Evaluation of triangle’s triple restriction on conventional construction and modular construction- Example: New building of the University of the Coast

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Abstract. This document evaluates and compares the modular construction system against the conventional construction system, analyzing it from the triangle of the triple restriction of the PMBOK guide (5th edition), which corresponds to the analysis of the scope, time and cost that can be achieve in the execution, which is focused directly on a real building of higher education, as a case study was used the university corporation of the CUC coast located in the city of Barranquilla. The main purpose of the research is to demonstrate the strengths, advantages and disadvantages of each construction system and once the real results were obtained to be able to make the application in professional practice for the management of the works and the execution of higher education projects, in this way the new construction processes are potentialized as a contribution to the development of architecture and innovation in Colombia, which is a country that is seeking to enter new methodologies and construction systems which must be aligned with the management issues that are being applied in the construction guild.

1. Introduction

This document is structured on the basis of a research process based on the evolution of modular construction [1] and its relationship to traditional construction, this, in order to show the advantages and disadvantages that each one establishes, highlighting the physical, functional and economic characteristics, in order to promote a balance between both methods of construction.

Therefore the document is arranged based on the historical transcendence that has been transforming the way of seeing architecture and its construction systems, specifically in the evolution of industrialization processes that lead to the integration of a prefabricated modular construction [2] on a specific environment.

The objective of the research project is to know the limit of application of modular unconventional construction and how far it is possible to be implemented. In the other hand, it is necessary to know if it has the same resistance capacities as a conventional construction systems [3]; to know if it is possible with the modular construction, to reduce time and execution costs, besides verifying if the profitability margin is favorable. Finally, it will be determined if it is applicable in constructions for educational use with emphasis on higher education.

In the same way we want to show to what extent the unconventional modular construction can be counteracted or adapted in front of a conventional constructive system; in this way establish its
constructive viability evaluated from the triangle of the triple restriction (scope, time and cost) [1] that is shown in the PMBOK Guide 5th Edition.

Part of the tangible scope of the document is that it has a significant contribution for project management [4] and encourages companies engaged in construction, to evaluate the possibility of applying the prefabricated modular construction as necessary and as much as possible as a tool for making decisions for the benefit of both business and those interested in this type of construction. The purpose of the intangible scope corresponds to giving value to modular unconventional construction and generating a social acceptance of the new trends in architecture so that, based on the comparative evaluation of the two types of construction, it could be possible to break the paradigm that the modular construction is inefficient.

2. Methodology
This research is a comparative and analytical type, where the advantages and disadvantages presented by conventional construction versus prefabricated modular construction were basically established, highlighting the potential that each offers for the management and application in construction projects of higher education institutions in Colombia. In addition, a qualitative and quantitative analysis of the two types of constructions is shown based on a case of study according to the triple restriction triangle. [5]

2.1. Project Development Phases
This research was carried out in four main phases, which are described below:

Phase 1: Overall evaluation based on the description and comparison of the two construction systems (Conventional and modular prefabricated).

Phase 2: Analysis of the parameters of scope, time and cost of each construction system, based on the triangle of the triple restriction of the PMBOK Guide 5th Edition in Chapter 1.

Phase 3: Determine the balance between the two constructive alternatives highlighting the one that represents greater efficiency and feasibility, establishing indicators that facilitate the management of educational projects within the companies of the infrastructure and building sector.

Phase 4: Emphasize on the construction system that represents the best processes within the stages for the Construction Management.

2.2. Tools to use
For data collection there were used several books, articles and monographs from which an analysis of information relevant to the research project was done. On the other hand, some regulations and normativity documents were applied during the research process, as well as websites associated with companies or corporations dedicated to these types of construction in Colombia.

Other important data was taken from architectural and structural 3D models that were develop for this investigation, in order to support the lists of activities, programming and costs of each type of construction, and, also to represent the different construction phases through more realistic images (renders).

3. Results and discussion
There were found that the modular system can be equated to a conventional constructive system, when evaluated from the triangle of the triple restriction (Scope, time and cost) of the PMBOK guide. Below it is possible to analyze the reasons that support the equity of both construction systems.

From the scope point of view, the modular construction system is equal to the conventional construction system, given that it has the same ability to meet technical, functional, structural and aesthetic needs, in addition to ensuring the spatial thermal comfort of the building, as shown by the project object of comparison Corporación Universidad de la Costa CUC [7], where it was proved that this modular construction process achieves the same scope of architectural compliance as the conventional process at the end of its execution as shown in figure 1.
When analyzing the traceability of the project from the beginning to the end, it was observed that two large variables interfere with time and cost, since this is where the modular system highlights its own characteristics to show the benefits of optimization, performance and cost.

