International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 24-34
Published Online March 2021 in IJEAST (http://www.ijeast.com)

SUSTAINABILITY-ORIENTED INNOVATION, TECHNOLOGIES & FINANCE IN CONSTRUCTION: A MULTI-CRITERIA METHODOLOGY

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Abstract—**Considering the efforts to adjust the great demand of the civil construction in the developing countries and the economic interests of the sector, in line with current sustainable trends, this article presents a methodology to support the planning and decision making of construction companies. An analysis of the elements involved in the process, their interaction and proposed application priorities are evaluated using the AHP *(Analytic Hierarchy Process)* method as a multi-criteria decision support tool. The results obtained allow us to observe the parameters that guide the decision-making of the managers in the construction sites, the impact of low productivity and limited investments in innovation and processes, which still adopts the traditional methods of construction. However, exists a margin that is sustainable, without major financial impact, through the management and encouragement of the environmental awareness of investors, entrepreneurs and construction workers. The actions that interfere with the process and its application priorities in construction are related, within the context of innovation, technology and finance oriented to sustainability. Supported by the concepts of management and SOI *(Sustainability-oriented innovation)* topics, a discussion of the civil construction scenario in Brazil is carried out through the economic, social, technological and managerial issues typical of developing countries, guided by the strong trends in the macro-economics adjustments and rational use of natural resources in the coming decades. It highlights the main challenges of the sector and presents a analysis, planning, decision-making approach and collective impact actions that could support the development actions of the sector, in order to reduce the distance from the concepts of environmental awareness and attitudes existing in developed countries.**

Keywords— **Sustainability-oriented innovation (SOI); Construction; Multi-criteria decision; AHP;**

I. INTRODUCTION

The technological advances in recent years have made the Brazilian Construction industry gradually incorporating innovations and management forms, despite its traditionally conservative character. In the constant search for higher quality, productivity and customer satisfaction, in an economic scenario which have been increasingly competitive and global. The advances are commonly accompanied by detailed and favourable financial analysis to attract investors and partners. The construction industry in Brazil functions as a lever of development and has important socio-economic points of view, helping to deal with the lack of housing, as well as contributing to infrastructure solutions, which restricts the rapid growth of the country. The industry continues to be one of the leaders of the current pattern of economic growth in the country [1], with formal participation of 5.6% of total salaries paid to Brazilian economy workers and 9% of employees. The construction industry needs more growth. In 2010, the Brazilian housing shortage was estimated at 6,273 million families, of which 82.6% are concentrated in urban areas [2]. Data on construction expansion indicate that there is robust growth in the industry. Between 2006 and 2013, construction investments totalled more than 39.3% of the country's gross fixed capital formation [3]. However, in comparison to the country's growth, it can be observed that the Brazilian construction did not follow the real growth of its GDP in relation to the national GDP.

On the other hand, the environment and sustainability are each more demanding topics for commercial and governmental trends, And the construction industry in many developing countries has much to advance. In the case of Brazil, the increase in costs, the lack of qualification of the workforce, the adequacy of the processes of suppliers of materials and raw materials, the lack of sustainable urban policies and the generation of waste are the challenges to be faced in the implementation of sustainable enterprises [1, 3]. The construction sites in the sector need to consolidate their management with solid actions to optimize natural resources and focus on sustainability.

One way of contributing to the optimization and rationalization in the productive processes at the construction site would be through actions of collective impact and structural transformations, strongly guided by more effective methods of decision support with multiple criteria, since this is characterized mainly by ability to analyse situations incorporating quantitative and qualitative analysis, conflicting or not. Different and efficient decision support tools available in the market can be found at an affordable cost, and their use in the industry would be feasible. This study will make use of the AHP *(Analytic Hierarchy Process)* method and will consider the parameters of Sustainability-oriented innovation, technologies and finance in construction sites.

II. PRODUCTIVITY AND INNOVATION IN THE GROWTH OF THE BRAZILIAN CONSTRUCTION INDUSTRY

Productivity in the construction industry has long been a focus for industry and academia alike, because the construction industry is a leading sector, with a key role in growing and sustaining general economic activity [4, 5]. Companies increasingly use strategies to drive productivity improvement through efficiency and elimination of waste in targeted industry practices, such as procurement, integrated design: BIM [6, 7], project management [8, 9] and innovation in the construction [10, 11]. Within this context, it can be argued that productivity improvement, or at least innovations and the process efficiency should be an important focus in construction research [12]. However, productivity in construction has multiple meanings grounded in discipline perspectives, especially in developing countries such as Brazil.

2.1 Latin America´s productivity versus developed nations

Differences in growth rates of labour participation or the accumulation of capital (human in the form of labour skills and physical in the form of capital per worker) typically pale in comparison with the gap opened by lagging productivity improvements, or reversals, in the typical Latin American country. In many cases, such as Brazil and Peru in Latin America, the relative inefficiency of the services sector when compared with the developed nations - and the low growth rates of the sector in recent years - contributed significantly to the reversal of the productivity convergence and the technology innovations [10,13,14]. The productivity failure can be traced to distortions in the workings of the economy that drive aggregate efficiency below the technological frontier [14, 15, 16, 17].

