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Barriers to Introduce Mass Timber in Construction in Ecuador - An Exploratory Study

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Abstract: In recent years, there has been a great interest in the use of mass timber in the construction industry. Thanks to configurations such as laminated timber (GLT and CLT), it has been possible to build high-rise buildings with its entire structure (beams, columns, slabs, and walls) made of wood. As technology improves, the gap between the use of reinforced concrete, steel, and wood will be reduced, and within a few years, wooden buildings may be as common as their concrete and steel counterparts. In Ecuador, the use of wood in construction is quite limited, with its most common use being with guadua cane (guadua angustifolia) and hardwoods for two-story houses. Mass timber could change this perception and be introduced as an alternative to concrete and steel. As its implementation is relatively new in the world, there is an opportunity to develop and exploit the potential of a new industry in the country. However, despite the potential of this material, its introduction may not have the expected impact, and this can occur due to a wide range of factors. This study developed a questionnaire using existing literature on mass timber in relation to: raw material production, manufacturing process, construction process, maintenance, cultural context, and environmental impact. With this, 10 interviews were conducted with professionals related to the construction industry. The responses were transcribed, analyzed, and coded to identify the perceived barriers for the introduction of this construction system in Ecuador. Finally, the article proposes ways to deepen academic research as well as the professional use of this material.

Key words: sustainable construction, CLT (Cross Laminated Timber), GLT (Glued Laminated Timber)

1. Introduction

From the end of the 19th century to the present, the construction industry has been based on the use of reinforced concrete and steel. This industry is one of the largest on the planet and has been fundamental for the development of mankind. However, these materials have a great environmental impact [1]. Therefore, sustainable alternatives are being sought to help reduce this impact. This industry alone is responsible for about 40% of global CO_2 emissions. Concrete, which is the second most used material in construction after water, contributes about 8% of total CO_2 emissions [2]. In addition, steel production requires high energy consumption and its extraction causes irreparable damage to the ecosystem where it is found.

Global warming is an increasingly relevant issue in the world and, therefore, in 2015, the UN proposed 17 goals for sustainable development, within which the construction industry has received special attention due to its high environmental impact [3]. One of the alternatives to this sustainability issue, is the development of materials less invasive

to the environment, taking into account the whole process from its extraction to the end of its useful life. "Sustainability is a future-based approach that involves a comprehensive and balanced understanding of the environmental, economic and social aspects of decision making" [4]. One of these materials is wood which, thanks to new technologies such as GLT (glued laminated timber), CLT (cross laminated timber) and their variants, has made it possible to develop more versatile structural elements with which to build large-scale civil and architectural works that were previously only possible using steel and concrete [5]. Timber construction can benefit, mainly, aspects related to objectives: nine (adapt construction to be more sustainable and promote forest innovation), eleven (develop sustainable cities and communities), twelve (efficient use of resources and energy for sustainable infrastructure), and, especially, thirteen associated with the fight against climate change in Latin America and the Caribbean [3, 6].

These materials are relatively new and their use is limited to a few countries that have invested resources for their implementation. In developing countries, such as Ecuador, the existence of these new technologies and the possible effects of their exploitation are ignored because "civil infrastructure systems that fail to achieve their intended objectives exhaust financial resources and erode the public's willingness to invest in future improvements and new systems" [7]. It should be taken into account that, in 2009, the Stadthaus Tower was built in London and was one of the first high-rise buildings of this type, exceeding 29 m [8]. On the other hand, this technology has not yet been officially established in Ecuador.

Therefore, in this article, an investigation was carried out through interviews with experts in the area of construction and wood production in Ecuador, in order to know the current situation of the material in the country. Thus, it was possible to reveal the limitations that exist in the production, assembly and maintenance of this construction method in order to establish the necessary bases with which to combat these limitations. In this way, the gap will be reduced in comparison to countries where this material is already implemented.

