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Original Article

Quantitative Study of the Average Productivity Indices of Civil Works in the Cusco Region in the Period 2023-2025

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Abstract *- For civil works, labor productivity indices (man-hours per unit) are frequently used to estimate labor demand, cost and duration, but use of national reference values is not always accompanied by validation of the execution conditions in the region. This research aims to measure and compare the Average Productivity Ratios (APR) of a structural activity of works for civil engineering services that were carried out in the Cusco region for the years 2023-2025. A quantitative and comparative design is coupled with a descriptive design, and two data sources are used: (i) CAPECO reference values, then productivity ratios are calculated via unit cost analyses, and (ii) data from field-based records, which is gathered from UNSAAC thesis documentation and professional internship performance logs, and productivity ratios are calculated directly from quantities executed and man-hours actually spent. Differences are evaluated based on descriptive statistics and percentage variation analyses by activity and by family (reinforcing steel, concrete, formwork/stripping). The findings indicate that productivity behavior is very item-specific. The averages of reinforcing steel and formwork are near CAPECO and have moderate deviations, so there is some level of applicability as a starting point. In comparison, the man-hours per unit for concrete-related activities show the greatest variation and, in several items, significantly less per man-hour than CAPECO, indicating greater efficiency for the local conditions, which are often repetitive, with readily available work fronts and continuity of supply. Further, the study finds preliminary reference ratios for activities not included in CAPECO that are commonly used in road and sanitation works, including ready-mix concrete pavement slabs and certain formwork activities. Based on these findings, localized productivity benchmarks could be developed to increase the accuracy of estimates, reliability of schedules, and productivity control in Cusco based civil works.*

Keywords *- Civil works, Construction productivity, Labor productivity, Man-Hours, Productivity Ratios.*

1. Introduction

Labor productivity is a critical indicator of performance in the execution of civil works. It enables a direct estimation of the necessary labor, associated costs, and the duration of construction activities. In professional practice, ratios of productivity are used as fundamental inputs for budget formulation, work programming, and the control of physical-financial progress. Recent investigations have proposed an expansion of the conventional approach, which is currently predicated on "man-hours," to encompass the incorporation of ergonomic restrictions associated with postural exposure ("posture-hours") into the scheduling process. This modification is intended to reduce the risk of musculoskeletal disorders and enhance the well-being of the crew. However, it should be noted that this adjustment may necessitate slight increases in the duration of the project [1]. The Peruvian Chamber of Construction (CAPECO) has established the ratios that are most widely used in Peru as technical reference for analysing the unit cost and estimating the labour productivity. The values, however, established in certain execution conditions and are generally used without being systematically tested for the actual construction situations from around the country.

The academic evidence shows that productivity varies significantly depending on the type of activity, the execution environment, and the organizational process; therefore, its use

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as a universal value can distort project management [2]. Besides, based on studies in the analysis of time use, evidence that an important proportion of the labor day does not correspond to work directly, affecting the ratios used for programming and control [3]. In the context of the Cusco region, factors such as how supplies are delivered, how easily workers can get to their jobs, how often supplies are delivered, how much is available, and how technology has improved work crews can make a big difference compared to the rest of the country. This can lead to errors in estimating worker hours, schedule changes, and problems with work control.

Previous studies on construction labor productivity have shown that productivity is not a fixed value, but a context-dependent indicator influenced by technical, managerial, logistical, and environmental factors. In civil works, labor performance may vary according to crew experience, work-front accessibility, activity complexity, material availability, supervision quality, weather conditions, equipment support, and the continuity of construction processes[2, 3, 4]. Other studies have also emphasized that field-based productivity records are necessary because planned or reference values do not always reflect the real execution conditions observed on site[5, 6].

More recent approaches have incorporated digital planning, productivity prediction models, and data-driven techniques to estimate construction performance; however, these methods require reliable local databases to be effective[7, 8]. Therefore, the literature indicates that productivity benchmarks should be validated and adjusted according to regional and project-specific conditions rather than being applied as universal values.

In spite of the use of productivity values of CAPECO in the professional practice, it has not been verified empirically if the national reference ratios are representative of the real conditions in which civil works are executed in the region of Cusco. Labour productivity in construction activities has been found to be strongly affected by buildability factors, structural factors, as well as factors related to how the work is organized, which can differ depending on the project context [4]. This is a gap in research because productivity can differ based on regional conditions, including the availability of work fronts, the continuity of supplies, labor organization, construction techniques, and the type of structural element being constructed. As a result, applying national benchmarks without local validation may lead to inaccurate estimates of labor demand, construction costs, and activity durations. Therefore, it is necessary to compare CAPECO reference values with field-based productivity ratios obtained from actual works executed in Cusco.

The novelty of this study lies in the development of field-based and region-specific productivity ratios for civil works executed in the Cusco region, a context where national benchmark values such as CAPECO are commonly applied without empirical validation. Unlike previous studies that mainly identify factors affecting construction productivity, such as work organization, buildability conditions, crew performance, environmental constraints, or predictive modelling approaches [2, 4, 7, 8, 9] this research directly compares national reference ratios with actual man-hour records obtained from local civil works executed between 2023 and 2025. Therefore, the study contributes to the existing literature by providing empirical evidence on the applicability and limitations of CAPECO values in a regional context, while also establishing preliminary localized benchmarks for activities frequently executed in road and sanitation projects in Cusco.