2.2 Innovation as a driver of development

There is broad consensus on the role of innovation as a major source for countries' economic growth [10]. The relationship between innovation and economic growth has been demonstrated by several studies over several decades that have found positive correlations between various measures of innovative performance and economic growth. It is through innovation that productive knowledge and creative ideas are transformed by companies into products and services with greater added value and novelty.

However, innovation should not be related only to R&D or patents. For companies in emerging countries, although R&D labs are rarer, many innovative activities can be found in the practical and commercial application of ideas not necessarily linked to cutting-edge technology [12]. In emerging countries, innovative activities often lie in engineering and design. In a second step, they can form the foundation and preconditions for achieving world-class R&D activities. Enterprises from the emerging high-tech world have begun their trajectory with duplicative imitation [18]. Imitation practices can be preconditions for the implementation of more sophisticated engineering and R&D activities, including expressive generation of patents (Fig. 1).

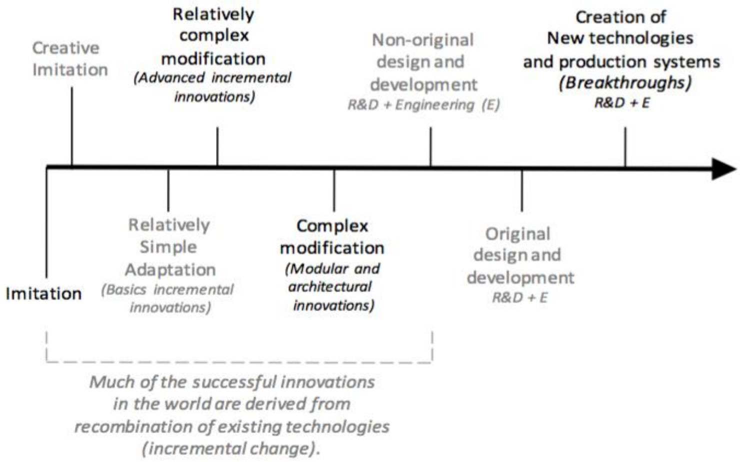

Fig. 1. Scales of types and degrees of innovation [12].

Much of the innovation does not depend on science, and the recombination of existing technologies accounts for a large part of innovative activity over the past 50 years. In the longer term, rather than focusing on innovative activities, it is important to strengthen the technological capabilities that allow companies develop their innovative process with their economic and sustainable growth.

2.3 Control as support in construction development

The introduction of new management models by the construction companies, which consider quality from a strategic perspective, is the result of a series of factors that characterize the current market situation of Brazilian civil construction, especially the subsector dedicated to building. ISO quality standards have not been developed focused on the construction industry; it is fundamental to undertake a discussion of their requirements in order to enable their implementation in the sector [12]. An efficient construction site project, in addition to ensuring the safety of its workers, brings in its core qualities that reflect in the total performance of the enterprise, such as:

- *Better use of the energy expended by the worker;*
- *Rational use of equipment;*
- *Optimization of time (human and material resources);*
- *Rationalization of activities and use of spaces;*
- *Minimizing interference that can cause waste.*

In Brazil, a growing increase has been observed in the introduction of improvements in the search for quality in construction sites. More companies have developed checklists, work orders, logistics and material storage, accessibility, quality tools, compliance with safety standards in workplaces, implementation of ISO certifications, Integrated Management System and the implementation of the Brazilian Program of Quality and Productivity - PBQP-H [12, 19].

Even though initially the awareness and training reside in the top management of the companies, through the directors and managers in search of a lean model, it is perceived that the demand for productivity is essential for sector development.

2.4 Challenges of construction companies in Brazil

In view of the literature, the size of the Brazilian challenge in the pursuit of higher productivity is clear, and that it incorporates the necessary innovation, both effective and lasting, since success depends on changes to the main structural problems of Brazil, such as social and cultural limitations due to the low quality of Brazilian education, lack of infrastructure, excessive bureaucracy, levels of informality in the workforce, high tax rates and little investment in Technologies [12]. In addition, it is not only the government that needs to leave its comfort zone and seek new actions to promote efficiency, companies must invest in the renewal of their productive processes and in the development of really effective management processes, but such actions derive from increased competition. Therefore, there will only be productivity growth if we work seamlessly [1, 3, 12].

A construction company's success can be basically defined in terms of its profitability and project success. However, long-term goals, strategies and competitiveness in the industrial environment force companies to measure their success with some strategic indicators such as innovation and technology transfer which also provide competitive advantage [20].

2.5 Management of technology and information in Brazilian Construction

The current dynamic and competitive market makes companies seek continuous improvement, a fundamental factor for an organization that aims to characterize its services and products. For this, the precision, speed and the overview, that facilitates the decisions, are fundamental, what has made the Technology and the Information an important competitive differential. Effective IT and technology management brings benefits to the company's operational and strategic areas by providing data, information and insights to the project consolidation process.