2. Background

Although wood is not a new material in construction, in fact, it is one of the oldest materials with which humans have worked, and in the last century its use has lost relevance to steel and concrete [9]. However, global warming is a relevant issue in current world politics, so, in 2015, the UN proposed 17 goals for a sustainable development that help to decrease our environmental impact. It has to be taken into account that, according to estimates, by 2050, seven out of ten people will live in urban areas [6]. Therefore, the demand for high-rise residential buildings will increase dramatically [10]. Wood buildings are highly sustainable and have great architectural potential. These characteristics are what caused the renaissance of this material in modern construction [11, 12]. For these reasons, Dr. Michael Ramage believes that this material is the future of construction to the point where he states that wooden skyscrapers will be as common as steel and concrete ones in the next decade [2]. However, these systems have suffered virtually no exposure to severe earthquakes, except for those simulated in laboratory conditions that show promising results. For example, the University of California at San Diego subjected a ten-story building to the historic Northridge and Chi Chi earthquakes. According to Dr. Shiling Pei, "the building remained free of design-level damage after the two consecutive earthquakes" [13, 14].

To meet the targets set by the Paris Agreement, building construction must be carbon neutral or negative by 2030 [15]. From the extraction of the raw material to the demolition of the building at the end of its useful life, wood has a smaller environmental footprint than steel or concrete in terms of energy use, greenhouse emissions, emissions to water, and solid waste production [16]. It should be noted that the most significant indicators of environmental impact are the carbon footprint and the energy required by each structural system [17]. According to Ravenscroft, "timber building components consume only 50% of the energy required to produce them in concrete and only 1% to produce them in steel" [18]. Additionally, it is important to consider that trees act as sponges that absorb CO_2 from the atmosphere. "A young and

growing forest produces 1 ton of O_2 and absorbs 1.4 tons of CO_2 for each ton of wood that is stored" [16]. Therefore, the production of these elements is not only carbon neutral, but can become carbon negative which is impossible to achieve with concrete and steel.

The structure of these buildings is made possible by two major innovations that revolutionized timber construction. The first is the GLT, which was invented by the German carpenter Otto Karl Freidrich Hetzer in 1910. The GLT consists of panels of wood boards that are glued one on top of the other in the same direction as the previous panel [19]. Thanks to this configuration, it was possible to produce timber beams and columns of greater strength and length than could be made using individual components. The other key component is the CLT, created by Austrian engineer Gerhard Schickhofer in 1994. In this configuration, the structural timber is composed of panels bonded in layers in a perpendicular direction to the previous panel [20]. Thanks to CLT, it was possible to manufacture very lightweight structural slabs and walls compared to their reinforced concrete counterpart. Therefore, using GLT beams and columns, together with CLT slabs and walls, all the structural elements needed to construct all-timber buildings except for the foundations were obtained [21].

In general, trees used for glulam are of low commercial value and are selected based on characteristics that facilitate processing, such as short growth time, regular trunk geometry, malleable and easy to treat wood, pest resistance of the plantation, etc. [22]. The trees most adapted to these characteristics are conifers. These species grow quite fast compared to other types of trees (approximately 20 years of growth), are resistant to various types of environments, their trunk is straight, uniform and easy to treat and work [23]. In Ecuador, the most widely planted coniferous trees are pinus radiata and pinus patula. Both species have been used in other countries for the production of both GLT and CLT [24].

Pine plantations in Ecuador should preferably be at an altitude between 1,400 and 3,500 m above sea level. Above this altitude, the yield of the plantation decreases because the trees will have a slower growth. The optimum soil type is sandy loam, well drained with a neutral to slightly acid pH, at an average temperature between 11°C and 18°C and rainfall between 700 and 2,000 mm. These trees reach heights of between 20 and 30 m, and their diameters can reach up to 1 m. Their final felling takes place between 15 and 20 years [24]. Another tree that adapts well to the climatic conditions in Ecuador and has been used for laminated wood is eucalyptus grandis and eucalyptus globulus, but since their impregnation with immunizing chemicals is not easy, it is preferable to limit their use to places covered from the elements and pests [5, 25].

