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INNOVACIÓN EDUCATIVA EN EDIFICACIÓN

Improving the Scoring System with the Choosing by Advantages (CBA) elements to evaluate Construction-Flows using BIM and Lean Construction

Mejora del sistema Scoring con los elementos de selección por ventajas (CBA) para evaluar los flujos de construcción utilizando BIM y Lean Construction

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HIGHLIGHTS

- Multicriteria decision-making (MCDM) method is synergetic with BIM and Lean Construction.
- Integration of the Choosing by Advantages (CBA) method and the Scoring method, based on practice.
- Dissemination of a successful teaching experience with feedback and improvement..

TITULARES

- El método de toma de decisiones multicriterio (MCDM) es sinérgico con el BIM y el Lean Construction.
- Integración del método de Selección por Ventajas (CBA) y el método Scoring con base en la práctica
- Difusión de una experiencia exitosa de enseñanza con retroalimentación y mejoras.

ABSTRACT

The multicriteria decision-making (MCDM) methods are used as Lean tools, specially, the Choosing by Advantages (CBA) method. CBA has been successfully applied to several construction management projects and it has proven many benefits over the traditional MCDM methods, among them, Scoring method, which is widely used in public and private projects. The main purposes are to improve the Scoring system with the CBA elements and to describe a teaching strategy applied in the School of Civil and Building Engineering. The present study proposes three methods to evaluate the best construction-flow option using 4D models and Lean Construction, based on the adaptation of the CBA system to the Scoring system. It offers a case study in which we select the best construction-flow option during structural work among four clusters of sectorization designs for a residential building. We compare and discuss how it is best to combine the Scoring and CBA approaches, which complement each other. The CBA and modified Scoring systems obtained very similar results. The methods were validated with the similar rankings, the improved collaboration, the survey responses from stakeholders and the transparency of the decision-making process. We recommend the inclusion of CBA elements in the overall framework, to create greater transparency and to reduce the time to reach consensus. The study suggests that MCDM methods combined with 4D models are useful means of achieving better comprehension of the construction flow and thus choosing the best construction alternatives.

Keywords: *Multicriteria decision-making; Scoring System; Choosing by Advantages; Building Information Modeling; Lean Construction*

RESUMEN

Los métodos de toma de decisiones multicriterio (MCDM) se utilizan como herramientas Lean, especialmente, el método de selección por Ventajas (CBA). CBA se ha aplicado con éxito a varios proyectos de gestión de la construcción y ha demostrado muchos beneficios sobre los métodos tradicionales de MCDM, entre ellos, el método de Scoring, el cual se usa frecuentemente en proyectos públicos y privados. Este trabajo tiene como objetivos principales mejorar el sistema de Scoring con los elementos de CBA y describir una estrategia de enseñanza aplicada en una escuela de Ingeniería Civil. El presente estudio propone métodos para evaluar la mejor opción de flujo de construcción utilizando modelos 4D y Lean Construction, basados en la adaptación del sistema CBA al sistema de Scoring. Se ofrece un estudio de caso en el que se selecciona la mejor opción de flujo de construcción entre cuatro grupos de diseños de sectorización para un edificio residencial. Se compara y discute sobre la mejor combinación de los enfoques de Scoring y CBA, los cuales se complementan entre sí. El CBA y el sistema de Scoring modificado obtuvieron resultados muy similares. Los métodos se validaron por medio de resultados similares, colaboraciones optimizadas, respuestas satisfactorias en las encuestas de las partes interesadas y por la transparencia del proceso de toma de decisiones que se percibió. Se recomienda la inclusión de elementos del CBA en el marco general del sistema Scoring, para crear una mayor transparencia y reducir el tiempo para llegar a un consenso. El estudio sugiere que los métodos MCDM combinados con modelos 4D son medios útiles para lograr una mejor comprensión del flujo de construcción y, por lo tanto, elegir las mejores alternativas..

Palabras clave: *Toma de decisiones multicriterio; sistema scoring; elementos de selección por ventajas Building Information Modeling; Lean Construction.*

1. INTRODUCTION

Multicriteria decision-making methods (MCDM) can aid designers in their choice of materials, components, and equipment during the detailed design stage [1]. However, the range of existing methods is broad, and there is no analytical framework to lay out their respective advantages and disadvantages. As a result, several researchers have recently begun to compare the main approaches that can be used for construction projects [2,3], among them, the Scoring system, with many arriving at the conclusion that the best overall system is Choosing by Advantages (CBA) [1,2,3]. CBA reduces time to reach consensus [4] thus, it can automate the decision making. Whatever the verdict, however, it's undeniable that these decision-making methods influence the choices of the designers, the decisions lead to actions, and the actions produce results [5]. The choice of materials in a building, workflow, staff, for instance, affects such elements as the life cycle of the building (including its environmental, social, and economic impacts), the project budget (including its initial, maintenance, and construction costs), the delivery time, etc. [1].

Once the most sustainable materials are selected during the design phase, the use of tools for decision making of the best workflow is needed. Having the best workflow implies having less waste, among them, less consumption of energy, less material residue, less work hours, a shorter schedule, among others. Thus, a positive impact on the sustainability indicators [6].

It's also worth noticing the importance of modularity, standardization, and industrialization in choosing the best alternative [7,8]. In parallel with this, the Lean Project Delivery System (LPDS) is a conceptual framework that adapts the principles of the Toyota production system and Lean Construction to the building sector. It involves a series of concepts, methods, tools, and techniques for decision-making, all oriented towards guiding execution and preventing waste in every phase of a building's life-cycle [9]. Management systems can be made compatible with LPDS by adapting sequences and processes flexibly [10,11], so that they can integrate decision-making methods and place them in an LPDS environment. Such integration can be achieved in both public and private projects [12]. On the other hand, Building Information Modeling (BIM) models, such as 4D, appear to be a means of improving visualization and comprehension early in the construction planning stage [13].

The aim of this research is to describe a teaching strategy applied in the School of Civil and Building Engineering that incorporated CBA, Scoring and 4D Models. It describes a method to evaluate the best construction-flow option using 4D models and Lean Construction, based on the adaptation of CBA system and Scoring system. Likewise, we compare and discuss how it is best to combine the Scoring and Choosing by Advantages approaches. A CBA-Modified Scoring workshop was developed. Graduate students were responsible for the design and modeling of four different construction options in a mock-up project. Then a pull-planning meeting was developed, using CBA and Modified Scoring as tools to choose the best construction-flow alternative. An outline of the workshop, results, and lessons learned is presented.

2 THEORETICAL FRAMEWORK

2.1 Lean Construction and Transparency

The network of information and the hierarchical structure of order giving are identical in the classical organization theory, and transparency means a separation of both [14]. "Lack of process transparency increases the propensity to err, reduces the visibility of errors, and diminishes motivation for improvement." [8]. There is a correlation between a lack of transparency and elevated levels of corruption [15,16]. In construction industry, transparency is an essential strategy of the Government primary approaches to promote openness and reduce corruption and corrupt behavior [17]. A higher level of transparency in decision making increases the probability of spotting corruption [16].

Lean construction refers to the application and adaptation of the concepts and principles of the Toyota Production System (TPS) to construction; its focus is on reduction in waste, increase in value to the customer, and continuous improvement [18].

Since Laurie Koskela published his technical report TR72 in 1992, giving rise to the Lean Construction philosophy, this trend has evolved. According to Koskela [8], due to these traditional managerial principles, flow processes have not been controlled or improved in an orderly fashion; this has led to complex, uncertain, and confused flow processes, expansion of non-value-adding activities, and reduction of output value.

Practical approaches for enhanced transparency include making the process directly observable through appropriate layout and signage, rendering invisible attributes of the process visible through measurements, embodying process information in information systems, among others. Computerized systems often provide unique and superior solutions for process improvement; for example, the transparency of a process may be augmented by computer visualization and simulation. However, technical integration does not help much if the processes are otherwise not of high quality. More specifically, information technology may be used for automating specific conversions and sub flows, adding transparency and may allow for process redesign, leading to radical process simplification. There is ample evidence that through increasing process transparency, the efficiency of flow processes can be considerably and rapidly improved [8].