In today's environment, it is decisive to provide real-world context within an intelligent digital model that ensures engineering-driven construction [21]. Conceptual and detailed design applications enable the analysis, interpretation, understanding and decision-making of the project in the virtual design and construction environment and to optimize bridge the gap between design and construction [21, 22]. A complete information model provides digital construction deliverables that improve construction methods, quality, delivery scheduling and communication, while improving safety, productivity and reducing costly construction delays [21,22, 23]. Processing the information, the technology is generating transformations in the companies organizations, allowing the integration between different technical areas, reflecting in the optimization of the following factors:

- *Communication patterns between people;*
- *Skills needed to perform tasks;*
- *Influence of people;*
- *People's level of privacy;*
- *Access to information;*
- *Roles played by people.*

In the sense of the economic growth of construction in Brazil, there is a constant diffusion of technologies, with competitive advantages of a dynamic market, and demands of flexibility, quality and innovation [24]. New market conditions and increasing competition are driving companies to technological modernization. There is an increasing use of software and applications to monitor the work associated with planning and budgeting, frequent use of digital signatures, integrated calendars, e-mails and corporate clouds by adopting a platform for managing and storing information and projects and Implementation of BIM - Building Information Modelling, shown as the centrepiece of the architecture, engineering and construction (AEC) technology market, to address building information, design, construction and operation aspects. The incorporation of new technologies requires changes in work practice in companies, since the development of an integrated model requires high collaboration and communication among those involved [22]. Standardized processes and protocols will be required to define responsibilities and conduct the review and validation of documents and projects as well as the good practices necessary for data management to be appropriate to the team structure and company requirements [21, 23].

Nevertheless, BIM and associated technologies, currently, is not meant to directly interface with the real world at construction sites, making it more suitable for design than operations. To provide an efficient interface between software and physical data, there is a need to leverage flexible and adaptive data collection systems [25, 26]. It is observed the growth in the studies in the exploration of the potential of existing tools and equipment to answer the above needs for productivity improvements in construction industry through some innovations, among them: Unmanned Aerial Systems (UAV or drones), GPS, Sensors, Imaging, 3D Models / SFM, Robotics, RFID, Lasers, (8) Standardizing and modularizing construction components. Although small and large companies have started the process of deploying new technologies and information management, there are several difficulties in this process that prevent their complete adoption in the Brazilian construction sector [12], among them:

- *Consciousness of entrepreneurs and managers;*
- *Equipment, software and training costs;*
- *Contraction of skilled labour;*
- *Resistance to change in the organizational culture;*
- *Monitoring focused on the final profit of works & services;*
- *Few indices of productivity and profitability (teams/stage).*

III. THE SUSTAINABILITY CONTEXT FOR INNOVATION AND DEVELOPMENT

3.1 Management of technology and information in Brazilian Construction

There is a growing understanding that society needs a greater environmental balance for its development. The rates of production and consumption of natural resources must be within the limits of nature's response. The challenge of balance requires political, economic, institutional, behavioural and technological changes, through principles and approaches that will require greater efforts for its implementation in the coming years. Currently, the most relevant topics within the Sustainable Development Goals, declared by the United Nations World Economic Forum in 2015 are: Water - ensuring availability and sustainable management of water and sanitation for all; Energy - ensuring access to affordable, reliable, sustainable and clean energy for all; Consumption - ensuring sustainable consumption and production patterns; And Sustainability - strengthening the means of implementation, and revitalizing the global partnership for Sustainable development [27]. Recent worldwide progress through population growth, economic development and the consumption model in the last decades has transformed concepts about development, environment and sustainability in organizations. Management systems invariably incorporate this theme in parallel with other strategic business topics.

However, the inability to accept a common "sustainable policy" shows the individualism of individuals, corporations, nations and countries, and not a collectivism in relation to our shared responsibility for future generations [28]. Since the emergence of the "science of sustainability" researchers have pinpointed about unsustainable trends. The core questions of the co-evolution of human and natural systems in the search for new approaches to the understanding of complex problems of environment and development [29]. Among the main challenges is to examine the future paths of social and environmental systems combined with the complex trends and conditions of present-day society, requiring a scientific line of thought and an expansion of the research agenda on global change.

Some data on the development between 1900 and 2000 are summarized below [30, 31]:

- *Global population increased 4 times from 1.5- 6bi people;*
- *Global economy increased 14 times;*
- *Industrial production increased 40 times;*
- *Energy use increased 16 times;*
- *Carbon dioxide emissions increased 17 times;*
- *Sulphur dioxide emissions increased 13 times;*
- *Ocean fishing catches increased 35 times;*
- *Number of pigs increased 9 times*
- *Deforestation was 20%.*

Figure 2 presents some information on Growth in global materials use [30], illustrating the development of inventories and material flows from 1900 to 2010, its extraction of global resources by uses, quantity of consumption and inventories by region.