Once the raw material is obtained, it is sawn into boards and dried to 12% moisture content. It is then graded according to its visual characteristics as defined by the regulations used by the country [26, 27]. An advantage of glulam is that growth-related defects are partially eliminated by the homogenization effect. Therefore, boards of different grades can be placed within the depth of the cross-section [12, 28]. An optimizer is then used to standardize and correct imperfections in the size of the boards. Since solid wood is composed of several layers of boards, these must be of exact dimensions in terms of width and thickness to avoid play or weak points between boards. Subsequently, the boards are assembled and the adhesive is placed on each one and then pressed so that the adhesive adheres uniformly throughout the element [5]. The most common adhesives are: polyurethanes (PUR), phenol-resorcinol-formaldehyde (PRF) and melamine-formaldehyde (MF). PURs are easier to work with and have a low environmental impact, but they decompose at temperatures below wood carbonization temperatures. In contrast, both PRFs and MFs do not separate even when the layer is fully carbonized, however, they produce harmful emissions and are not easily removable or recyclable [29, 30]. At the end of pressing, the wood is impregnated with immunizers such as maleic anhydride to reduce the moisture sensitivity of the wood [15]. Finally, for shipping, a protective layer is placed on the element to provide protection against humidity and UV rays. The level of protection will depend on the use and exposure to which the element will be subjected. Therefore, it is

recommended to use practices that isolate the elements from humidity, such as: the use of eaves, water absorbing surfaces, mechanisms to avoid water accumulation in extreme cases of humidity, and the separation of the wood structural elements from the floor. All these factors can significantly increase the service life of the glulam.

Regarding the construction process, it should be noted that the construction is elementary and only requires basic on-site carpentry skills [23]. This is partly due to the lightness of this material, which facilitates its handling on site. Glulam has a density that is approximately between 400 and 500 kg/m^3, whereas, the density of concrete is over 2,000 kg/m^3. Considering this consideration, the density of wood is between 4 and 5 times lower than that of concrete. This is consistent with the statement that the "building constructed in London, Dalston Lane, weighs one-fifth as much as similar buildings made of concrete" [32]. Therefore, the amount of concrete required for foundations in this type of structure is also substantially reduced. According to Michael Ramage, in theory, if a 10-story building made of concrete is demolished, a 40-story building made of wood can be built instead using the existing foundation [2]. These buildings benefit from the anisotropic properties of softwoods in the direction parallel to the grain that exhibit compressive strength and specific stiffness (which is the ratio of modulus of elasticity to the specific gravity of the material) comparable to those of steel, and significantly higher than those of concrete. However, these values are much lower if the analysis is performed in the direction perpendicular to the fiber [9]. "Glued laminated timber (GLT) performs well in column applications because it remains straight and true in cross-section" [33]. Cross laminated timber (CLT), on the other hand, is ideal for elements such as slabs, roofs and walls both structural and non-structural [34].

Cross laminated timber panels (CLT) are probably the structural wood product with the greatest potential for future development in Europe because of their constructive and environmental advantages [21]. This is because wood is known for its easy maintenance, durability, low cost, quality control in the production process and good environmental performance [35]. Developing countries such as Ecuador could benefit from the potential of wood construction to enter new markets related to this technology [5, 36].

3. Methodology

For this study, a qualitative exploratory research approach was used, in which semi-structured interviews were conducted with individuals according to the interest group formulated by the design. The instrument used for data collection consisted of interviews based on a fixed questionnaire with explicit protocols [37]. The interviews were divided into 2 parts. The first was composed of semi-structured questions regarding the following 6 segments related to this material: raw material production, manufacturing process, construction process, maintenance, cultural context and environmental impact. The second part was open-ended in order to get the opinion of the interviewees and also to identify additional data not considered or that did not fit in the questions of the first part.