2.2 Choosing by Advantages (CBA)

The decision-making system known as Choosing by Advantages (CBA) examines the benefits of different alternatives to decide which among them is the best [5]. CBA employs a common vocabulary, which includes the following: (1) alternative: a possible option; (2) criterion: a mandatory decision rule or desired guideline established by the decision-makers; (3) attribute: a feature or quality of a particular option; (4) advantage: a benefit-conferring difference between two and only two attributes; (5) factor: an "umbrella" concept, which includes the other concepts in the process (criteria, attributes, advantages, importance, etc.); and (6) importance of an advantage: a degree of importance is assigned to each advantage for purposes of comparison. Usually, the most valued advantage is assigned a value of 100 or 1000, and other valuations are subordinated to it. CBA considers the cost separately from other factors and does not treat it as a criterion. Also, in the CBA system, only the advantages are factored in, i.e., a disadvantage associated with one alternative can only appear as an advantage of another [5,19].

It should be noted that in making the final decision, this method omits the rows from its matrix containing the advantages in which the alternatives obtain the same score. Depending on what is being decided, this could mean the loss of valuable information when looking at the final table of results. It should also be remembered that multicriteria matrices such as these can be used to analyze risks and compliance with legal regulations, among other elements.

Multi-criteria decision making (MCDM) methods are used to help teams to choose the best alternative for the decision maker considering multiple factors and presenting benefits in terms of transparency and capacity to reach consensus [20].

It can be concluded that a well-designed and executed MCDM can be used to comply with the objectives of the Lean Construction philosophy and increase the transparency in decision making processes.

This system follows a series of steps that allow a transparent and reproducible framework to support the tendering procedure and overcomes speculative bidder behavior [21]. First, the alternatives are identified by prequalification, then the stakeholders define the factors and the must/want criteria for each factor. In a second phase, the submitted alternatives and their attributes are gathered, and the advantages and importance of each advantage are decided. Finally, the cost is evaluated, and a decision is made [21].

CBA has been successfully applied to several construction management projects [1,2,22] and it possesses several benefits above the traditional methods, among them, Scoring [3,21,23]. On the other hand, CBA is generally applied between two and 10 alternatives, however, it has been recently applied in an experiment with one thousand design alternatives applying the Cluster Analysis or Clustering [4]. Clustering groups the few representative alternatives, based on the similarity of the characteristics and it applies the lineal regression to measure the level of precision of the assigned values [24]. When the 8 clusters were used it was proved that decisions were always consistent, and that a lineal correlation exists between the alternatives attributes graphics and the Importance of the advantages (IoA) [4].

2.3 The Scoring system

The Scoring system (weighted sum) is a decision-making method that employs the direct weighting of factors. It is carried out directly, and indicates the importance of each factor for the decision-maker [3]. The steps in this system are as follows: (1) identify the available alternatives; (2) identify factors and criteria for evaluation; (3) determine the weighting factors; (4) classify alternatives for each factor; and (5) calculate the "value" of each alternative and make the final decision [3,23]. In this system, advantages are not explicitly considered. If the factor weights add up to 100%, the system is called Weighting Rating and Calculating (WRC) [3,25,20]. WRC is a method that allows assessing multiple factors easily, but the bidders' differences may not be highlighted, since factors are weighted independently of the attributes [3]. Scoring is a common method used to evaluate proposals in the public sector [26,27]. This system has been used to make decisions in construction management [7,28,29], as well as being applied to the selection of (1) the design team [28,30]; (2) the building with the greatest modularity, standardization, and industrialization [7]; and (3) the building that best meets the design concepts in the LPDS system [28]. Such method is widely used in the AEC industry [2].

2.4 Last Planner System (LPS)

The LPS is a production-planning system designed to produce predictable work flow and rapid learning in programming, design, construction, and commissioning of projects [31, 32]. LPS has five elements (1) Master Scheduling: setting milestones and strategy; identification of long lead items; (2) Phase Pull Planning: specify handoffs; identify operational conflicts; (3) Make Work Ready Planning: look ahead planning to ensure that work is made ready for installation; and of re-planning as necessary; (4) Weekly Work Planning: commitments to perform work in a certain manner and a certain sequence; (5) Learning: measuring percentage of plan completed (PPC), deep dive into reasons for failure, developing and implementing lessons learned [31,33]. LPS is based on the idea that all planning is forecast, and forecasts are always wrong [34, 35]. All of this is illustrated in figure 1.

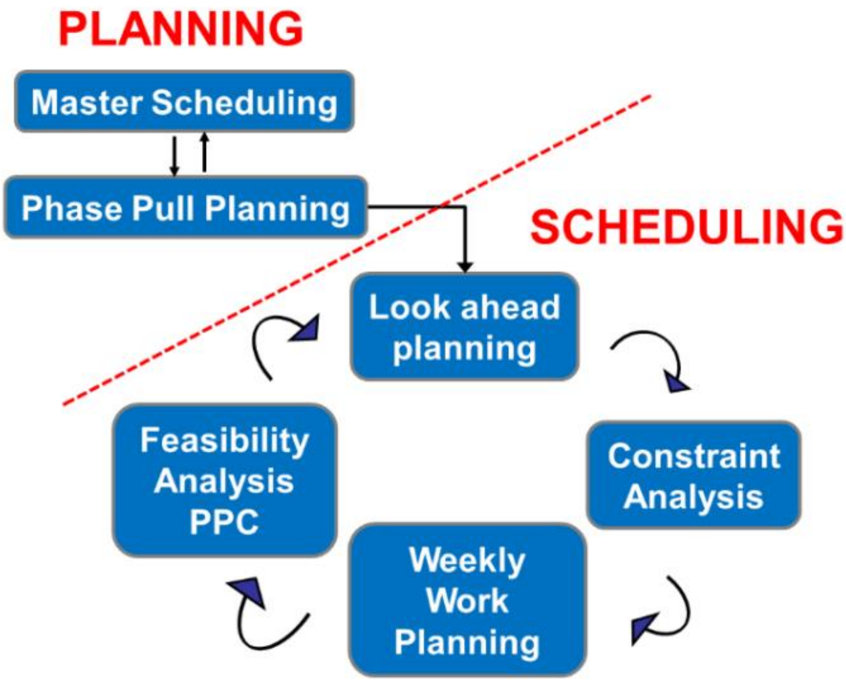

Fig. 1. *Last Planner System [33] (Adapted from [35])*

The challenge is to create a system with a steady rhythm (Takt-time) and design workstations to deliver on demand at a specific rate [36]. According to the LPS, "pull planning" is a technique to develop a production plan at any level of detail, such as during the structure phase in a residential building [37]. Pull planning is used to plan work, sequence activities, and collaboratively produce pull schedules [38]. In a residential building, each story is divided in a number of zones in which construction activities should flow at a steady rate. The quantities in the zones must be roughly the same, in order to maintain similar resource levels. Each trade spends a certain amount of time (Takt-time) in a zone in order to complete its work [39]. This allows the pull system to run smoothly.

It should be highlighted that a synergy exists between the CBA method and the Last Planner System. Both have a structured planning and programming system, are updated continually and the level of detail is increased as the moment of deciding is near. Likewise, the decision making is postponed until the last moment. This synergy is represented on figure 2.