In this context, it is also necessary to identify representative productivity ratios for recurrent structural activities recurring in civil works, as well as identify items that are not included in existing reference banks, but which are frequent in projects of viaduct infrastructure and of sanitation. Along the same lines, the literature recently emphasizes more “human-centered” approaches to productivity and efficiency, incorporating tools that reduce ambiguities operative and put the worker's well-being first [10]. This shows how important it is to measure actual performance and adjust benchmarks based on how they're actually executed.

The goal of this research is to calculate the average productivity ratios of civil works in the Cusco region from 2023 to 2025. The ratios suggested by CAPECO will be compared with the actual ratios obtained in the field for important structural activities. Common activities in local projects that do not have set ratios will also be identified. This helps suggest initial base values that make planning and controlling productivity in the region easier. This approach is in line with what we've seen in other countries, where it's clear that productivity on site depends on many factors, not just adding tools or practices [11]. It is important to check and adjust ratios using real measurements in the local context.

The study provides real productivity ratios based on reliable field data. It uses methods such as labor sampling, which are strong even if measurement conditions change [5]. Besides, recent approaches stand out the necessity of managing the productivity from a integral perspective of process: propose an approach of life cycle for productivity and identify critical risks associated with collaboration, Information exchange, supervision, interruptions, and changes show that performance depends on the crew and on how the production system is managed [12].

In general, creating a baseline that is customized to the situation in Cusco makes estimates and planning more accurate, reduces reliance on national references, and provides technical support for project management, academic training, and future research.

2. Materials and Methods

2.1. Study Focus

The investigation presents a quantitative approach, descriptive and comparative, oriented to the analysis of the labor productivity ratios in civil works. The productivity is understood as the evaluation of the efficiency with which resources are being managed to finalize a product in a determined time, maintaining an acceptable quality level, integrating both efficacy and effectiveness [6].

The study is structured as a comparison between the Productivity Ratios (PR) derived from references of CAEPCO and the real ratios obtained in the field in civil works executed in the Cusco region during the period 2023-2025.

2.2. Information Source

Two principal sources of information. The first corresponds to the values referenced published by the Peruvian Chamber of Construction (CAPECO), an institution that promotes the investigation and training in the sector of construction and establishes minimum labor productivity levels defined in the Ministerial Resolution N.° 175 for Lima and Callao [13].

These values constitute a widely used technical reference in the preparation of technical documents and cost analyses [14]. The second source is formed by real dates of work, compiled from (i) the documentary revision of the technical thesis developed in the National University of San Antonio Abad of Cusco (UNSAAC) and (ii) performance records from professional internships of students of Civil Engineering. These dates reflect real conditions of execution, considering the own variability of the civil work in the regional context.

2.3. Labor Performance, Man-Hours and Productivity Ratio

The performance of labor is defined as the amount of work done by a group of people working together on a project. This group can include operators, officers, and laborers in a determined activity, for the unity of human resources measure in Man-Hours (MH).

This indicator allows quantifying labor productivity through a specific calculation relationship [6]. In general, performance is expressed as shown in Equation (1).

$$Performance = \frac{\#workers * time\ of\ hours}{unitary\ contribution} \tag{1}$$

The man-hours (MH) are a unit of measurement that represents the effective working time of a worker. It is used to estimate the number of hours and the number of workers needed to complete an activity in a given period [15]. Total man-hours are calculated using the expression shown in Equation (2).

$$MH = (N.° \ of\ workers)\ x\ (\text{working hours}) \tag{2}$$

Based on these concepts, labor productivity is evaluated using the Productivity Ratio (PR), which is defined as the relationship between man-hours employed and the amount of work performed [6]. This indicator enables a comparative analysis of labor performance across various construction activities and is typically expressed as shown in Equation (3).

$$RP = (H)\ x\ (\text{Production hours}) \tag{3}$$

2.4. PR Calculation Procedure

For CAPECO's reference values, Productivity Ratios were not obtained directly, as the source does not explicitly present them. Conversely, the PRs were derived from the Unit Cost Analyses (UCAs) by aggregating the man-hours associated with each item and correlating them to the pertinent production unit[13, 16]. This procedure enables the derivation of productivity indices that are consistent with the cost structure employed in professional practice.In the specific case of the actual data from Cusco, the PR was calculated directly from the construction records, considering the man-hours actually worked by the crews and the quantities executed in each activity. This approach is consistent with the measurement of productivity in civil engineering works proposed by [6], who highlights the need to include effective working times and actual conditions of execution.

2.5. Analysis and Comparison Procedure

The productivity ratios obtained were then subjected to analysis using descriptive statistics, which entailed the calculation of average values per activity and per work family.

These values were then compared with CAPECO's benchmark indices by calculating percentage variations to identify similarities, discrepancies, and relevant trends. In this study, variance analyses were implemented to evaluate the consistency of the results and the degree of applicability of CAPECO's PRs to the regional context of Cusco. This analysis was based on the recognition that civil works are carried out under highly variable conditions in terms of aspects such as topography, logistics, and resource availability [17].

3. Results and Discussion

The materials and methods section should contain sufficient detail so that all procedures can be repeated. It may be divided into headed subsections if several methods are described.

3.1. General comparison (PRProfessional vs. PRThesis vs. CAPECO)

Productivity Indices (PI) are expressed in mh/unit (man-hours per unit). Conversely, a lower PI is indicative of higher productivity Table 1.

