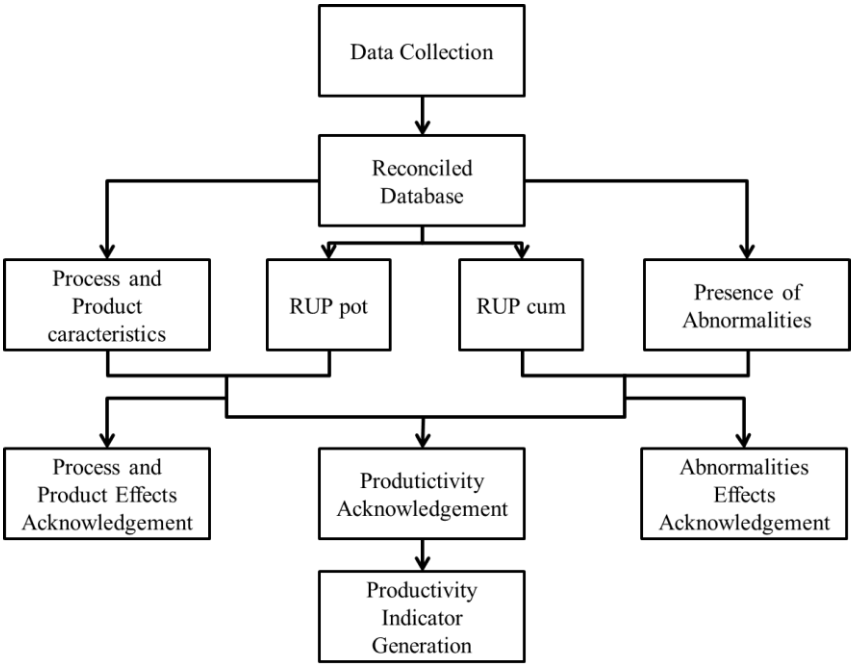


Figure 5 - Research Methodology

5 Results

5.1 Installation of Facility Sanitary Sewerage

Due to its inclusion in the project of improving the SINAPI, installation data were collected from 14 building sites distributed throughout the country in order to obtain nationally representative. In each followed-up the service for a period of 3 to 5 days generating a total of 112 data sanitary sewer installation. These data showed a vary installation productivity, as shown on Figure 6.

Figure 6 - General productivity of sanitary waste

The range between the minimum and maximum values found is very expressive. The data show that the number of pipe fittings per meter, the accessibility, the mounting position and the pipe diameters are different depending on which part of the system is executed. Therefore, it was decided to separate the productivity analysis according to the following sub groups:

- Branch drains;
- Soil stack and vent stack;
- Main drains.

As seen in Figure 7, by comparing the medians of each sub group, a wide variation between them can be noted, for instance the median for main drains is one third of the one found for branch drains. This shows the necessity of separation for analysis. For purposes of discussing the methodology applied, the factors and results obtained for branch drains will be analyzed herein.

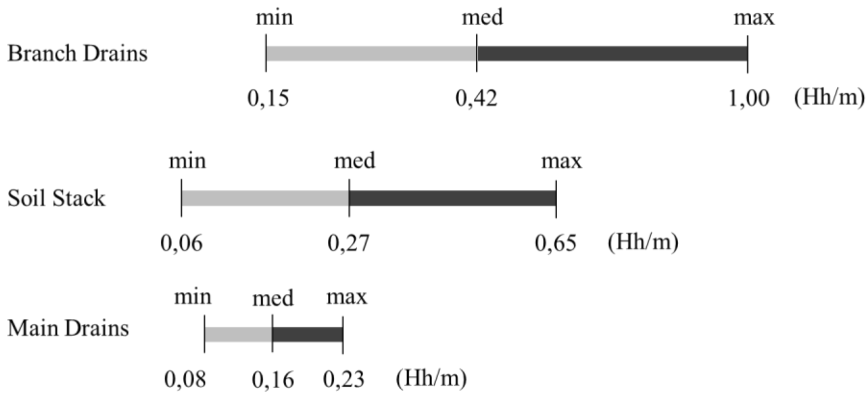


Figure 7 – Sub groups productivity ranges

The installation of building systems involves pipe, with varying diameters, and pipe fittings, varying both the diameter and the type (elbow, tee, Y, etc.). The most relevant factor found in the study was the number of fittings per meter of pipe. For example, for branch drains, the number that corresponds to the minimum value productivity is 2.00 fittings/meter, while for the maximum value is 4.17 fittings/meter, demonstrating that the greater the number of connections per meter, worse is the installation productivity.

The Unit Rate Productivity includes the installation of the branch drains as a whole (covering both the effort on the pipes and on the fittings). However, the compositions are not given by the slice installed, but by each component instead. Thus, the effort to install the sub group was shared between the pipe and the pipe fittings.