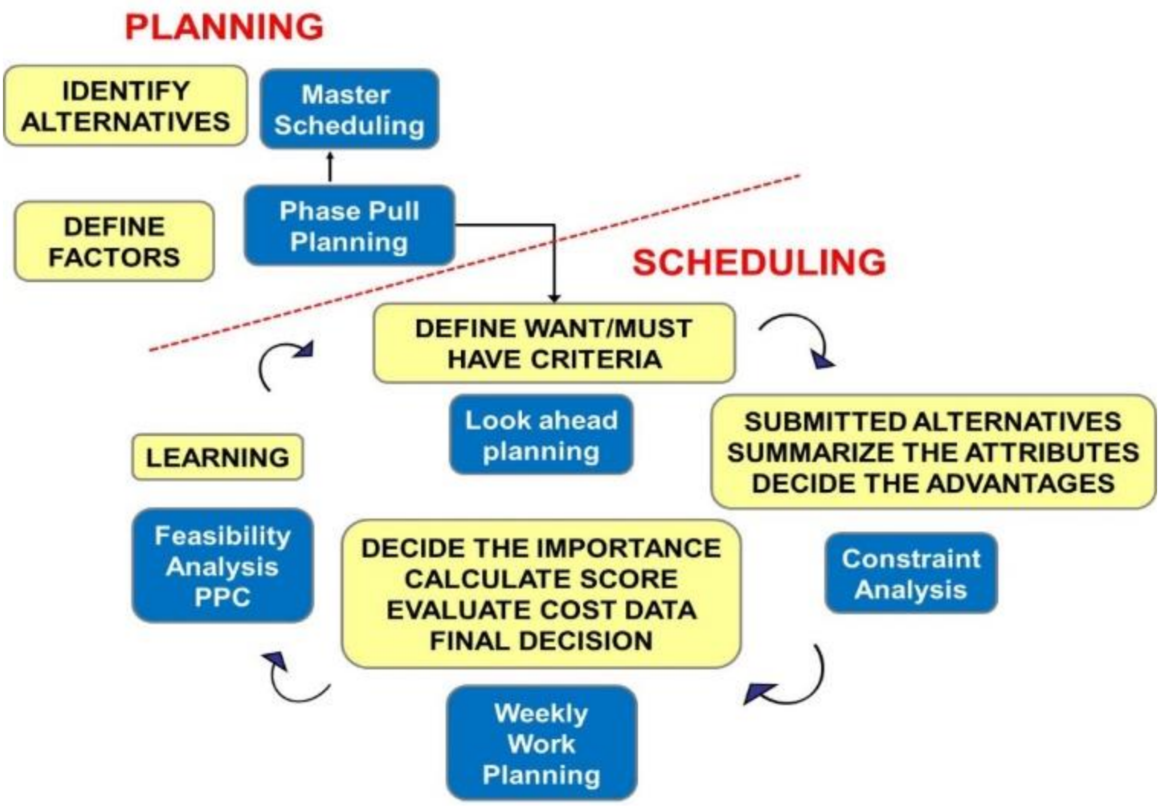

Fig. 2. *Synergy between the Last Planner System and CBA (Adapted from [20,35])*

2.5 BIM, Lean Construction and Transparency

BIM is a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation [40]. The result of BIM activity is a “building information model”. BIM tools are characterized by the ability to compile virtual models of buildings using machine-readable parametric objects that exhibit behavior commensurate with the need to design, analyze, and test a building design [41].

The level of development (LOD) of a BIM model can be divided in six categories according to the BIM forum. These categories start at LOD 100 with the graphic representation of the element, followed by the LOD 200 with the graphic representation of the element as a generic system, object, or assembly with approximate quantities, size, shape, location and orientation. A LOD 300 offers a graphic representation in terms of a specific system, object or assembly in terms of quality, size, shape, location and orientation. As for the LOD 350 it includes information regarding the interfaces with other building systems. LOD 400 includes information about detailing, fabrication, assembly and installation. Finally, LOD 500 presents a model element as a field verified representation in terms of size, shape, location, quality and orientation [42]

BIM provides “the basis for new construction capabilities and changes in the roles and relationships among a project team. When implemented appropriately, BIM facilitates a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration." [40]. This is evidently aligned with the objectives of the Lean construction philosophy.

Lean construction practices can be adopted without BIM, and BIM can be adopted without lean construction, however, the full potential for improvement of construction projects can only be achieved when their adoption is integrated [43].

This synergy exists because of the interaction between Lean and BIM in the development of the Relevant Lean Construction Principles. The many positive interactions include: (1) Reduce Batch Sizes; (2) Use Visual Management; (3) Design the Production System for Flow and Value; (4) Ensure Comprehensive Requirements Capture; (5) Focus on Concept Selection; (6) Decide by Consensus, Consider All Options; among others. The sheer number of the constructive interaction mechanisms identified strongly supports the argument of a significant synergy between BIM and lean [43]. If using Lean of BIM separately increases transparency, it is evident that implementing them in an integrated manner will increase the transparency of the process of the life cycle phase where they are applied.

The design phase in the construction life-cycle is an area where this synergy is most apparent. The BIM capabilities also include better visualization of the efficient modeling for constructability, powerful simulation options and advanced pre-construction analyses (e.g. integration of BIM models with schedules and costs or 4D BIM and 5D BIM respectively) [44,45].

BIM 3D and 4D models appear to be a means of improving visualization and comprehension early in the construction planning stage [13]. A 4D model allows planners to visualize the construction process, identify construction constraints, retrieve quantity take-off information, and make iterations as needed. It has also been proven that the integration of LPS and BIM generates larger benefits in the planning and management of construction projects [46,47].

It can be concluded that by implementing the Lean Construction philosophy a 4D model can be used preliminary on the Lean Design phase to evaluate the best construction-flow option. It is also inferred that after implementing the Last Planner System, it is extremely important to use the 4D model to evaluate the best construction-flow option in the pull planning phase meetings. On this paper a methodology for this evaluation using BIM 4D and the multicriteria tools CBA and modified is proposed, enhancing the transparency of these tools. The proposed simulation may be applied when the Lean Design or LPS are implemented.

2.6 Modularity, standardization, and industrialization

These concepts are closely related but need to be evaluated independently [7].

Modularity: Modular coordination is a standardization method based on dimensional coordination to measure the components of the building and locate them within a reference system [48]. Prefabrication and industrial production use this dimensional coordination to optimize the number of sizes for a particular component [49], reduce waste in situ, and facilitate the interchangeability of components [50].

Standardization: Standardization consists in fabricating products and processes with similar characteristics. Its goal is to make repeated models that fulfill the same function, thereby simplifying and reducing the production cost for construction components, which can be made industrially. This process is made easier if modularity was implemented previously [7].

Industrialization: Industrialization refers to the replacement of skilled workers with machines. Its aim is to produce products by means of a reduced labor force, machines used by specialized workers, or automated technology [51].

From the above, we can conclude that if a building is better modulated, standardized, and industrialized, it will generate less waste both during construction and in the suppliers' factories. Likewise, it will be possible to manage the labor force more efficiently, thereby cutting down the amount of resources used. All this would contribute decisively to making the building more sustainable.

	Profession	Last position	Experience in private construction projects (Years)	Experience in public construction projects (Years)	Experience in structural design (Years)	Experience in facility management (Years)	Experience in BIM modeling (Years)
1	**Civil Eng.**	Project supervisor	8	10	2	2	0.5
2	**Mechanical Eng.**	Metalworking project manager	2				1
3	**Civil Eng.**	BIM coordinator	2.5				2.5
4	**Civil Eng.**	BIM assistant	1				1
5	**Civil Eng.**	Road maintenance		2	1	2	0.5
6	**Civil Eng.**	Structural design engineer	1		2		0.5
7	**Civil Eng.**	Project manager	5		2		2
8	**Civil Eng.**	Project supervisor	5	8	1.5	2	0.5
9	**Civil Eng.**	Facility manager		1		2	0.5
10	**Civil Eng.**	BIM assistant	1				1

Table 1. *CV of the simulated stakeholders*

3 METHODOLOGY

Recent research has used CBA to choose the best option for globally sustainable materials [1]. This research begins with the notion that these materials have already been chosen and a decision needs to be made to choose best workflow option that makes the project more sustainable, with a smaller amount of waste, among them, consumption of energy, residue, etc.

The proposed methodology consists of: (1) Adaptation of CBA to Scoring Workshop; (2) Application of CBA using lineal relations in the graphics of Alternatives Attributes vs. The

Importance of Advantages (IoA); (3) Survey to the stakeholders and validation of the obtained results.

A total of 10 graduate students participated in the decision- making experiment. Students were familiar with the CBA method, since they had previously undertaken CBA simulations. The workshop was conducted by one of the researchers.

The students simulated construction-planning stakeholders. Table 1 shows the years of experience for each of the participants, we can note that the range is ideal, since they have varied experience in different fields.

The mock-up project consisted of a four-story residential building with a footprint area of 950 m2. The structural system is of reinforced concrete; its elements include footings, columns, shear walls, beams, and slabs.