Table 1. PRProfessional vs. PRThesis vs. CAPECO

No	TASK	UND	PR_{CAPECO}	$PR_{Profesional}$	PR_{Thesis}	Δ% $PR_{Profesionals}$	Δ% PR_{Thesis}
1	Rebar f'y = 4200 kgf/cm² in foundations	mh/kg	0.06800	0.01991	***	-70.71%	***
2	Rebar f'y = 4200 kgf/cm² in horizontals (beams and slabs)	mh/kg	0.06800	0.11943	0.10000	75.63%	47.06%
3	Rebar f'y = 4200 kgf/cm² in retaining walls	mh/kg	0.06800	0.06635	0.05000	-2.42%	-26.47%
4	Rebar f'y = 4200 kgf/cm² in verticals	mh/kg	0.06800	0.07452	0.05000	9.60%	-26.47%
5	Rebar f'y = 4200 kgf/cm² others (manholes, channels, etc.)	mh/kg	0.06800	0.08731	***	28.40%	***
6	Reinforced concrete in retaining walls	mh/m³	13.76000	9.26552	3.56000	-32.66%	-74.13%
7	Cyclopean concrete in retaining walls	mh/m³	13.60000	6.15062	7.36000	-54.77%	-45.88%
8	Cyclopean concrete f'c = 140 kgf/cm² + 30% stone	mh/m³	13.60000	1.96526	***	-85.55%	***
9	Concrete in floor-slabs	mh/m³	6.17600	3.46700	***	-43.86%	***
10	Concrete in vertical elements	mh/m³	13.76000	7.67517	10.67000	-44.22%	-22.46%
11	Concrete in beams	mh/m³	6.88000	7.86675	***	14.34%	***
12	Concrete in foundation beams	mh/m³	13.60000	2.86645	***	-78.92%	***
13	Concrete in footings and foundations	mh/m³	4.54000	2.81227	***	-38.06%	***
14	Ready-mix concrete f'c = 210 kgf/cm² in pavement slabs	mh/m³	***	2.92018	2.05000	***	***
15	Ready-mix concrete f'c = 245 kgf/cm² in pavement slabs	mh/m³	***	2.21265	2.13000	***	***
16	(F&S) for culvert abutments	mh/m²	***	3.07008	2.07000	***	***
17	F&S for concrete slabs	mh/m²	1.62400	2.30894	***	42.18%	***
18	F&S for retaining walls and underpinning	mh/m²	1.62000	1.53708	1.86000	-5.12%	14.81%
19	F&S for walls and columns	mh/m²	3.22000	1.17438	1.33000	-63.53%	-58.70%
20	F&S for sidewalks and curbs	mh/m²	1.62000	1.44160	1.07000	-11.01%	-33.95%
21	F&S for beams	mh/m²	3.22000	4.57707	3.00000	42.15%	-6.83%
22	F&S for footings	mh/m²	1.62000	1.25589	***	-22.48%	***
23	F&S others (manholes, channels, etc.)	mh/m²	***	2.39052	2.80000	***	***
24	Lean concrete	mh/m²	1.02000	0.56129	0.40000	-44.97%	-60.78%

In general terms, PRProfessional has lower productivity indices (PI) than CAPECO in most items, especially in concrete and various formwork, reflecting greater production efficiency. The most significant improvements over CAPECO are seen in cyclopean concrete and foundation concrete, with reductions exceeding 70% in certain elements, associated with low complexity, high repetitiveness, clear fronts, and continuity of supply. These conditions reduce downtime and promote crew learning. Nevertheless, these variations can also be influenced by the prevailing economic environment, which exerts an influence on the sector's labor productivity (e.g., shifts in price indices and economic activity). This phenomenon has been substantiated at the industry level through the utilization of econometric models that examine dynamic relationships between macroeconomic indicators and productivity in construction [18].

Other items have higher IPs than CAPECO, especially in steel horizontal elements (beams and slabs) and beam formwork/stripping. These activities are affected by traffic problems, working at height, interference, and safety restrictions, which increase working time. These differences between PRProfessional and PRThesis indicate an important influence of the construction method, formwork and cycle planning. It is found that, as the productivity deteriorates because of construction constraints, the cost goes up and "premium factors" need to be added to more complex construction conditions, such as skyscrapers with ratios that represent penalties for lower productivity [19].

Lastly, the IP values for items that are similar to CAPECO (such as the steel in retaining walls or some of the vertical elements) demonstrate that CAPECO is a very good representation of an average for standardized activities. The overall findings indicate that caution should be used in applying the reference values and that they should be applied for specific construction conditions. With this, they should not be used spontaneously. At the same time, organisations should enhance how they record technology (like 'process maps' or method statements) and how they create these (from information modelling and CAD tools) to boost productivity and process control, says [20]. This will help to simplify techniques and make them more uniform in execution.

3.2. Summary by Activity Family (Averages)

In Table 2, the PR/IP (mh/unit) allows for direct comparison between families, but the averages conceal high variability between batches. Therefore, a single national benchmark may be insufficient for planning and control in Cusco. It has been said that to improve performance, it is necessary to plan and control in a continuous and organized manner, and to take concrete actions to manage productivity within project management [21], which results shows the need for context-adjusted references and finer tracking mechanisms instead of relying on a single average.

- Rebar: Pre-Professionals and Thesis have lower relative productivity as seen in their higher relative PRs of +10.3% and +2.0%, respectively, whereas Thesis is still very close to the benchmark.
- Concrete: Pre-Professionals sees an improvement when compared with CAPECO (−8.4%), whereas Thesis sees a significantly higher PR (+108.4%) due to a particular execution condition or more stringent measurement criteria.
- Formwork: Both exceed CAPECO (+9.8% and +6.5%), highlighting the fact that formwork is particularly affected by geometry, repeatability and formwork systems.