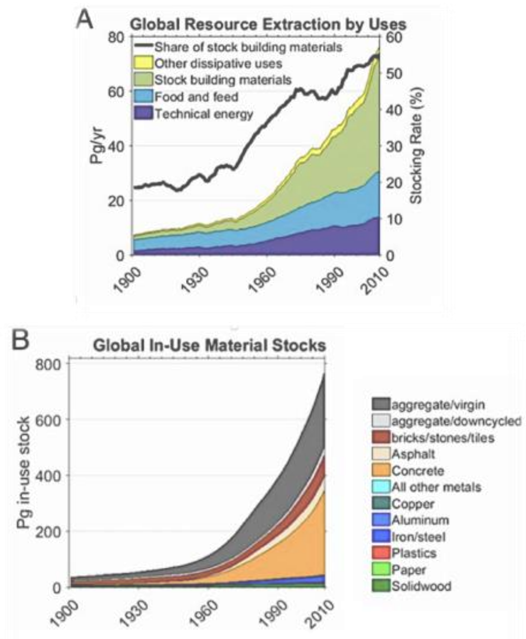

Fig. 2. Development of material stocks :1900 to 2010. (A) Global resource extraction by uses; (B) Global in-use material stocks; [5].

In the last century, global materials use increased 8-fold. Humanity currently uses almost 60 billion tons (Gt) of materials per year and the material intensity (i.e. the materials amount required per unit of GDP) declined, while materials use per capita doubled from 4.6 to 10.3 t/cap/year [30]. We will not be able to continue in this rhythm forever and we will have limitations of consumption and growth. Our limits are set by earth. Today, the society development also involves the energy dilemma. In the world, 85% of the energy supply relies

International Journal of Engineering Applied Sciences and Technology, 2021
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on fossil carbon: coil, oil and gas. The non-renewable fossil fuel is to its estimated end. Researchers affirm that use is predicted to continue up to 2050, at which moment the conventional resources could be depleted. The energy dilemma is three-fold: non-renewable energy option, inefficiency and quantity used [31].

Therefore, radical changes are necessary in the current economic model, with respect to consumption, cleaner production, resource efficiency and associated terminologies. It should be guided by macroeconomic approaches as proposed by the green, blue and circular economy for better prospects for the coming decades. There is a need for solid actions and studies focused on environmental awareness and global thinking for all agents involved, associated with population growth, demand for buildings and infrastructure, especially in developing countries.

3.2 Sustainability through environmental awareness and global thinking

Business sustainability has become a market standard because the term is not fashion, but a way of working [30,31]. Increasingly, sustainable business technology strategies are being developed through conscious companies, with a view to transforming into today's unsustainable practices, with each having the potential to grow and consolidate for the next business generations. Emerging clean technologies, including the generation and distribution of renewable energy, biofuels, water purification at the time of use, biomaterials, non-sustainable information Technologies, sustainable agriculture and circular economy can be the key to solving many of the Environmental and social challenges [30,32].

The decision to consume, utilization and practice is strongly guided by the consumers' environmental awareness and should not be associated with social class and consumer opportunities. Individual consumption practices of sustainable consumption its has been be considered into on-going academic and policy debates [31,32,33]. It is observed the lack of consolidation of environmental awareness of the citizen, can directly reflect on the practical results of consumer actions, sustainable practices, work performance and positive results society in which he is inserted, especially in developing countries. The global environmental awareness and change thinking, associated with efficient public norms and structures, is an integral part of the sustainable model we are experiencing today, and needs to be inserted as a prerequisite of managerial models adopted.

According with *Stroh* (2015), conventional thinking is not suited to address the complex, chronic social and environmental problems you want to solve [34]. These problems require systems thinking, which differs from conventional thinking in several important ways [30, 33]. The involvement of all agents of the process, besides contributing to the development of the project and search for results, allows the dissemination of knowledge through brainstorming, research, sharing, suggestions and ideas. In addiction, it allows to generate impact results, a promising synergy in the team and motivation to those involved.

3.3 Sustainability-oriented innovation (SOI)

The concept of Sustainability-oriented innovation (SOI) is a concept that is associated in making viable the gain and adopting compensations between the economic performance versus its environmental impact. SOI suggests that these goals should be associated in order to create global, integrated business products, services and models. Business innovation emerges as a facilitator of processes, products, services and organizational forms, in order to better integrate the agents involved and achieve different results [35]. Some companies innovate in areas that go beyond technical aspects, such as the adoption of new business models or the substitution of products for services that represent alternatives or additions mainly to technological solutions, suggesting that the focus is not just technological. But also about how innovations are used, who they involve, and how they influence behaviour change [36, 37].

Sustainability-oriented innovation thinking extends across the enterprise regardless of innovations being associated with prior planning demands in targeted industries. It is observed in successful cases how innovation for sustainable manufacturing has gone from final, stand-alone solutions to modes of practice that require sustainability to be more deeply embedded in the company's culture: for example, through adoption of product life cycle thinking, integrated environmental strategies and environmental management systems. In other words, SOI goes from being an add-on to disseminating and disseminating throughout the organization as a strategic sustainability behaviour [35,38]. Business model innovation emerges as enabler of radically changing processes, products, and organizational forms in order to more successfully integrate core business [35]. It can be understood that the potential of SOI can exist in any company, from the management and specific focus. A mapped approach to SOI activities is illustrated in Table 1, as shown.