The graduate students developed BIM models on Revit of the structure (LOD 300) and presented a series of alternatives for sectorization. Figure 3 represent proposals of 3 and 5 sector respectively.

The project was modeled using Revit and Navisworks. Before the workshop, students were assigned the tasks of (1) developing the 3D model; (2) developing a pull-planning schedule for each alternative; and (3) developing a 4D model for each alternative.

Figure 3 shows two examples of BIM models analyzed on the workshop.

(a) (b)

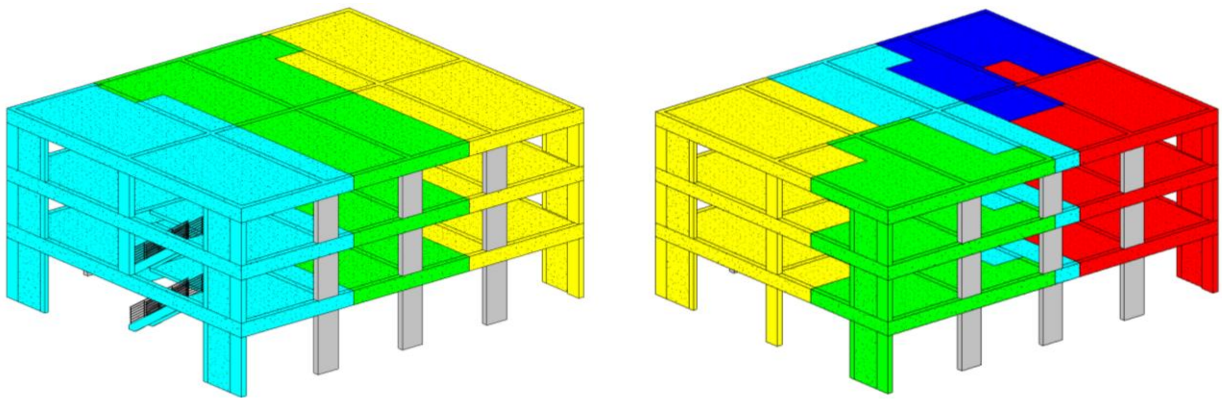

Fig. 3. *(a) BIM model: 3 zones – 3 days per story; (b) BIM model: 5 zones – 4 days per story*

When implementing the CBA method, the following steps were adapted from [4,52,53].

- Step 1: Identify alternatives: Stakeholders identify several construction alternatives.
- Step 2: Define factors: Stakeholders define factors which will help to differentiate alternatives.
- Step 3: Define want/must have criteria for each factor
- Step 4: Submitted alternatives: Stakeholders submit the different construction options.
- Step 5: Summarize the attributes of each alternative: Stakeholders summarize the attributes of each characteristic.
- Step 6: Decide the advantages of each alternative: Stakeholders choose the least-

preferred alternative for each option and then state the advantage of each alternative compared to that least-preferred choice.

- Step 7: Decide the importance of each advantage: Stakeholders decide collaboratively on the importance of each advantage.
- Step 8: Calculate score of each alternative: Once all the factors have been assessed for each alternative, the scores are summed up for each alternative.
- Step 9: Evaluate cost data: If applicable, evaluate cost data.
- Step 10: Final decision: The higher the score, the more advantageous the alternative.

3.1 Adaptation of CBA to Scoring Workshop

The workshop will formally use Modified Scoring as a method for choosing the best construction-flow option. As such, the factors and criteria were designed by researchers. Factors were catalogued in a number of categories and a criterion was selected for each factor.

When implementing the Modified Scoring method, the following steps are followed. For the case study, these steps are adapted from [1,21,28].

<u>Step 1: IDENTIFY ALTERNATIVES</u>

Stakeholders identify several construction alternatives. For each alternative, a takt-time schedule and a 4D model are developed. The researchers choose four different construction options to be modeled and analyzed by students. A LOD 300 is used, this way, 4 clusters of 10 similar alternatives are obtained.

<u>Step 2: DEFINE FACTORS</u>

Stakeholders define factors which will help to differentiate alternatives. Said factors are catalogued under the headings of modularity, standardization, flow, quality, and logistics. For example, in the modularity category, a factor is defined as “amount of horizontal formwork per zone.”

<u>Step 3: DEFINE WANT/MUST HAVE CRITERIA FOR EACH FACTOR</u>

Stakeholders define the must and want criteria for each factor. For example, for the factor “amount of horizontal formwork per zone,” the want criterion is, “the more similar the quantities are between zones, the better.”

Step 4: SUMMARIZE THE ATTRIBUTES OF EACH ALTERNATIVE

Stakeholders summarize the attributes of each characteristic. For example, alternative 1 has up to a 5% difference in quantity take-off between zones. Similarly, option 2, option 3, and option 4 have up to 10%, 15%, and 20% quantity take-offs, respectively.

<u>Step 5: DECIDE THE ADVANTAGES OF EACH ALTERNATIVE</u>

Stakeholders choose the least-preferred alternative for each option and then state the advantage of each alternative compared to that least-preferred choice. Here, alternative 4 is the least-preferred, as it has 20% difference between zones. The advantage of alternative 1 compared to alternative 4 is therefore 15%. Similarly, the advantage of alternative 2 compared to alternative 4 is 10%.

<u>Step 6: DECIDE THE WEIGHT (IMPORTANCE) OF EACH ADVANTAGE</u>

Stakeholders decide collaboratively on the weight of each advantage. They first identify the most important advantage for each factor and then select the paramount advantage. The paramount advantage is scored on a scale of 100 (or any other number) and the advantages of other factors are scored decreasingly (90, 80, 70, etc.) along the same scale. Points are then assigned to the other advantages, with a score of 0 for the least-preferred in each factor.

Step 7: SUBMITTED ALTERNATIVES

Stakeholders choose and submit the best four different construction options, one per cluster.

Step 8: RATE ALTERNATIVES FOR EACH ADVANTAGE

Once all the factors have been assessed for each alternative, the scores are summed up for each alternative.

Step 9: CALCULATE SCORE OF EACH ALTERNATIVE

Once all the factors have been assessed for each alternative, the scores are summed up for each alternative.

Step 10: EVALUATE COST DATA

If applicable, evaluate cost data. The research considers that construction-flow options are defined to improve productivity and increased transparency in the construction-site layout. Even though the implementation cost does not vary among the alternatives, the best flow-option will have an impact on construction costs [36].

Step 11: FINAL DECISION

The higher the score, the more advantageous the alternative.

Table 2 shows a comparative summary between Scoring, CBA and a proposal of modified scoring methods.

With the obtained results, using both methods, the values and decisions made by the stakeholders are analyzed. Likewise, a final survey will be taken to gather the most important opinions of the participants.

Step	Scoring	CBA	Modified scoring
1	Identify alternatives	Identify alternatives	Identify alternatives
2	Identify factors and criteria. Cost can be used as a factor	Define factors	Define factors
3	Weight factors.	Define want/must have criteria for each factor	Define want/must have criteria for each factor
4	Submitted alternatives	Submitted alternatives	Summarize the attributes of each alternative
5	Rate alternatives for each factor	Summarize the attributes of each alternative	Decide the advantages of each alternative
6	Calculate score of each alternative	Decide the advantages of each alternative	Decide the weight of each advantage
7	Evaluate cost, if necessary	Decide the importance of each advantage	Submitted alternatives
8	Evaluate score and cost if applicable	Calculate score of each alternative	Rate alternatives for each advantage
9	Final decision	Evaluate cost data	Calculate score of each alternative
10	---	Final decision	Evaluate cost data
11	---	---	Final decision

Table 2. *Scoring, CBA and Scoring with additional improvements from the CBA*

3.2 Application of CBA using lineal relations in the graphics of Alternatives Attributes vs. The Importance of Advantages (IoA)

As it was previously indicated, Arroyo et al. proved that decisions were consistent and that there exists a lineal correlation between the graphics of the Attributes vs. Importance of advantages (IoA) by using 8 clusters of numerous design alternatives [4]. In our experiment, the 4 four clusters of 10 alternatives each are more uniform, since they are only differenced by the constructive sequence and takt-time. For this reason, we propose that in cases like this, the lineal relation between Attributes and IoA may be assumed. Consequently, step 7 of CBA, where the importance of each advantage is determined, for each attribute it will be determined: (1) the IoA of the greatest advantage, the worst advantage maintains the value of cero; (2) The values of the intermediate IoA with lineal relations. This proposal would be a useful tool to automate the process of obtaining the scores, giving clear rules and reducing the time of decision making sessions.