5.2 Pipes

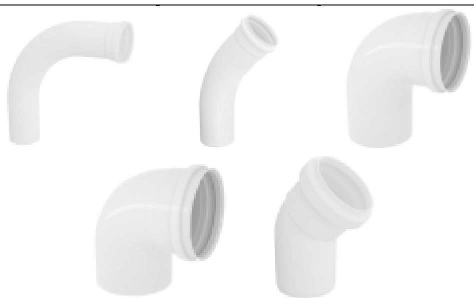
Based on the data collected, the analysis of the relation between URP and the pipes diameters demonstrated that the productivity of pipe installation is worsen with increasing diameter. The diameters considered were: 40mm, 50mm, 75mm and 100mm.

5.3 Pipe fittings

In order to obtain the URP separated by fitting type, the difficulty of installation of each type was analyzed. The study has shown that for some fitting types, the productivity coincided. Thus we proposed a classification of the pipe fittings in groups that had similar characteristics as the difficulty of implementation, as Table 2.

Table 2 – Classification of fittings

Classification	Fittings	Dificulties
Siphoned Drain		1 inicial fit 3 posterior fits 2 different directions

Classification	Fittings	Dificulties
Shower Drain		0 inicial fit 1 posterior fit 0 different direction
3 access		1 inicial fit 2 posterior fits 1 different direction
2 slop access		1 inicial fit 1 posterior fit 1 different direction
2 alined access		1 inicial fit 1 posterior fit 0 different direction

The effort of each connection type was determined according to the compatibility of efforts in implementing solidarization tubes.

5.4 Global Overview

Based on the analytical approach shown in the previous sub-items of this item, was generated URP representing different situations encountered. Table 3 shows the possible situation for the case of branch drains.

Table 3 – Differents possible situations for URP associations

Nº	Sub group	Pipe/pipe fittins	Ø (mm)
1	Branch drains	Pipe	40
2	Branch drains	Pipe	50
3	Branch drains	Pipe	75
4	Branch drains	Pipe	100
5	Branch drains	Pipe fittings 2 slop access	40
6	Branch drains	Pipe fittings 2 slop access	50
7	Branch drains	Pipe fittings 2 slop access	75
8	Branch drains	Pipe fittings 2 slop access	100
9	Branch drains	Pipe fittings 2 aligned access	40
10	Branch drains	Pipe fittings 2 aligned access	50
11	Branch drains	Pipe fittings 2 aligned access	75
12	Branch drains	Pipe fittings 2 aligned access	100

Nº	Sub group	Pipe/pipe fittins	Ø (mm)
13	Branch drains	Pipe fittings 3 access	40
14	Branch drains	Pipe fittings 3 access	50
15	Branch drains	Pipe fittings 3 access	75
16	Branch drains	Pipe fittings 3 access	100
17	Branch drains	Siphoned drain 50 mm	50
18	Branch drains	Siphoned drain 75 mm	75
19	Branch drains	Shower drain	40

The compositions relating to sewage plants are in the final stage of cooking. Once completed the drafting process, the same shall be available on site open to the public for receiving critical market. In Figure 8 the ranges of productivity related to pipes and connections are presented.

Figure 8 - Productivities range for pipe and pipe fittings

6 Conclusion

This research in particular will allow new cost estimations for SINAPI. Firstly, because it generates the productivity level based on data collected at the construction site and, secondly, for it provides technical specification for data analysis, the effort involved, the steps of execution and bibliographic and normative references. No previous manual explicitly presents the methodology adopted, being this one the pioneer.

The obtained results follow the style of other manuals (variation regarding diameter and type of connection), however, a significant reduction in the current number of SINAPI was found, approaching the TCPO and RSMEANS, as shown in Table 4.

Table 4 – Results Comparison

	TCPO	SINAPI	RSMEANS	RESULTS
PVC pipe, 40mm	0,24 Mh/m (without connections)	0,60 Mh/m (with connections)	0,25 Mh/m (without connections)	0,30 Mh/m (without connections)
PVC pipe, 100mm	0,52 Mh/m (without conections)	1,09 Mh/m (with conections)	0,42 Mh/m (without conections)	0,74 Mh/m (without connections)
PVC elbow 90°, 50mm	0,28 Mh/ea.	0,27 Mh/ea.	0,43 Mh/ea.	0,13 Mh/ea.
PVC tee, 50mm	0,29 Mh/ea.	0,28 Mh/ea.	0,66 Mh/ea.	0,17 Mh/ea.

Knowing the productivity level allows the cost estimation to be more accurate, in addition to deciding whether to use certain types of technology in site and foster the development of new technologies of construction. Apart from that, this information also provides planning and organization of production. The current results of this paper are unique and will be fostered by Caixa's publishments contributing to the achievement of a higher quality construction. The methods described herein can be used in other subgroups of the sewage plant building and also in other hydraulic systems.

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