Table 2. Averages per family (PRProfesionales vs. PRThesis vs. CAPECO)

TASK	CAPECO	Professional	Thesis	VAR. % Profesional vs CAPECO	VAR. % Thesis vs CAPECO
Rebar	0.06667	0.07351	0.06800	+10.3%	+2.0%
Concrete	5.15400	4.72019	10.73950	−8.4%	+108.4%
Formwork	2.02160	2.21945	2.15400	+9.8%	+6.5%

3.3. Comparison of Reinforcing Bars (mh/kg): (PRProfessional vs. PRThesis vs. CAPECO)

The average PR values in Figure 1 are similar, which indicates that the process is relatively consistent. The performance of Pre-Professionals is approximately 8.1% ahead of CAPECO, however, Thesis is slightly behind, approximately −2.0%, which is very close to the benchmark. Steel can be essentially assumed as stable for Cusco, but different values of PR should be adopted for each element type, rather than one value. This need is consistent with the evidence that negative deviations in productivity from a baseline ("baseline productivity") directly increase the final cost of the project, because longer actual times than estimated are accumulated [22].

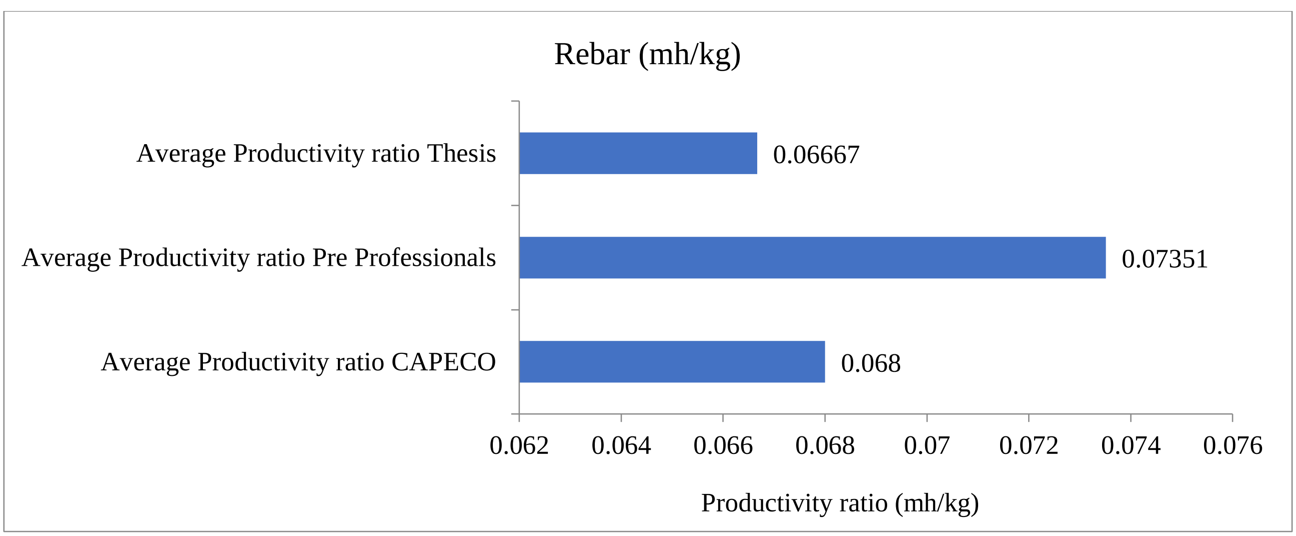

Fig. 1 Comparison of reinforcing bars (mh/kg) (PRProfessional vs. PRThesis vs. CAPECO)

3.4. Comparison of Reinforcing Bars in Concrete (mh/m³): (PRProfessional vs. PRThesis vs. CAPECO)

The averages for Pre-Professional and Thesis projects are much lower than CAPECO's (drops of about 56% and 52%, respectively), as shown in Figure 2, which indicates increased productivity. This is similar to how they've made improvements in how they plan and organize their work, and how they've been able to keep their supply chain going stronger than before. The improvement is not the same for all items and depends on the type of concrete, element, and pouring conditions. So, concrete should be treated as a set of context-dependent indices. Today's planning often adds to the traditional "man-hours" approach by including limits related to how long someone can stand up ("posture-hours") and the ability to keep standing as a limited resource. This allows for scheduling the emptying process while also thinking about both productivity and crew well-being [1].