3.3. Survey

The survey consists of questions regarding the use of CBA and Scoring methods. The answers are in a scale of Likert from 1 to 5 were 1 is definitely disagree, 2 is mostly disagree, 3 is neither agree or disagree, 4 is mostly agree, and 5 is definitely agree.

4 RESULTS AND DISCUSSION

The fourteen factors and criteria proposed by [22] were discussed for the alternatives. Table 3 shows the factors and criteria for both experiments.

4.1 Adaptation of CBA to Scoring Workshop

During the pull-planning meeting, students first made presentations on their 4D models and construction schedules. Second, they were given the list of categories, factors, and criteria to use in choosing the best construction-flow alternative. According to the method, factors and criteria should be decided by stakeholders. However, it was agreed to fix this stage for the convenience of the research and due to time constraints. At this point, stages 1 to 3 described in section 3.2 were completed. Third, the team described the attributes of each alternative, and then highlighted the advantage of each alterative compared to the least-preferred alternative for each factor. Fourth, the team decided the weight (importance) for each factor, and then selected the paramount advantage. The paramount advantage was assigned a score of 10, and the other important advantages for other factors were scored decreasingly in a collaborative effort. For example, the most important alternative in factor 1.4 was scored at 9.4, and the most important alternative in factor 4.4 was scored at 7.9. Fifth, the team assigned rates for all the alternatives, with a score of 0 for the least-preferred option in each factor. Finally, the team summed up all the scores for each alternative, as shown on table 4.

The alternative with the highest score is alternative 3 with a score of 938.13, on second, third and fourth place are alternative 4, 2 and 1 respectively. Alternative 1 of 3 zones on 3 days obtained the lowest score of 314.28. Alternative 3 obtained higher scores on the factors modularity and construction flow.

Alternatively, the values can be rounded off and placed on the table before processing the information and choosing the winner. As it was expected, on this case results are very similar as it is shown on table 5.

Category	Id	Factors and Criteria
Modularity	1.1	F1.1: Horizontal formwork per zone
		C1.1: The more similar amount of formwork, the better
	1.2	F1.2: Vertical formwork per zone
		C1.2: The more similar amount of formwork, the better
	1.3	F1.3: Horizontal concrete per zone
		C1.3: The more similar amount of concrete, the better
	1.4	F1.4: Vertical concrete per zone
		C1.4: The more similar amount of concrete, the better
Standardization	2.1	F2.1: Horizontal formwork standardization per story
		C2.1: Running only one set of formworks per story is better
	2.2.	F2.2: Vertical formwork standardization per story
		C2.2: Running only one set of formworks across zones is better
Industrialization	3.1	F3.1: Construction process industrialization
		C3.1: The greater the amount of industrialization, the better
Construction flow	4.1	F4.1: Slab concrete pouring
		C4.1: Daily is better
	4.2	F4.2: Clashes in consecutive stories
		C4.2: The fewer the number of clashes, the better
	4.3	F4.3: Labor required per zone
		C4.3: The more constant, the better
	4.4	F4.4: Construction lead time per story
		C4.4: The less the better
	4.5	F4.5: Working hours
		C4.5: The flow allows crews to be planned 8 hours daily
Quality	5.1	F5.1: Mep systems quality assurance
		C5.1: The flow allows plumbing systems to be tested 24 hours, the better
	5.2	F5.2: Slab division between zones
		C5.2: Division line is at one third of the length of any span, the better

Table 3. *Factors and criteria for both experiments (Adapted from [22])*

Category	Id	Factors and Criteria	Attributes	Weights (W) and Advantages	Alternative 1 (3 zones - 3 days)			Alternative 2 (4 zones - 3 days)			Alternative 3 (4 zones - 4 days)			Alternative 4 (5 zones - 4 days)		
						Rate (R)	W x R		Rate (R)	W x R		Rate (R)	W x R		Rate (R)	W x R
Modularity	1.1	F1.1	%difference	7.4	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.1		Adv: 10%	Adv:	0	0	Adv: 10%	10	74	Adv: 10%	10	74	Adv: 5%	7.9	58.46
	1.2	F1.2	%difference	7.5	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.2		Adv: 10%	Adv:	0	0	Adv: 10%	10	75	Adv: 10%	10	75	Adv: 5%	7.9	59.25
	1.3	F1.3	%difference	8.6	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.3		Adv: 10%	Adv:	0	0	Adv: 10%	10	86	Adv: 10%	10	86	Adv: 5%	7.9	67.94
	1.4	F1.4	%difference	9.4	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.4		Adv: 10%	Adv:	0	0	Adv: 10%	10	94	Adv: 10%	10	94	Adv: 5%	7.9	74.26
Standardization	2.1	F2.1	Set	9.1	Att: 2 sets			Att: 1.5 set			Att: 1.5 set			Att: 1 set		
		C2.1		Adv: 0.50 set less	Adv:	0	0	Adv: 0.33 set less	7.8	70.98	Adv: 0.33 set less	7.8	70.98	Adv: 0.50 set less	10	91
	2.2.	F2.2	Set	4.1	Att: 1 set			Att: 1 set			Att: 1 set			Att: 1 set		
		C2.2		Adv: 1 set	Adv:	10	41	Adv:	10	41	Adv:	10	41	Adv:	10	41
Industrialization	3.1	F3.1	Level	1.1	Att: level 1			Att: level 1			Att: level 1			Att: level 1		
		C3.1		Adv: level 1	Adv:	10	11	Adv:	10	11	Adv:	10	11	Adv:	10	11
Construction flow	4.1	F4.1	Day	8.2	Att: daily			Att: daily			Att: daily			Att: daily		
		C5.1		Adv: daily	Adv:	10	82	Adv:	10	82	Adv:	10	82	Adv:	10	82
	4.2	F4.2	Clash	10	Att: 2 clashes			Att: 1 clash			Att: 0 clashes			Att: 0 clashes		
		C4.2		Adv: 0 clashes	Adv:	0	0	Adv: 1 clash less	6.1	61	Adv: 2 clashes less	10	100	Adv: 2 clashes less	10	100
	4.3	F4.3	%difference	6.1	Att: 20% diff			Att: 22% diff			Att: 15% diff			Att: 17% diff		
		C4.3		Adv: 7%	Adv: 2	4.8	29.28	Adv:	0	0	Adv: 7%	10	61	Adv: 5%	7.9	48.19
	4.4	F4.4	Day	7.9	Att: 5 days			Att: 7 days			Att: 7 days			Att: 9 days		
		C4.4		Adv: 4 days	Adv: 4 days	10	79	Adv: 2 days	7.9	62.41	Adv: 2 days	7.9	62.41	Adv:	0	0
	4.5	F4.5	Hour	6.7	Att: 11 hours			Att: 9 hours			Att: 9 hours			Att: 8 hours		
		C4.5		Adv: 3 hours	Adv:	0	0	Adv: 2 hours	6.8	45.56	Adv: 2 hours	6.8	45.56	Adv: 3 hours	10	67
Quality	5.1	F5.1	Hour	7.8	Att: 8 hours			Att: 16 hours			Att: 16 hours			Att: 24 hours		
		C5.1		Adv: 16 hours	Adv:	0	0	Adv: 8 hours	8.1	63.18	Adv: 8 hours	8.1	63.18	Adv: 16 hours	10	78
	5.2	F5.2	Yes/no	7.2	Att: yes			Att: yes			Att: yes			Att: yes		
		C5.2		Adv: yes	Adv:	10	72	Adv:	10	72	Adv:	10	72	Adv:	10	72
		Grand total importance of advantage					**314.28**			**838.13**			**938.13**			**850.1**