Ten interviews were conducted with experts with several years of experience in the construction industry in Ecuador. The protocol proposed by Petruch and Walcher (2021) was followed for the selection of the interviewees. The study is qualitative because the topic needs to be explored. Variables cannot be clearly identified since there are no theories available to explain the behavior of the participants or their study population, and therefore, such theories need to be developed [38]. The questions are focused to extract data related to the 6 items mentioned above. The interviews are semi-structured to give flexibility and freedom to the experts [10]. Since the interviewees are experts in different areas, they may provide information that was not previously considered or did not fit with the questions asked.

For the analysis of the data, thematic or content analysis methodology was carried out, according to Yin [37], and reduced to a few themes or categories [38]. The responses obtained from each of the interviewees were compared with the information previously collected. Thus, it was possible to assess the points of view based on the experience of the

professionals and their knowledge regarding the material. In this way, the information obtained was coded to organize the responses into different groups, indicating the most relevant barriers. These are the basis of the research and are the key to understanding the current situation of structural laminated timber in Ecuador. Only professionals and not the general public were chosen, because "studies have shown that misconceptions about the stability, longevity, stiffness, and combustibility of wood have discredited the industry in the eyes of the general public" [39].

4. Results

Below is a table with the main results obtained from the interviews on barriers to the use of structural glulam.

Table 1. Limitations reported by professionals

Limitations in the production chain	Limited forest mass at present.
	Lack of wood industrialization.
	Lack of products and specialized labor.
	Lack of knowledge for maintenance.
Cultural limitations of the construction industry	Loss of wood construction culture.
	Acceptance of the material by professionals.
	Lack of knowledge and interest of the population about the material's performance.
Limited market	Demand necessary to sustain the industrialization of the product.
Limitations by control entities	Inefficiency of entities that control the production of raw materials.
	Lack of standards regulating the construction process.

4.1 Limitations in the production chain

Regarding the production process, "we do not have the large forest mass that Chile or Argentina have, for example, to be able to industrialize large quantities of timber, nor do we have industrial factories that allow us to generate this line of production, which is necessary to reduce costs" (interviewee 2). Interviewee 7 commented that "there was a forestry incentive program that planted 27,000 hectares, but we should at least reach 150,000 hectares in the short term. He also says that: There are only advantages here. Our forestry cycles like eucalyptus, where you can produce on the coast with cycles of 6 to 7 years, no country in the world can do that. Pine in Finland or in any of the Nordic countries takes 30 or 35 years, here it can take 15 years. However, "although tree growth is faster here, there is a reduction in wood strength" (interviewee 8).

Regarding the manufacturing process, it was commented that "none of the materials used to make the glues are domestic products; they have to be imported and are very expensive. I understand that most of them are petroleum derivatives" (interviewee 5). According to interviewee 4, "the process of treating it is very delicate, drying must be done technically, as well as eliminating fungi and using chemicals for preservation". Interviewee 7 mentions that he does not believe there is a problem in manufacturing. It is a relatively simple process. What you do in the end is to take sheets/boards from the unrolled trunk, which you then join together to make a solid beam.

Regarding implementation, it was stated that "it is necessary to industrialize in order to improve time, quality and obviously costs". He also considers that, "in terms of construction, wood has all the advantages; you don't need a very large infrastructure" (interviewee 3). According to interviewee 9, "foreign technology is needed in the factories for the wood curing and processing process".

One of the most important things is the labor force. Here, there is indeed resistance to the use of new materials, which may also be due to the lack of necessary training for the installation or maintenance of this type of system" (interviewee 6). Interviewee 4 adds that: "to qualify labor, it is necessary to invest time in specializing it, as workers are often reluctant to undergo training.