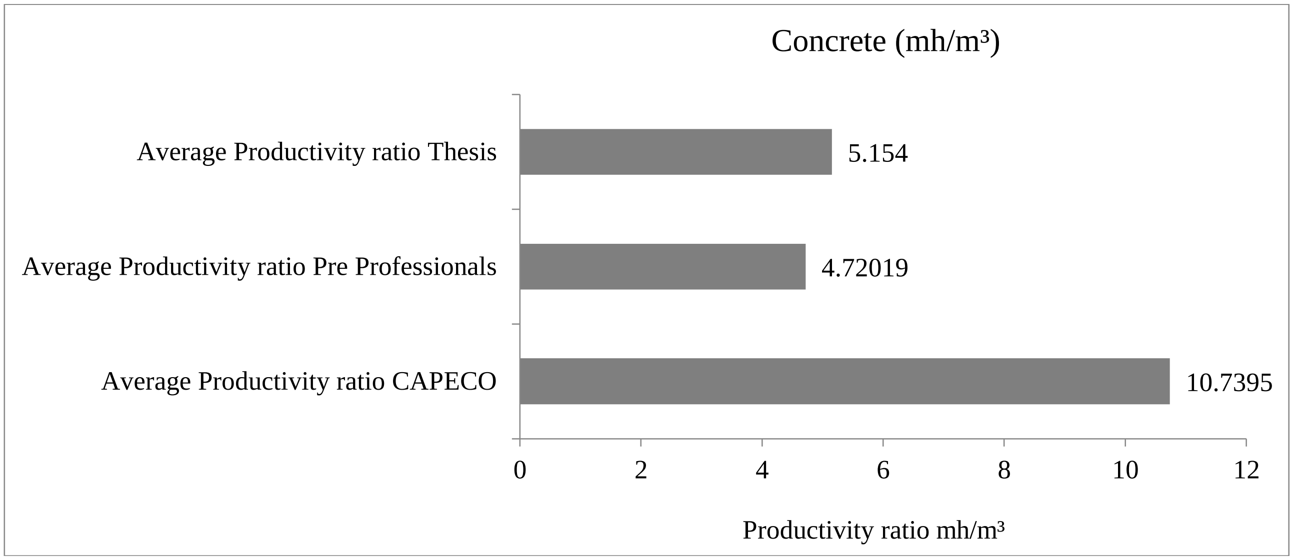

Fig. 2 Comparison of reinforcing bars in concrete (mh/m³) (PRProfessional vs. PRThesis vs. CAPECO)

3.5. Comparison of Formwork and Stripping (mh/m²) (PRProfessional vs. PRThesis vs. CAPECO)

The averages are similar between CAPECO, Pre-Professionals, and Thesis. Pre-Professionals is slightly higher than CAPECO (≈ +3.0%), and Thesis is lower (≈ −6.1%) in Figure 3, indicating moderate differences. Formwork depends on geometry, repeatability, and formwork type. In projects with geometric diversity, the overall average may be insufficient. Recent studies show that formwork productivity can be accurately predicted using data-driven approaches, such as neural networks, and considering various project factors. This demonstrates its sensitivity to specific conditions and the importance of not relying on an average [7].

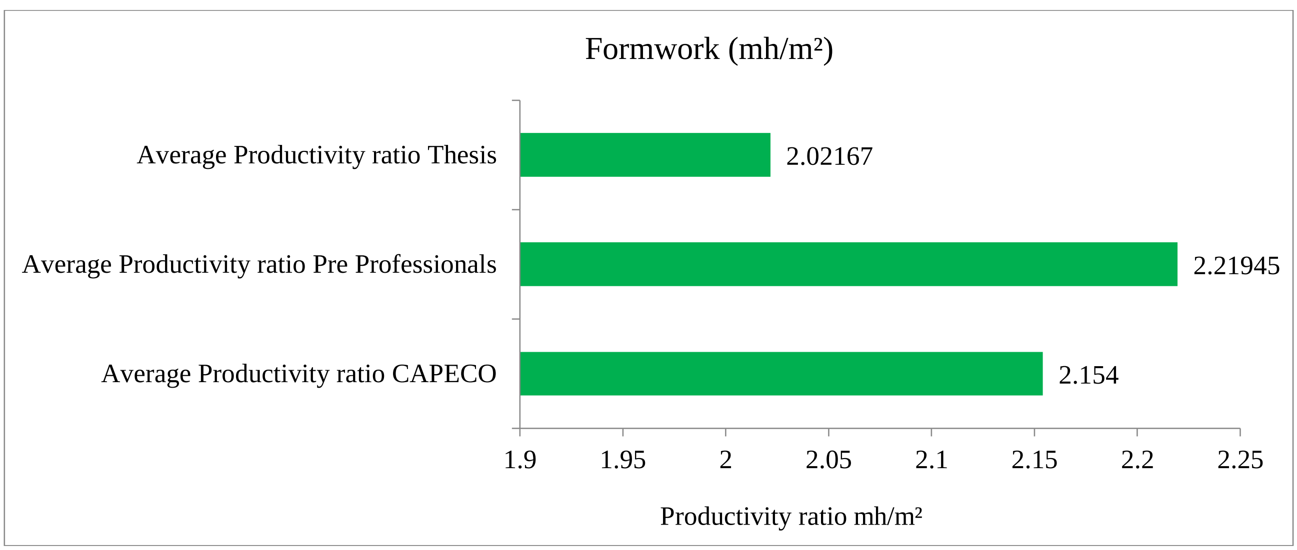

Fig. 3 Comparison of formwork and stripping (mh/m²) (PRProfessional vs. PRThesis vs. CAPECO)

3.6. Reference Indices for Items without CAPECO Reference

Table 3 shows that CAPECO does not include these items, indicating that the benchmark does not adequately cover the types of work commonly found in road construction and sanitation. This study provides information on PR for ready-mix concrete in pavement slabs and for specific formwork (stirrups, wells, channels), expanding the reference base for regional scheduling and control. Recent literature shows that productivity estimates for specific tasks (such as steel placement) are improved by predictive models based on machine learning and job site variables. This reinforces the importance of having local databases by type to feed more accurate and explainable forecasts [8].

- In ready-mix concrete pavement slabs, low PR values show high efficiency because of simple geometry, surface application, and continuous pouring.
- In culvert abutments, Thesis performs better than Pre-Professionals. This is consistent with the differences in organization and repeatability.
- Thesis takes more time to use in manholes/channels because of their uneven shapes, small spaces, and the fact that it is hard to do the same task more than once.