Table 4. *Modified Scoring Tabular Results (No Round off)*

Category	Id	Factors and Criteria	Attributes	Weights (W) and Advantages	Alternative 1 (3 zones - 3 days)			Alternative 2 (4 zones - 3 days)			Alternative 3 (4 zones - 4 days)			Alternative 4 (5 zones - 4 days)		
						Rate (R)	W x R		Rate (R)	W x R		Rate (R)	W x R		Rate (R)	W x R
Modularity	1.1	F1.1	%difference	7	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.1		Adv: 10%	Adv:	0	0	Adv: 10%	10	70	Adv: 10%	10	70	Adv: 5%	8	56
	1.2	F1.2	%difference	8	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.2		Adv: 10%	Adv:	0	0	Adv: 10%	10	80	Adv: 10%	10	80	Adv: 5%	8	64
	1.3	F1.3	%difference	9	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.3		Adv: 10%	Adv:	0	0	Adv: 10%	10	90	Adv: 10%	10	90	Adv: 5%	8	72
	1.4	F1.4	%difference	9	Att: 20% diff			Att: 10% diff			Att: 10% diff			Att: 15% diff		
		C1.4		Adv: 10%	Adv:	0	0	Adv: 10%	10	90	Adv: 10%	10	90	Adv: 5%	8	72
Standardization	2.1	F2.1	Set	9	Att: 2 sets			Att: 1.5 set			Att: 1.5 set			Att: 1 set		
		C2.1		Adv: 0.50 set less	Adv:	0	0	Adv: 0.33 set less	8	72	Adv: 0.33 set less	8	72	Adv: 0.50 set less	10	90
	2.2 .	F2.2	Set	4	Att: 1 set			Att: 1 set			Att: 1 set			Att: 1 set		
		C2.2		Adv: 1 set	Adv:	10	40	Adv:	10	40	Adv:	10	40	Adv:	10	40
Industrialization	3.1	F3.1	Level	1	Att: level 1			Att: level 1			Att: level 1			Att: level 1		
		C3.1		Adv: level 1	Adv:	10	10	Adv:	10	10	Adv:	10	10	Adv:	10	10
Construction flow	4.1	F4.1	Day	8	Att: daily			Att: daily			Att: daily			Att: daily		
		C5.1		Adv: daily	Adv:	10	80	Adv:	10	80	Adv:	10	80	Adv:	10	80
	4.2	F4.2	Clash	10	Att: 2 clashes			Att: 1 clash			Att: 0 clashes			Att: 0 clashes		
		C4.2		Adv: 0 clashes	Adv:	0	0	Adv: 1 clash less	6	60	Adv: 2 clashes less	10	100	Adv: 2 clashes less	10	100
	4.3	F4.3	%difference	6	Att: 20% diff			Att: 22% diff			Att: 15% diff			Att: 17% diff		
		C4.3		Adv: 7%	Adv: 2	5	30	Adv:	0	0	Adv: 7%	10	60	Adv: 5%	8	48
	4.4	F4.4	Day	8	Att: 5 days			Att: 7 days			Att: 7 days			Att: 9 days		
		C4.4		Adv: 4 days	Adv: 4 days	10	80	Adv: 2 days	8	64	Adv: 2 days	8	64	Adv:	0	0
	4.5	F4.5	Hour	7	Att: 11 hours			Att: 9 hours			Att: 9 hours			Att: 8 hours		
		C4.5		Adv: 3 hours	Adv:	0	0	Adv: 2 hours	7	49	Adv: 2 hours	7	49	Adv: 3 hours	10	70
Quality	5.1	F5.1	Hour	8	Att: 8 hours			Att: 16 hours			Att: 16 hours			Att: 24 hours		
		C5.1		Adv: 16 hours	Adv:	0	0	Adv: 8 hours	8	64	Adv: 8 hours	8	64	Adv: 16 hours	10	80
	5.2	F5.2	Yes/no	7	Att: yes			Att: yes			Att: yes			Att: yes		
		C5.2		Adv: yes	Adv:	10	70	Adv:	10	70	Adv:	10	70	Adv:	10	70
		Grand total importance of advantage					**310**			**839**			**939**			**852**

***Table 5**. Modified Scoring Tabular Results (with round off)*

4.2 Application of CBA using lineal relations in graphics of Attribute of Alternatives vs. Importance of Advantages (IoA)

As a part of our methodology, we are not eliminating the factors that have draws. This will allow the comparison between the CBA and Scoring results. According to the variant of the proposed method, lineal relations between the Attributes and the IoA have been assumed, in other words, for each attribute the IoA of the greater advantage was determined, for the worst advantage the value of cero was maintained and the value of the intermediate IoA with lineal relations was calculated. In table 6 the results are shown. The proposal of linearity will be a useful tool to automate the process of obtaining the scores, giving clear rules for the stakeholders and reducing the time of decision making sessions. Furthermore, in figures 4 and 5 the graphics of lineal relations of attributes vertical concrete per zone and working hours and the corresponding IoA's are shown.

Category	Id	Factors and Criteria	Attributes	Alternative 1 (3 zones - 3 days)		Alternative 2 (4 zones - 3 days)		Alternative 3 (4 zones - 4 days)		Alternative 4 (5 zones - 4 days)	
	1.1	F1.1	%difference	Att: 20% diff		Att: 10% diff		Att: 10% diff		Att: 15% diff	
		C1.1		Adv:	0	Adv: 10%	75	Adv: 10%	75	Adv: 5%	37.5
	1.2	F1.2	%difference	Att: 20% diff		Att: 10% diff		Att: 10% diff		Att: 15% diff	
		C1.2		Adv:	0	Adv: 10%	75	Adv: 10%	75	Adv: 5%	37.5
Modularity	1.3	F1.3	%difference	Att: 20% diff		Att: 10% diff		Att: 10% diff		Att: 15% diff	
		C1.3		Adv:	0	Adv: 10%	85	Adv: 10%	85	Adv: 5%	42.5
	1.4	F1.4	%difference	Att: 20% diff		Att: 10% diff		Att: 10% diff		Att: 15% diff	
		C1.4		Adv:	0	Adv: 10%	95	Adv: 10%	95	Adv: 5%	47.5
	2.1	F2.1	Set	Att: 2 sets		Att: 1.5 set		Att: 1.5 set		Att: 1 set	
		C2.1		Adv:	0	Adv: 0.33 set less	45	Adv: 0.33 set less	45	Adv: 0.50 set less	90
Standardization	2.2	F2.2	Set	Att: 1 set		Att: 1 set		Att: 1 set		Att: 1 set	
		C2.2		Adv:	45	Adv:	45	Adv:	45	Adv:	45
Industrialization	3.1	F3.1	Level	Att: level 1		Att: level 1		Att: level 1		Att: level 1	
		C3.1		Adv:	10	Adv:	10	Adv:	10	Adv:	10
	4.1	F4.1	Day	Att: daily		Att: daily		Att: daily		Att: daily	
		C5.1		Adv:	80	Adv:	80	Adv:	80	Adv:	80
	4.2	F4.2	Clash	Att: 2 clashes		Att: 1 clash		Att: 0 clashes		Att: 0 clashes	
		C4.2		Adv:	0	Adv: 1 clash less	50	Adv: 2 clashes less	100	Adv: 2 clashes less	100
Construction flow	4.3	F4.3	%difference	Att: 20% diff		Att: 22% diff		Att: 15% diff		Att: 17% diff	
		C4.3		Adv: 2	17	Adv:	0	Adv: 7%	60	Adv: 5%	34
	4.4	F4.4	Day	Att: 5 days		Att: 7 days		Att: 7 days		Att: 9 days	
		C4.4		Adv: 4 days	80	Adv: 2 days	40	Adv: 2 days	40	Adv:	0
	4.5	F4.5	Hour	Att: 11 hours		Att: 9 hours		Att: 9 hours		Att: 8 hours	
		C4.5		Adv:	0	Adv: 2 hours	43	Adv: 2 hours	43	Adv: 3 hours	65
	5.1	F5.1	Hour	Att: 8 hours		Att: 16 hours		Att: 16 hours		Att: 24 hours	
Quality		C5.1		Adv:	0	Adv: 8 hours	40	Adv: 8 hours	40	Adv: 16 hours	80
	5.2	F5.2	Yes/no	Att: yes		Att: yes		Att: yes		Att: yes	
		C5.2		Adv:	70	Adv:	70	Adv:	70	Adv:	70
		Grand total importance of advantage			**302**		**753**		**863**		**739**