For maintenance, it is necessary to consider that "the material used will depend on the sector, the environment and the culture in which it is worked" (interviewee 10). For example, "wood bleaches brutally here in Ecuador; UV rays are the main problem in the equatorial zone" (interviewee 6). Thus, interviewee 3 comments that "the material must be easy to maintain; moths, other pests and everything that affects these elements are habits to consider for maintenance" (interviewee 6).

Regarding the strength of the material, interviewee 1 believes that "the advantage of laminated wood is that you can achieve pieces with much greater strength, and you can improve the design. Therefore, it seems to me that if its use is not widespread, it is due to lack of knowledge". For this material to be used, interviewee 9 states that "it is important that the product complies with safety standards so that the builder feels comfortable". It should also be taken into account that "as we are in a strong seismic zone, the resistance of wood in this type of construction systems should indeed be promoted" (interviewee 6).

Regarding fire and weather resistance, interviewee 3 comments that: it is not that the structure will not be damaged in a fire, whether it is made of concrete or steel. The steel structure collapses because it melts in a fire. The important thing is how much time I give people to evacuate. We have to see if this option can be implemented both on the coast and in the mountains, whether it is multi-climatic or not. What really happens is that we generate a housing solution and we want to implement it everywhere.

4.2 Cultural limitations of the construction industry

On the one hand, interviewee 7 mentions that "the first problem is cultural. That is the essence: we are not used to using wood for construction. On the other hand, interviewee 3 comments that "here, it was a pity that we had a culture of wood and it was lost". In his experience, interviewee 7 affirms that particleboard was not even 5% of the components of a house. Today it turns out that there are more teachers who know how to work with boards than solid wood. This is because we have become culturally familiar with particleboard.

Then, to speed up the acceptance process, interviewee 3 recommends: make a show where you can see columns, beams, walls, everything, and show people that it works. Then talk to the architects, who have this vision of sustainability and maybe they really like noble materials, and they can offer it to their clients. The formal issue should be addressed by the guilds, the professionals, and the designers, perhaps through awareness marketing, so that people start to listen and say: it is interesting that I can do this and that. In the informal sector, where our workers are, they build with what they know. That is why you will see that 99% of them are made of concrete and blocks, but maybe if they had worked in companies with wood, they would no longer be blacksmiths or masons, but carpenters.

Plantation management also has an important cultural component

It turns out that the forestry issue has not had the necessary momentum. It has not only lacked the impetus, but has also encountered a series of barriers. Society does not understand that if you plant a hectare of corn, what controls and permits restrictions do you have? None. It should be the same in the forests (interviewee 7).

It should be mentioned that "it is important that people understand that the way to have forests is for someone to consume those forests, but of course, the bad thing about forests is that if you don't take care of them they are garbage" (interviewee 1).

As for the client, "if you don't have certain basic issues for people resolved, their priorities will be different" (interviewee 3). In any case, he asserts, "it is important that, throughout the chain, everyone is aware of the environmental issue and that it is not only the consumer who asks for an environmentally friendly product. One of the most important points highlighted by interviewee 9 is the ability of professionals to sell the product. "Professionals can understand the benefits of a good product, but convincing the customer is another thing. Generally, people are not going to take a risk and spend their money on a product they don't know." For this reason, he says it is important to give builders reliability. If it is a good product, with good advice given and guarantees provided, I think there should be no problem.

It should also be emphasized that "in our profession, it will always be very important to have alternatives; we are not always going to work with concrete or steel, which is the usual" (interviewee 4). However, he also comments that it is very difficult for our colleagues, both engineers and architects, especially those who are already somewhat advanced, to change their mindset and introduce new teachings. According to interviewee 9, "there are many professionals in this industry who like to innovate".

Finally, there were some mentions of the influence of the aesthetic and visual component on culture. "I use and have used the different derivatives that have to do with wood, such as, for example, the pleasure, the pleasure of being in an environment that meets aesthetic conditions, not only functional, but also aesthetic and pleasant" (interviewee 5). For interviewee 1, "the way is to sell the advantages of wood as a healthy house; it is much more beautiful or much more pleasing to the eye". However, for interviewee 3: It will be very a very specific customer who wants his house, his industry or his building with this type of material. It will be, perhaps, for an aesthetic concept more than for an economic concept. So, if you consider all these things, it is already a material that can easily compete with steel and concrete.