Table 3. Proposed reference indices for items not included in CAPECO

No	TASK	UND	PR_{CAPECO}	$PR_{Profesionals}$	PR_{Thesis}
14	Ready-mix concrete f'c = 210 kgf/cm² in pavement slabs	mh/m³	***	2.92	2.05
15	Ready-mix concrete f'c = 245 kgf/cm² in pavement slabs	mh/m³	***	2.21	2.13
16	(F&S) for culvert abutments	mh/m²	***	3.07	2.07
23	F&S others (manholes, channels, etc.)	mh/m²	***	2.39	2.8

3.7. Productivity Behavior for the Lean Concrete Activity

Table 4 shows that, for CAPECO (1.02000 mh/m²), Pre-Professionals and Thesis reduce PR by 44.97% and 60.78%, respectively, demonstrating higher productivity. This is because they are simple, repetitive, easy to access, and have few interferences. Thesis has an added benefit: it helps with planning and making sure there's a steady supply. Overall, the CAPECO benchmark for lean concrete is conservative for current conditions in Cusco. This result is in line with what other studies have found. These studies showed that factors like experience and skills of the workers, the quality of management, and environmental conditions can explain differences in productivity between different situations and regions. Therefore, it's better to use localized approaches and references instead of general values [9].

Table 4. Productivity behavior for the activity of lean concrete

No	TASK	UND	RP_{CAPECO}	$RP_{Profesional}$	RP_{Tesis}	$\Delta\%\ RP_{Profesional}$	$\Delta\%\ RP_{Tesis}$
24	Lean concrete	mh/m²	1.2000	0.56129	0.40000	-44.97%	-60.78%

4. Extended Analysis and Practical Implications

4.1. Comparative Productivity Analysis

The productivity indices obtained for the Cusco region show that national benchmarks such as CAPECO cannot be applied uniformly to all civil works activities. While reinforcing steel and formwork present values relatively close to the national reference, concrete-related activities show wider differences and, in several cases, lower man-hour consumption, indicating higher productivity under local conditions.

This behaviour is consistent with the wider regional and international evidence which indicated that productivity is directly influenced by the context in which it is executed – such as access to work fronts, the continuity of supply, terrain of the work, organisation of the crew, and the repetitiveness of the work – as well as the characteristics of the project and the operational conditions affecting labour efficiency [23]. For this reason, Cusco is a particular region that requires productivity ratios for the field to be used in addition to the national references for better cost estimation, scheduling and control of productivity.

4.2. Impact of Technology and Management

The results indicate that not only the nature of the activity, but also the technological and managerial context in which the activity is carried out, affects productivity. Where ready-mix concrete, pavement slabs, and repetitive concrete placement can be involved, they tend to have better productivity due to the fact that they have a continuous supply, simple geometry and more standardized production cycles. Horizontal reinforcement work, formwork for beams and stripping, however, are more impacted by congestion, safety limitations, sequencing of work and coordination issues. Similarly, the implementation of technologies and practices, such as the application of ready-mix concrete, modular formwork, prefabricated reinforcement, daily planning, look-ahead planning, and the coordination of the supply chain, can help to minimize idle time and boost labor productivity, which has also been seen in other more technologically advanced construction settings, where the automated production of concrete and optimization of concrete batch-plant operations play a major role in productivity improvement [24].

The increased productivity achieved in this study, when compared to state of the art techniques and to previous studies recorded in the literature, was not only due to the technological innovation, but was due to the interaction between the favourable field conditions, the optimal work organisation and the execution characteristics of the activities. Although the studies above focus on the predictive models, digital productivity records, automated concrete production systems and the improvement of planning techniques for enhancing the performance of the labour force, the outcomes of this research indicate that it is also possible to improve productivity in construction activities when these activities are performed under stable and repetitive production conditions. The lower consumption of man hours for the analyzed works compared with CAPECO was due to the simplicity of geometry, the close approach of the work fronts, the material supply during the entire work, the absence of internal transport and the regular production cycles. These conditions reduced idle time, interruptions and crew learning losses, enabling them to carry out the activities more efficiently than the national benchmark. Some activities did not benefit this improvement as horizontal reinforcement, beam formwork and stripping, which needed more working hours as a result of congestion, work at height, safety restrictions, sequencing and coordination issues. The results are not therefore an indication that the local productivity ratios are always better than national, nor than they are always better than those previously reported, but that the ratios can be higher in the field where technical, logistic and managerial conditions are favourable.

4.3. Comprehensive Analysis of Productivity Determinants

Labor productivity in civil works is influenced by a set of factors such as labour, logistics, environment, technical and managerial aspects. Possible factors are labor-related, logistical, environmental, technical and managerial. Labour-related: experience of the workers, stability of the crew, specialization, learning effects, quality of supervision; logistical: availability of materials, transport distance, continuity of supplies, availability of equipment; environmental: climatic variability, rainfall, topography, altitude, access roads, dispersion of work fronts; technical: nature of the structural element, geometry, construction method, formwork system, repetition; managerial: planning, coordination, safety control, documentation, and quality supervision. Construction productivity research also has documented the importance of weather, the skills of the worker, crew composition, and the nature of the work as important factors in productivity [25]. The determinants of productivity are reasons why productivity should not be considered as a constant, but rather as a context dependent indicator that can vary based on the actual execution conditions on the ground.