Table 6. *CBA tabular results using linear relations*

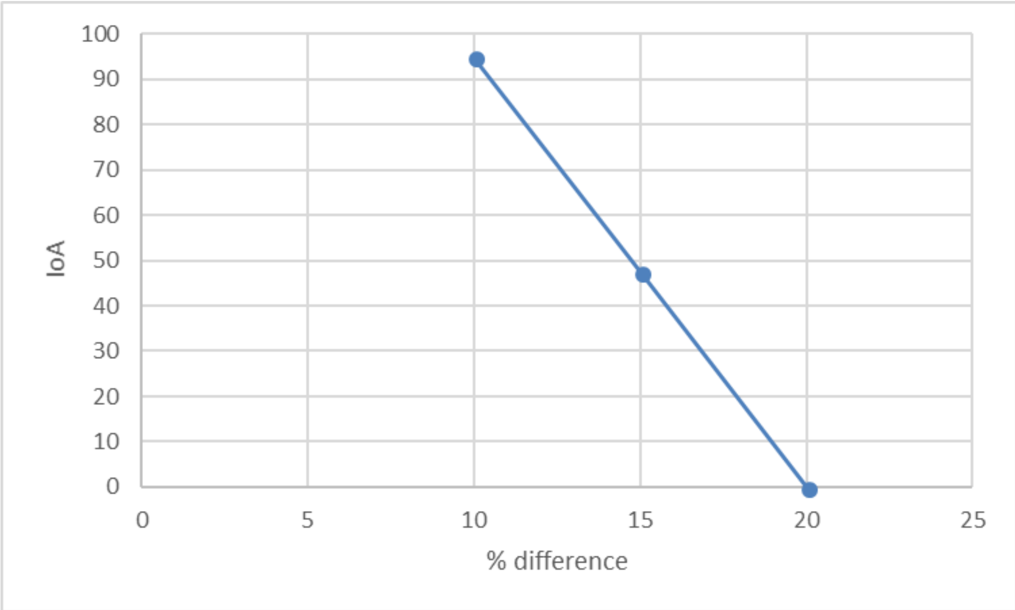

Fig. 4. *Lineal relation between IoA and attributes of vertical concrete per zone*

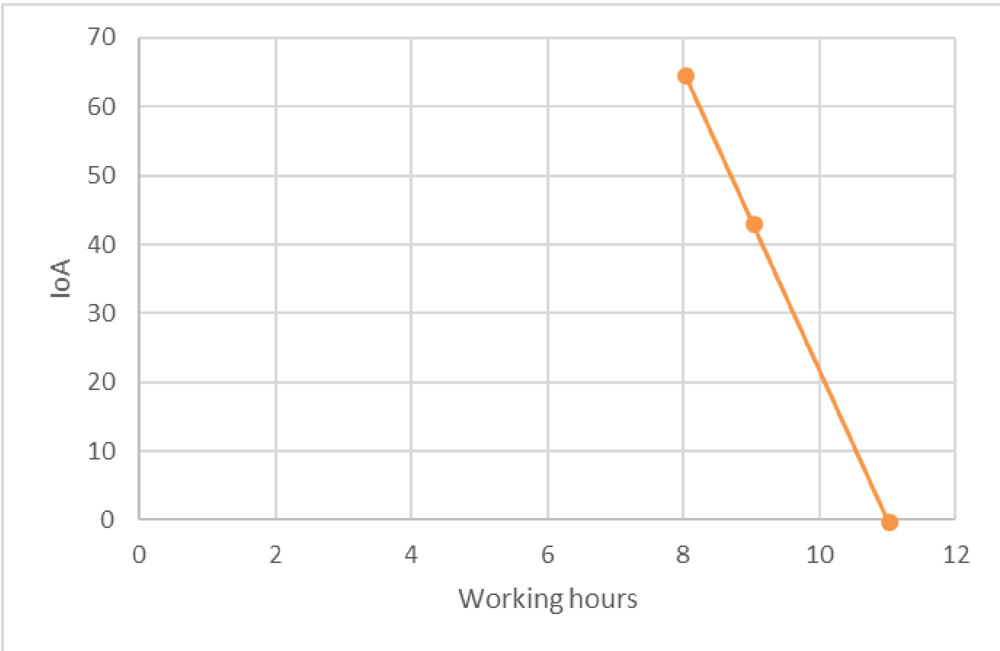

Fig. 5. *Lineal relation between IoA and attributes of working hours*

Category	Id	Factors And Criteria	CBA				Modified Scoring (No round off)				Modified Scoring (with round off)			
			Alt 1	Alt 2	Alt 3	Alt 4	Alt 1	Alt 2	Alt 3	Alt 4	Alt 1	Alt 2	Alt 3	Alt 4
			Imp.	Imp.	Imp.	Imp.	WxR	WxR	WxR	WxR	WxR	WxR	WxR	WxR
Modularity	1.1	F1.1												
		C1.1	0	75	75	37.5	0	74	74	58.46	0	70	70	56
	1.2	F1.2												
		C1.2	0	75	75	37.5	0	75	75	59.25	0	80	80	64
	1.3	F1.3												
		C1.3	0	85	85	42.5	0	86	86	67.94	0	90	90	72
	1.4	F1.4												
		C1.4	0	95	95	47.5	0	94	94	74.26	0	90	90	72
Standardization	2.1	F2.1												
		C2.1	0	45	45	90	0	70.98	70.98	91	0	72	72	90
	2.2.	F2.2												
		C2.2	45	45	45	45	41	41	41	41	40	40	40	40
Industrialization	3.1	F3.1												
		C3.1	10	10	10	10	11	11	11	11	10	10	10	10
Construction flow	4.1	F4.1												
		C5.1	80	80	80	80	82	82	82	82	80	80	80	80
	4.2	F4.2												
		C4.2	0	50	100	100	0	61	100	100	0	60	100	100
	4.3	F4.3												
		C4.3	17	0	60	34	29.28	0	61	48.19	30	0	60	48
	4.4	F4.4												
		C4.4	80	40	40	0	79	62.41	62.41	0	80	64	64	0
	4.5	F4.5												
		C4.5	0	43	43	65	0	45.56	45.56	67	0	49	49	70
Quality	5.1	F5.1												
		C5.1	0	40	40	80	0	63.18	63.18	78	0	64	64	80
	5.2	F5.2												
		C5.2	70	70	70	70	72	72	72	72	70	70	70	70
		Grand total importance of advantage	**302**	**753**	**863**	**739**	**314.28**	**838.13**	**938.13**	**850.1**	**310**	**839**	**939**	**852**

Table 7*. Comparing the results of CBA and Scoring method*

4.3. Survey

Figure 6 show the results of the survey performed on the participants. The survey consisted of 17 questions regarding the use of CBA and Scoring method. The answers were in a scale of Likert from 1 to 5 were 1 is definitely disagree, 2 is mostly disagree, 3 is neither agree or disagree, 4 is mostly agree, and 5 is definitely agree.

Students scored each question on the Likert Scale from 1 to 5. A summary appears below.