Table -1 Activities of Sustainability-oriented Innovation [35].

	Operational Optimization: doing more with less	Organizational Transformation: doing good by doing new things	Systems Building: doing good by doing new things with others
Strategy	• Comply with regulations or pursue efficiency gains	• Embed sustainability as a cultural and strategic norm in a shaping logic that goes beyond greening	• Logic of wide collaborations and investing in systems solutions to derive new, co-created value propositions
Process	• Focus on internal and incremental innovation facilitated by use of tools	• Adopt new values and platforms (e.g. reverse innovation) and new ideation practices (e.g. biomimicry)	• Adopt new collaborative process platforms with diverse stakeholders
Learning	• Exploit existing knowledge management capabilities to identify and access relevant knowledge	• Engage with key stakeholders of the firm – internal and external	• Develop ambidextrous skills enabling 'shadow tracking' and learning from experimentation with multiple new approaches
Linkages	• Recruit external domain experts for new knowledge	• Shift focus from intra-firm linkages to collaborations with immediate stakeholders	• Get the whole system in the room to diagnose problems, understand system complexity, build trust and identify levers for change
Innovative organization	• Exploit existing innovation capabilities	• Embed SOI culture through the organization	• Adopt new business paradigms (e.g. B-Corps)

IV. METHODOLOGY

The methodology adopted in this study is classified as qualitative-quantitative. The qualitative analysis is present when identifying and representing the elements involved in the process, the interaction between them, the applicable interventionist practices and the proposal of application priorities. While the quantitative one, it is present in the transposition of the quantitative qualitative model through academic version of software BPMSG© [39], analysis and adequacy of the data in electronic spreadsheets, through the AHP *(Analytic Hierarchy Process)* method to calculate the Matrix of Comparison, indices, coherence factors and vectors as a multi-criteria decision support tool. It was decided to use this methodology because of its ability to identify the managers' perceptions of the situation analysed, to provide conditions to measure such elements and to offer suggestions for improvement in those in which the performance of the elements in the organization is not as expected.

For the development, it was identified the parameters related to management in construction sites, related to the workforce, structural and external agents that most commonly influence the results and decision making in the companies of the sector as illustrated in Table 2.

Table -2 Internal and external factors selected, with their parameters associated in the management at construction sites.

Factors	Associated parameters
Labour	*Skills* *Productivity* *Awareness*
Structural	*Material* *Process* *Technology* *Quality* *ABC Analysis* *Added value*
External	*Available natural resources* *Customer satisfaction* *Demand*

These criteria are shown in the second level, and are further broken down into 12 sub-criteria, shown in the third level of the hierarchy. Considering the improvements of sustainability-oriented innovation, technologies and finance, Figure 3 shows the organization of the parameters for analysis.

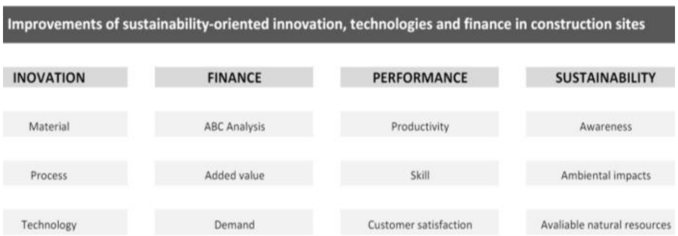

Fig. 3. Research parameters adopted for evaluation related to management in construction sites.

Traditional multi-criteria decision making methods evaluate all alternatives in a single level, which inadvertently restricts the simultaneous comparison of numerically heterogeneous alternatives. For dealing with the comparison of homogeneous elements, it is known that one cannot usually compare more than about seven homogeneous elements without increasing the overall inconsistency of the judgments. The scale used for comparing homogeneous elements in the AHP is restricted to the absolute numbers 1–9 and their reciprocals when evaluating the relative importance of one element against another element [40].

The AHP makes use of the principles of decomposition, comparative judgments, and synthesis. Decomposition involves constructing a hierarchy which puts the goal of the problem at the top and places the criteria, sub-criteria, and alternatives at descending order of the hierarchy. For comparative judgments, the comparison matrix is arranged at each level to compare pairs of (sub) criteria or pairs of alternatives. The fundamental scale of absolute numbers used to represent dominance with regard to a common property by using pairwise comparisons ranges from 1 to 9. The comparison-matrices are synthesized to estimate the relative priorities for all alternatives. Thus, the AHP provides rank order and relative value on an absolute scale for each parameter [40]. The evaluation criterion from the related parameters was obtained from Saaty´s nine-point scale of comparison of two pairs, for the AHP preference, as shown in Table 3 and Figure 4.

Table -3 Saaty's pair-wise comparison nine point scale for AHP preference [40].