4.4. Policy and Practice Recommendations

To be applied practically, there must be some reference limits, and it is suggested that these reference limits, for the first time, be the CAPECO values, but not in all regional projects. Local productivity ratios must be increasingly added, differentiated by activity, by structural element and by execution condition, to the technical files, budgets and schedules of public institutions. The construction companies need to document the quantities performed, man hours used, composition of the crews, supply conditions, equipment availability, weather conditions and interruptions to compare productivity levels planned and accomplished. It is important that the supervisors and project managers closely track weekly productivity and implement any necessary corrective measures, as collaboration, information sharing, supervision quality, and work interruptions have been found to be important factors that can impact productivity in construction projects [12]. Lastly, universities and professional institutions should encourage the development of a regional productivity database for Cusco, including data from public works, private projects, theses, internships and professional field records to draw up updated and context-sensitive benchmarks.

5. Conclusion

There are two significant practical aspects of the results to be noted. Firstly, CAPECO is still valuable in providing initial estimates for families showing average consistent behavior, especially with regards to reinforcing steel and formwork, where the thesis is very close to the CAPECO benchmark, and the differences are not large. Secondly, high dispersion is seen per item and concrete improvement in relevant activity in Cusco (plain, cyclopean and lean concrete). This is a reminder of the need for establishing localized productivity ratios (PRs) for the different elements and activities to provide better estimation of cost and schedule, and the need to avoid a single national value that could be misleading for such estimates.

Looking at the data at the item level, the PR of PRProfessional is generally higher than that of CAPECO. The conclusion that the benchmark has been met could indicate that, because of these results, the benchmark is not indicative of what could possibly be, but rather is the typical result of the work. The profits go with those concretes which are low in complexity and high in repeatability; there is continuity of the process, more stable logistics, and accessible fronts. On the other hand, the productivity measures indicate that when steel and formwork are being used for horizontal elements, the application of these materials is linked to a higher level of congestion, execution variability in height, and interference in operations, which all contribute to an increase of hours consumed. Moreover, the results of PRProfessionals and the PRThesis show that the game is not the only factor that affects productivity, but also the constructive approach used, the organization of the team and the indicators used to measure.

These findings are confirmed by the analysis of families: in both types, the families show that they tend to underperform the benchmark, but the thesis stays in line. Professionals perform better than CAPECO in concrete and score a substantial amount of hours in the thesis in formwork, but there are differences across geometry, repetitiveness, and formwork system. The investigation's results add to the field of Public Relations (PR) because they deal with aspects that are not covered by the CAPECO. Premixed concrete is used for pavement slabs, and special formwork is used in abutments, wells and channels. The study highlights the need to update and improve productivity benches to meet the changing needs and challenges of modern R&D (Research and Development) projects.

From a management perspective, the utilization of CAPECO, such as baseline, in conjunction with PR-specific to Cusco, for activity and element type, is recommended. In this method, it is updated every so often as evidence of work builds up. Unconditional application of normative values must not be done without checking the actual execution conditions.

Recommendations

The following are suggested as a starting point for reference only and not as a standard maximum, minimum values, as would be used for any specific project, depending on the following: accessibility, geometric complexity, logistic of material supply, organization of work fronts, etc., particularly in regional contexts, as in Cusco.

The results fundamental gradually replace the national values of the productivity indices, which are subdivided by activity family, type of element and execution conditions, for a more precise management. In the context of reinforcing steel and formwork, it is recommended that the following considerations be taken to enhance productivity. These recommendations include the optimization of construction cycle planning, the standardization of processes, and the utilization of modular systems and reusable materials. Furthermore, where feasible, the prefabrication of reinforcements should be considered to minimize references, time out, and consumption hours per unit. Furthermore, it is imperative to enhance the logistics of steel processing, encompassing activities such as cutting, folding, and front-end feeding. This optimization should be accompanied by the reinforcement of training and the stability of work crews, leveraging the learning effect inherent in repetitive tasks.

For the concrete, it is recommended to update the value of reference of productivity, incorporating consistent performances with the current supply conditions, transport, and colocation. The planning and the controls should be based on differentiated indices by concrete type and structural element, in place of a single average value in mh/m³, ensuring the continuity of emptying and minimization of waiting times. In the case of comparative studies, it is suggested review and standardize measurement criteria to avoid overestimations of consumption of hours.

Regarding the use of formwork and stripping, the following recommendations are made: The indices should be adjusted based on the geometry of the element, level of repeatability, and formwork system and should not be based on the use of unique average values. Incorporating planning for the formwork stripping cycle process and minimising rework and waiting times is essential to improve performance.

With respect to items not included in CAPECO and to activities like the lean concrete, it is recommended to use the proposed indices in this studio as preliminary references, adjusting them to the specific conditions of the work and systematically documenting the actual performance to build bases of regional data. Finally, it is suggested that future investigations expand the number of analyzed projects and go deeper into the effect of technical variables and organizational, to develop regional benchmarks more representative and useful for planning and project control

References

[1] Kai Qi, and Ming Lu, "Integrating Posture-Hour Constraints into Construction Scheduling to Enhance Workforce Wellbeing," *Computer-Aided Civil and Infrastructure Engineering*, vol. 40, no. 30, pp. 6107-6126, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[2] Luis Otavio Cocito Araujo, Neuton Ribeiro Neto, and Carlos Caldas, *Analyzing the Correlation between Productivity Metrics*, Construction Research Congress 2020, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[3] Søren Wandahl, Hasse H. Neve, and Jon Lerche, "What a Waste of Time," *Proceedings 29th Annual Conference of the International Group for Lean Construction*, Lima, Peru, pp. 157-166, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[4] Abdulaziz M. Jarkas, "Buildability Factors Influencing Formwork Labour Productivity of Isolated Foundations," *Journal of Engineering, Design and Technology*, vol. 8, no. 3, pp. 274-295, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[5] Søren Wandahl et al., "Robustness of Work Sampling for Measuring Time Waste," *30th Annual Conference of the International Group for Lean Construction*, Edmonton, Canada, pp. 247-258, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[6] Luis Fernando Benavides Irigoín, and Ronald Torres Torres, "*Evaluation of Productivity and Labor Performance in Concrete Beams and Columns in Housing Construction in the City of Chota*," Thesis, National Autonomous University of Chota, pp. 1-554, 2024. [Google Scholar] [Publisher Link]