According to the results obtained, it can be guaranteed that when talking about time, the modular construction system equals and exceeds conventional construction, given that a project of this magnitude can be constructed by reducing 70% of the time compared to a conventional construction system executed under the same planned activities. As it is an industrialized and prefabricated system, it reduces on-site execution times and in turn grants certain advantages that make project planning more accurate, such as risk reduction, contingency reduction and resource optimization.

The building based on the modular construction, within its planning manages to execute the project under 91 days, while the conventional construction reaches 320 days, contemplating a significant difference of 229 days in favor of the modular construction system, executing the same programmed activities in a shorter time, as shown in figure 2.

### Figure 1. Comparative analysis of the scope management between conventional construction and modular construction. Own source

|                      | Conventional Construction | Modular Construction |
|----------------------|----------------------------|----------------------|
| **Activities**       | Preliminary                | Preliminary          |
| **Foundation**       |                            |                      |
| **Structure**        |                            |                      |
| **Nets**             |                            |                      |
| **Stair and Envelopes** |                          |                      |
| **Finishes**         |                            |                      |
| **Town planning**    |                            |                      |
| **Result**           |                            |                      |
| **Meet needs**       | Town planning              |                      |
|                      | Functional                 |                      |
|                      | Structural                 |                      |
|                      | Aesthetic                  |                      |
|                      | Special comfort            |                      |
|                      | Customer satisfaction      |                      |
The latest comparative analysis of cost management, the modular construction system equals the conventional construction system, since the cost ratio between the same activities is clearly lower in the modular system simply because it requires fewer construction processes, less material handling and implementation and less labor recruitment compared to the number of activities and processes required by conventional construction.

A clear example of what was mentioned above, is the structural deliverable of the building which for the modular system has no greater involvement, since due to the standardization of this construction leads to minimal cost varies based on the daily change of the TRM, whereas in the conventional construction system the structural deliverable is one of the most relevant items because of the variation in costs it can have during the execution time. This can occur either by incidents of external agents such as location, delays in the work as a result of weather conditions or by delays in the work as a result of weather conditions or by delays characteristic of the materials because of their time of forging and stiffness.
Figure 3. Comparative analysis of cost management between conventional construction and construction modular- Own source

The total value of the building based on modular construction is ($ 3,745,938,818) and the total value of the building under conventional construction is ($ 6,632,127,856), yielding a large difference corresponding to the total of ($ 2,886,189,038). Equivalent to a significant reduction of 43.51% in cost savings.

3.1. Impacts of the results
Based on the comparative analysis and the results obtained previously, it is considered that there are 3 primary impacts that directly affect the variation of time and costs, that in turn influence the total difference of each of the construction systems, showing the relevance that the modular construction can have on the conventional construction.

Based on the cost estimates and implementation schedules of the two educational buildings, three common activities of great relevance for the proper performance of the construction are identified below, considered as the differential impacts between the two systems.

3.1.1 Foundation

Figure 4. Conventional and modular foundation system. Own source.
3.1.2. Structure

Conventional system

Modular system

Figure 5. Conventional and modular system structure. Own source.

3.1.3. Finishes

Conventional system

Modular system

Figure 6. Conventional and modular system finishes. Own source.
4. Conclusions

The conclusion of this research is the support tool for construction managers and their team, this reference will facilitate the running of construction projects specifically for higher education, since from the comparison of both methods in the same project, specific information can be obtained to measure the limitations and performance of execution of each system. In addition it is also possible to gather information about the financial traceability of the entire duration of the project that allows to estimate the cost of each of the systems, as well as determine which can become profitable and economically more attractive to the client.

In addition, with the incentive of promoting a starting point for pioneer construction companies, this document can encourage the implementation of new project construction alternatives, providing the same functional capacity, reducing execution and delivery time, obtaining more profitable and environmentally friendly projects, which for project management of any construction company is a plus of architectural and constructive innovation.

Given that Colombia is a developing country in all its aspects and more so when it comes to construction area, this is where the implementation of new construction systems can reduce traditional practices for the improvement and performance of the execution processes, as an added contribution from the construction management, the industrialization division can be boosted by the creation of companies dedicated to serial production and construction typing in order to enhance scope efficiency, time optimization and cost reduction of any type of construction project.

5. References

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