Scale	Numerical rating	Reciprocal
Extremely importance	9	1/9
Very to extremely strongly importance	8	1/8
Very strongly importance	7	1/7
Strongly to very strongly importance	6	1/6
Strongly importance	5	1/5
Moderately to Strongly importance	4	1/4
Moderately importance	3	1/3
Equally to Moderately importance	2	1/2
Equally importance	1	1

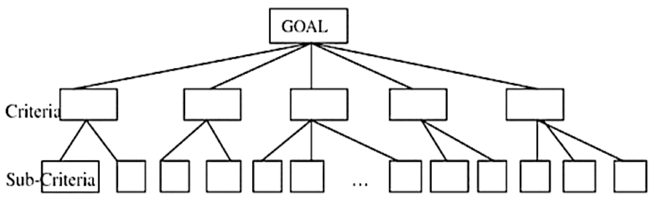

Fig. 4. Saaty´s orders-of-magnitude AHP schema to mutli-criteria decision making [40].

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The other parameters to be considered in the analysis are: λ_{max}, CI and RC, as follows:

- *Principal eigenvalue of the matrix ($\lambda_{max.}$)*, and the expected value will be equal to the number of criteria n of the matrix. The closer λ_{max} from *n*, the greater the coherence of the analysis.

- *Consistency index* (CI), indicates how much eigenvalue is away from *n*. Is given by Equation 1.

$$CI = (\lambda_{máx.} - n) / (n-1) \quad (1)$$

- *Consistency Ratio* (CR), indicates the consistency of the two-to-two evaluations carried out in the matrix.

The lower the index, the greater the consistency. Its calculation considers the Random Index, obtained from the average of square matrices of order *n* (Table 4). The CR is given by Equation 2.

$$CR = CI / RI \quad (2)$$

Table -4 SRandom Index (RI) obtained from the mean square matrices of order n [18].

Order of the matrix	1	2	3	4	5	6	7	8	9
RI value	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

All matrix calculations and associated indices were performed using BPMSG© software [39], which processes quickly and accurately, speeding up data processing for analysis.

V. RESULTS AND DISCUSSION

The Saaty's pairwise comparisons matrix [40] applied to the related parameters are presented in Table 5. The values of comparative evaluations, local, global and group priority parameters are illustrated, in addition to individually ranking each parameter between them, as follows.

Table -5 Saaty´s pairwise comparisons matrix [40] applied to the research related parameters.

	RATING CRITERIA	Materials	Process	Technology	ABC Analysis	Added value	Demand	Productivity	Skills	Customer satisfaction	Envir.l Awareness	Environmental impact	Nat. Resources avail.	Local priority (Group)	Global priority	Global/Group priority	RANK (Individual)
		Inovation			Finance			Performance			Sustainability						
Inovation	Materials	1	3	3	1	1/5	1/7	1/7	3	1/7	1/5	1/5	1/3	0.412	0.028	0.068	8
	Process	1/3	1	1/3	1	1/7	1/7	1/7	1/7	1/5	1/3	1/5	1/3	0.250	0.017		12
	Technology	1/3	3	1	1	1/7	1/7	1/7	3	1/5	1/3	1/5	1/5	0.338	0.023		10
Finance	ABC Analysis	1	1	1	1	1/5	1/5	1/3	1	1/5	1/3	1/3	1/3	0.058	0.025	0.433	9
	Added value	5	7	7	5	1	1/5	1/3	5	3	3	3	3	0.309	0.134		3
	Demand	7	7	7	5	5	1	3	7	5	5	5	5	0.633	0.274		1
Performance	Productivity	7	7	7	3	3	1/3	1	5	1/3	6	4	4	0.532	0.167	0.314	2
	Skills	1/3	1	1/3	1	1/5	1/7	1/5	1	1/5	1/3	1/7	1/3	0.057	0.018		11
	Customer satisfaction	7	5	5	5	1/3	1/5	1	5	1	3	3	7	0.411	0.129		4
Sustainability	Environmental awareness	5	3	3	3	1/3	1/5	1/4	3	1/3	1	1/5	1	0.270	0.050	0.185	7
	Environmental impact	5	5	5	3	1/3	1/5	1/4	7	1/3	5	1	2	0.459	0.085		5
	Avaliable natural resources	3	3	5	3	1/3	1/5	1/4	3	1/7	1	1/2	1	0.270	0.050		6

It can be observed that from the selected parameters 66 comparisons were made, where the generated matrix generated a *Principal Eigen Value* $\lambda_{máx.}$ = 13.625. The *Consistency Index* (CI) is calculated from Equation 1 and resulted in CI = 0.147. *Consistency Ratio* (CR) calculations through equation 2 and table 4, results CR = 9.6%. This value, according to AHP model theory [40], being below 10 is acceptable and indicates that the analysis is coherent.

The decision matrix, comparison criteria and their associative indexes, generated by the BPMSG© software [39], are illustrated in figure 5.