- All students gave only the highest scores (4-Mostly Agree and 5-Definitely Agree) to the following questions. The extreme values were (ix) (Mean =4.90, STD = 0.32) and (viii) (Mean = 4.10, STD = 0.57).
  - i. CBA is a structured MCDM that includes planning, programming, and, finally, the date that the decision is made (The last moment that stakeholders are responsible for). The 4D model allowed for improved visualization of the construction zones (locations).
  - ii. CBA has a planning system structured similar to The Last Planner System.
  - iii. Scoring can be modified so that the advantage is added following the sequence of CBA for planning, programming, and, finally, the date the decision is made.
  - iv. When applied simultaneously with the same stakeholders modified scoring can be used to verify the results of CBA.
  - v. When applied simultaneously with the same stakeholders modified CBA can be used to verify the results of Modified Scoring.
  - vi. When applied with the same stakeholders, any of the methods (CBA or Modified Scoring) can be used and the same decision will be obtained.
  - vii. CBA method is transparent.
  - viii. Modified Scoring is transparent.
  - ix. The workshop accomplished the objective of simulating a decision using CBA.
  - x. The workshop accomplished the objective of simulating a decision using Modified Scoring.
  - xi. The workshop accomplished the objective simulating a decision comparing CBA and Modified Scoring.
  - xii. Using BIM helped the transparency of the decision making.
  - xiii. If it's mandatory to use Scoring to determine the evaluation formula of providers for a project or public service using Modified Scoring with the advantage is a transparent method.
  - xiv. If we use Modified Scoring with the advantage to assign the scores of the alternatives in the selection of a project or public service is a transparent method.
  - xv. Using CBA to evaluate providers for a project or public service is a transparent method.

- The vast majority agreed with the following:
  - i. Using BIM helped detecting incongruencies in the scores and rectifying them.
  - ii. Using BIM helped eliminate the influence factor between stakeholders

- Finally, we asked one interrelated questions and obtained the following result:

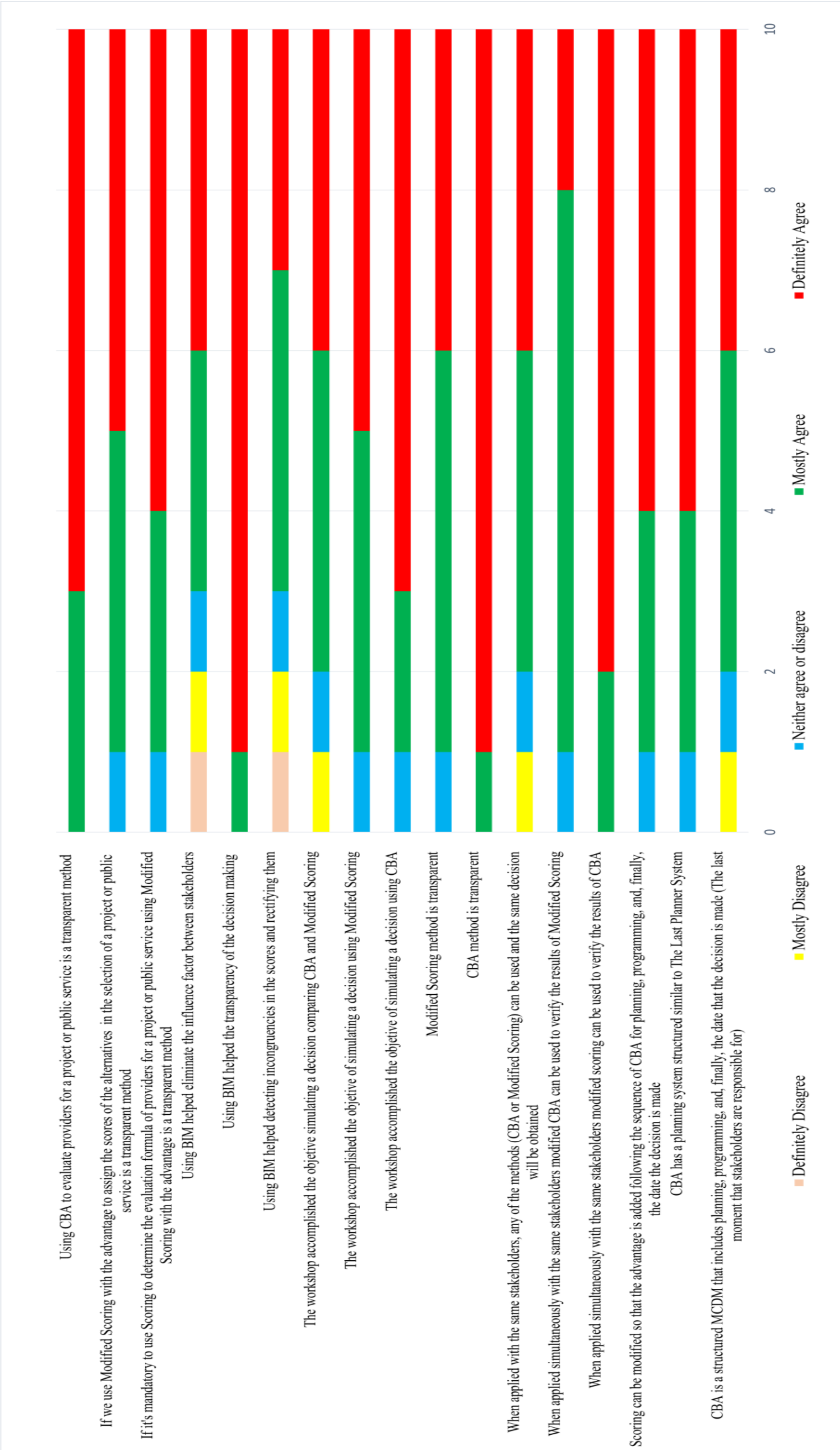

Fig. 6. *Survey Results*

i. When applied simultaneously with the same stakeholders modified scoring can be used to verify the results of CBA (Mean = 4.80, STD = 0.92);

ii. When applied simultaneously with the same stakeholders modified CBA can be used to verify the results of Modified Scoring (Mean = 4.10, STD = 0.57). These values show that students do not perceive much advantage for one method compared to the other.

5. CONCLUSIONS

The study suggests that multicriteria decision making (MCDM) methods combined with 4D models are useful means of achieving better comprehension of the construction flow and thus choosing the best construction alternatives. If the building is better modulated, standardized, and industrialized, it will generate less waste both on the work site and in the suppliers' factories, and workforce planning will be optimized. Such prep work also contributes to making the building more sustainable. When developing a project in the Lean Construction environment, many stakeholders are involved, including investors, developers, users, government entities, and the design team. The use of decision-making tools, such as Scoring or Choosing by Advantages (CBA), will help the latter meet the needs and values of the key players. The alternative should be selected that will align the purposes of all those involved in the best way. Stakeholders consider that CBA is a structured MCDM that includes planning, programming, and, finally, the date that the decision is made (the last moment that stakeholders are responsible for) and that CBA has a planning system with similar structure to the Last Planner System (LPS). It may be inferred that CBA and LPS present a synergy since they both allow stakeholders to reach a consensus for decision making in the "last moment of responsibility". Owing to its simplicity, the Scoring system allows users to make decisions regarding the design alternative that best suits the interests of both developers and users. However, it does not take advantages into account, as the CBA system does. For this reason, we recommend the inclusion of CBA in the overall framework, to create greater transparency, as described above. The strategy used for the improvement of the Scoring method was the incorporation of the CBA elements, satisfying one of the main purposes of this research. In this study, the CBA and modified Scoring systems obtained very similar results. The two methods are equally transparent and comprehensible in decision-making. On the other hand, the application of the proposed methods to clusters of alternatives was successful and validated by the results, fulfilling the other main purpose of the research. Likewise, the consideration of applying lineal relation between attributes and values of the Importance of advantages (IoA) was verified as a variant of the proposed method, which was validated by obtaining the same results with both methods. It is concluded that using the lineal relations make the CBA method simpler and more automated since the decision makers only must assign the IoA for the best attributes and the rest of the scores are obtained without the need of further discussion.

From the results of the survey we can state that the use of CBA simultaneously with BIM model increases the transparency. Also, the use of Modified Scoring also has an important level of transparency because the advantage is defined at the beginning, but not as high as the CBA, so a good option would be to use CBA and then adapt it to the Scoring table when the regulation allows it. According to the stakeholders, using a Modified Scoring with the advantage to assign the scores of the alternatives in the selection of a project or public service is a transparent method and using CBA to evaluate providers for a project or public service is a transparent method. Thus, the adaptation and implementation of this method to real projects and public services is proposed as a future line of research. Another future line of research would be to use other multicriteria methods to test the validity of this adaptation. CBA reduces the time to reach consensus [4] and its adaptation to the Scoring system enriches and simplifies the traditional Scoring method. The development of a software that implements the proposed methods, automating even further the collection of results and decision-making process is also proposed as a future line of work.

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