[7] Vijay Bhilwade et al., "Predicting Labour Productivity for Formwork Activities in High-Rise Building Construction: A Case Study," *Asian Journal of Civil Engineering*, vol. 24, no. 4, pp. 959-968, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[8] Farah Faaq Taha et al., "Explainable Machine Learning-Based Estimation of Labor Productivity in Rebar-Fixing Tasks," *Eng*, vol. 6, no. 9, pp. 1-22, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[9] Feihong Jianet al., "Critical Factors Affecting Construction Labor Productivity: A Systematic Review and Meta-Analysis," *Buildings*, vol. 15, no. 14, pp. 1-23, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[10] Anthony Franze, "Informing User-Centred Approaches to Augmented Custom Manufacturing Practices," *Proceedings of the 28th CAADRIA Conference*, Ahmedabad, pp. 353-362, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[11] Qinglin Wu et al., "Identifying Impact Factors of MEP Installation Productivity: An Empirical Study," *Buildings*, vol. 12, no. 5, pp. 1-18, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[12] Idil Calik, Kerim Koc, and Onur Sahin, "Life Cycle Risk Management for Improving Labor Productivity in Construction Projects in Türkiye, *Buildings*, vol. 15, no. 3, pp. 1-23, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[13] Yolita Amaringo Linares, and Hector Luis Janampa Quispe, "*Comparison of Labor Productivity and Material Costs in Laying and Plastering Walls with Clay Bricks and Concrete Blocks in Iquitos – 2023*," Thesis, Scientific University of Peru, pp. 1-116, 2023. [Google Scholar] [Publisher Link]

[14] Isaí García Córdova, "*Labor Productivity in Basic Sanitation Projects by Direct Administration, in Rural Areas of the Shamboyacu District – Picota – San Martín*," Thesis, Catholic University, pp. 1-121, 2021. [Google Scholar] [Publisher Link]

[15] Miller Olortegui Flores, "*Labor Productivity in the Masonry Walls and Partitions Section of Housing Construction in the Municipal Urbanization of the City of Pucallpa*," Thesis, Alas Peruanas University, pp. 1-81, 2018. [Google Scholar] [Publisher Link]

[16] Carlos Mayer Tinoco Lozano, and Rudi Erixson Espinoza Oblitas, "*Evaluation of Labor Productivity in the Main Items of Informal Construction in the Los Aromos Sector of the City of Jaen*," Thesis, National University of Jaén, pp. 1-103, 2022. [Google Scholar] [Publisher Link]

[17] Iris D. Tommelein, and Samir Emdanat, "Takt Planning: An Enabler for Lean Construction," *Proceedings 30th Annual Conference of the International Group for Lean Construction*, Edmonton, Canada, pp. 866-877, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[18] Argaw Tarekegn Gurmu, "Econometric Analysis of Macroeconomic Factors Influencing Construction Labour Productivity at Industry Level: Evidence from Australia," *Construction Management and Economics*, vol. 44, no. 1, pp. 23-40, 2026. [CrossRef] [Google Scholar] [Publisher Link]

[19] Jong-San Lee, Hyun-Soo Lee, and Moon-Seo Park, "Schematic Cost Estimating Model for Super Tall Buildings using a High-Rise Premium Ratio," *Canadian Journal of Civil Engineering*, vol. 38, no. 5, pp. 530-545, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[20] Tatyana Barabanova, "Information Modeling in the Design of Organizational and Technological Documentation," *MATEC Web Conference*, vol. 106, pp. 1-6, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[21] Upul Ranasinghe, and Janaka Ruwanpura, *Continuous Process Planning and Controlling Techniques for Construction Productivity Performance Enhancement*, Construction Research Congress 2012: Construction Challenges in a Flat World, pp. 310-320, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[22] Mohamed Abdel-Hamid, and Hanaa Mohamed Abdelhaleem, "Impact of Poor Labor Productivity on Construction Project Cost," *International Journal of Construction Management*, vol. 22, no. 12, pp. 2356-2363, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[23] Şahin Tolga Güvel, "Forecasting Slipform Labor Productivity in the Construction of Reinforced Concrete Chimneys," *Ain Shams Engineering Journal*, vol. 16, no. 1, pp. 1-13, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[24] Hesham A. Abdel Khalek, Remon F. Aziz, and Ahmed H. Abdeen, "Identify and Prioritize the Major Influencing Causes of Automated Concrete Mixing System for Mega Construction Projects using Analytic Hierarchy Process," *Alexandria Engineering Journal*, vol. 57, no. 4, pp. 3451-3461, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[25] Ronald Ekyalimpa et al., "Towards Human-Robot Collaboration in Construction: Understanding Brickwork Production Rate Factors," *Buildings*, vol. 13, no. 12, pp. 1-20, 2023. [CrossRef] [Google Scholar] [Publisher Link]