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons

	Category	Priority	Rank
1	Material	2.8%	8
2	Process	1.7%	12
3	Technology	2.3%	10
4	ABC Analysis	2.5%	9
5	Added Value	13.4%	3
6	Demand	27.5%	1
7	Productivity	16.7%	2
8	Skills	1.8%	11
9	Customer satisfaction	12.9%	4
10	Environmental Awareness	5.0%	7
11	Environmental Impacts	8.5%	5
12	Available natural resources	5.0%	6

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	3.00	3.00	1.00	0.20	0.14	0.14	3.00	0.14	0.20	0.20	0.33
2	0.33	1	0.33	1.00	0.14	0.14	0.14	1.00	0.20	0.33	0.20	0.33
3	0.33	3.00	1	1.00	0.14	0.14	0.14	3.00	0.20	0.33	0.20	0.20
4	1.00	1.00	1.00	1	0.20	0.20	0.33	1.00	0.20	0.33	0.33	0.33
5	5.00	7.00	7.00	5.00	1	0.20	0.33	5.00	3.00	3.00	3.00	3.00
6	7.00	7.00	7.00	5.00	5.00	1	3.00	7.00	5.00	5.00	5.00	5.00
7	7.00	7.00	7.00	3.00	3.00	0.33	1	5.00	1.00	6.00	4.00	4.00
8	0.33	1.00	0.33	1.00	0.20	0.14	0.20	1	0.20	0.33	0.14	0.33
9	7.00	5.00	5.00	5.00	0.33	0.20	1.00	5.00	1	3.00	3.00	7.00
10	5.00	3.00	3.00	3.00	0.33	0.20	0.17	3.00	0.33	1	0.20	1.00
11	5.00	5.00	5.00	3.00	0.33	0.20	0.25	7.00	0.33	5.00	1	2.00
12	3.00	3.00	5.00	3.00	0.33	0.20	0.25	3.00	0.14	1.00	0.50	1

Number of comparisons = 66
Consistency Ratio CR = 9.6%

Principal eigen value = 13.625
Eigenvector solution: 7 iterations, delta = 3.9E-9

Fig. 5. Decision matrix and comparison criteria generated by the BPMSG© software [39], for the selected parameters.

Considering the coherence and validation of the data obtained by the selected parameters, the Hierarchy of criteria to evaluation, according to figure 6, is elaborated below.

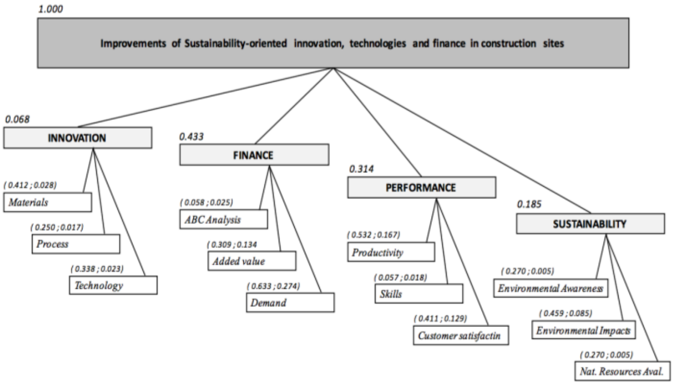

Fig. 6. Hierarchy of criteria to evaluation

It is observed that the aspects of market demand, performance and finances are strong guiding factors in the decision-making in construction sites, representing together 74.7% of the related parameters. As a result, the sustainability and social-environmental awareness of those involved are second to the company goals, representing 18.5% of the preference. It is also worth noting that innovation and improvements, which may impact on the results are very low, and represent 6.8% of the focus to be guided in the company, making it difficult to obtain improvements by the models adopted in the construction sites, once Who are not willing to change the organization, methods and materials adopted. It can be concluded that the low productivity and lack of study of the process, compromise the production and financial results, and end up being always more valued for the decisions taken by the managers. This scenario, which together with the motivational factor and environmental awareness of those involved will make difficult the prospects of changes in the sector without actions of great impact. In the same way we can associate health, work safety, quality control, social responsibility and other administrative parameters that were not part of the scope of this analysis, but that can keep their advances compromised in the organization.

After the judgments have been made and the impacts on all elements and priorities across the hierarchy have been computed, sometimes unimportant elements can have a large impact on the overall outcome. This sensitivity analysis is important because it leads to a reassessment of priorities and may or may not change the remaining judgments. It is also necessary to be attentive to the inconsistencies of the decision maker, because when assigning values he can contradict and this must be checked to validate the weights assigned. The AHP admits some small inconsistencies due to its robustness, but we must always avoid them. Inconsistencies must be identified and presented to the decision maker and eliminated through further two-to-two evaluations.

5.1 Sustainability through environmental awareness and global thinking

Considering the results of the multi-criteria analysis, and facilitating the acceptance of the managers for the change, it can be understood that the actions of SOI in construction sites should seek continuous improvement of results, especially increasing the productivity indexes, through the elements of Higher value added, which will directly impact financial results, as shown in Figure 7.

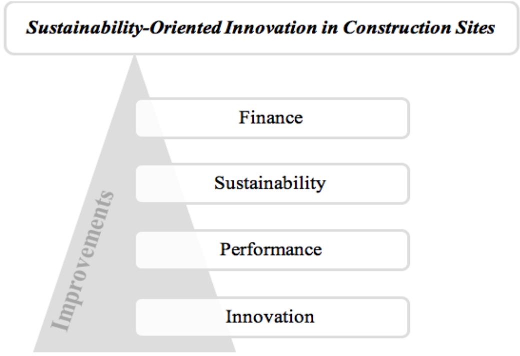

Fig. 7. Improvements of the Sustainability-oriented innovation in construction sites

It is understood that suggestions for improvements must come from the staff of the site and managers directly involved in the process, guided by the company's guidelines and goals, supported by contents and technical training, associated with integration and socio-cultural valorisation of the worker, in order to To improve workers' awareness, as a permanent contribution to corrective actions, which will directly and indirectly impact on the company, its various parameters, and the society that it is inserted. It is believed that all agents know strongly the concepts, understand their limitations, and know the importance of their actions to obtain results. Although this understanding seems trivial, it is increasingly becoming more prevalent in developing countries, especially in sectors with low turnover and high turn-over characteristics, such as the construction industry.

In order to achieve better results, companies must implement a managerial model that allows impacting individual and collective modifications, such as the five conditions of collective impact [41] approach, proposed in Table 6.

Table -6 Five conditions of collective Impact [41].

Conditions	Expected results
Common Agenda	All participants have a shared vision for change including a common understanding of the problem and a join approach to solving it through agreed upon actions.
Shared Measurement	Collecting data and measuring results consistently across all participants ensures efforts remain aligned and participants hold each other accountable.
Mutually Reinforcing Activities	Participant activities must be differentiated while still being coordinated through a mutually reinforcing plan of action.
Continuous Communication	Consistent and open communication is needed across the many players to build trust, assume mutual objectives, and create common motivation.
Backbone Support	Creating and managing collective impact requires a separate organization(s) with staff and a specific set of skills to serve as backbone for the entire initiative and coordinate participating organizations and agencies.

VI. CONCLUSION

To deal scientifically with construction sites, with a great number of uncertainties, in different managerial models, for different levels of internal and external demand, we can compare results to derive priorities and make decisions. Making comparisons is a natural choice made by humans, but we must consider our universe, its values, trends and expectations. We need to constantly observe the parameters and activities that play a significant role in the formation of this universe to better identify its meaning and determine its role that leads us into the future.

The application of the proposed AHP model can be extended to other managerial models and organizational structure of the construction sites, but an impartial and contemporary analysis with an overview of the market is relevant in order to avoid analyses that tend to the company's own values and not to inform aspects that have not been explored, which may be legal requirements, aspects that reduce profit, productivity or even market trends. It is imperative that the analysis identify the bottlenecks and deficiencies of the company, in the most diverse sectors for a conscious and promising decision making, aiming at the competitiveness. The application of the proposed AHP model allows site managers to have a more comprehensive view of the operations and effectiveness of all parameters involved in the process.

In recent years, the multi-criteria decision model has attracted a lot of attention from construction companies. However, a distinct area, dealing specifically with the presence of significantly heterogeneous data on innovation, sustainability, finance and technology, is little explored in the industry. Linking such different topics in decision making can be very much about the type of region, culture and method of work, especially in the construction industry in developing countries. It is noticed the need of dynamic models and studies involving the individual identification of workers and their teams, in relation to management, process, potential of innovation through knowledge, materials and domain technology, existing in the own construction site. Much of the available literature on the subject is associated with developed countries with high rates of productivity, education and culture, not applying to the economic realities and social weaknesses of developing countries such as Brazil.

The changes will invariably take place in the next few decades. Available resources, population demand, costs, social pressure, legislation and consumers will strongly guide needs. A balance between environmental impacts and the financial advantage of producing a product and service will increasingly be required. Companies should maximize the efficiency of the resources used, creating a system where, ideally, there will be no litter or environmental impact, maintaining product quality and its economic potential. Investors and construction companies will have to revise their concepts, especially in the medium and long term, through a new sustainable macro-economic model that will be in place. They will have to re-organize their work organization into design, construction, operation and maintenance. The rational use and better use of the useful life of natural resources will be essential factors for the product and service offered, directly impacting the permanence of the companies in the market.

The main contribution of this research is the presentation of a methodology to support the planning and decision making of construction companies through Sustainability-oriented innovation, technologies and finance in construction. An analysis of the elements involved in the process, their interaction and priorities through the AHP (*Analytical Hierarchy Process*) method as a multi-criteria decision support tool, considering efforts to adjust the large demand for civil construction in developing countries and the economic interests of the sector, according to current sustainable trends. A System that identifies the priorities of the principal parameters and their sub-criteria in the construction sites, seeking to weigh and synthesize the measures that have the greatest impact on results and decision making.

Scenario analysis, including new participatory and problem-oriented approaches, provides a powerful tool for integrating knowledge, analysing the future in an organized way, and internalizing human choice in the science of sustainability.

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International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 24-34
Published Online March 2021 in IJEAST (http://www.ijeast.com)

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