In addition, interviewee 9 considers that "wood is very noble and has many advantages. Among them, if you can have a good finish in wood, you don't need other expenses that are required in concrete and steel."

4.3 Market constraints

The size of the market is another issue on which much more emphasis was placed. "One of the big problems we have for the introduction of this material at the moment is that there is no demand for it" (interviewee 2). In addition, interviewee 3 mentions that "you have two very large industries that consume a lot of wood, and what they make is playwood, MDF". Interviewee 5 reiterates: Look, I think that in the first place, you have to calculate the possible demand. The possible demand is not to find out if people like or dislike it; they will like it if you manage to have a product that meets their interests, architects will be happy to design houses with that material if it is available.

In addition, interviewee 7 confirms that "the degree of technification depends on the volumes you expect to sell with that product. That is where I find the problem - the limiting factor is the market" (interviewee 3). As for the economic capacity of the population, "for a material to be used here in Ecuador, it must not be expensive. That will generate a prohibitive issue" (interviewee 3). However, interviewee 5 says: "I don't think the objective is to see how to minimize the cost so that it replaces cement. I think that designers can develop more and more interesting shapes with new materials and the industry should support that". Interviewee 3 believes that: Construction must be industrialized. Labor is becoming more and more expensive and these 25 dollars that the government raised this year are going straight to the vein of all projects. Next year it will be another 25 and so on. In addition, any material that has to be imported is complex, and all steel materials such as the rods of certain elements need to import scrap. Cement also needs labor because you have quarries to exploit. So, the fewer processes, the less labor and the more industry. In theory, we should have a more economical product and that is where any construction system should go.

Finally, interviewee 9 believes that "the wood used here in construction is expensive, difficult to treat, and often is in a closed season because it is difficult to replace. Pine, on the other hand, is not used much in structures, which would be good because it would reduce costs.

4.4 Limitations by control entities

The interviewees agree that, for the market to develop, it is necessary to have laws that support the entire process. According to interviewee 4, there is a need for "a control entity that is concerned about doing things right in logging. For example, "Quito's metropolitan forests are beautiful, but they are very prone to fire, they are poorly managed, and even their timber potential is wasted" (Interviewee 1). This is supported by the following comments: "there are many ways to efficiently manage forest plantations, but here is the big 'but' of Ecuador: it does not have a strong public policy to deal with these plantations" (interviewee 2). "We don't have an inventory of the forest in Ecuador, we don't know how much wood there is. The Ministry of Agriculture and the Ministry of Environment, which are linked to this issue, do not have management plans for this" (interviewee 5).

When you make a forest plantation you have to inform the Ministry of Environment. When you want to cut, you have to report and ask for a cutting permit. When you want to transport, you need a permit to transport the wood. So society still does not understand that plantations are a crop. On the one hand, there are no incentives and, on the other hand, there are a lot of brakes, but Ecuador has absolutely everything. (interviewee 7).

Interviewee 3 also mentioned that Ecuadorian regulations need to be updated. If you want to have an impact on formality, you have to go to the authorities so that they make the codes and you can design under the code the structure of solid wood, laminated, precast concrete, etc. To do that, you have to have the regulations. If you do not have the regulations, you will not be able to build because they will not give you the permits.

Regarding the environmental context, interviewee 2 confirms: Something extremely important is that Ecuador is part of the Paris Agreement and, precisely in that agreement, it is said that there is a 2030 agenda in which we must, as nations, reduce greenhouse gases. So, we are reducing by using this type of materials that at the moment absorb the greatest amount of CO_2.

This is supported by the following comment from interviewee 3: What does a tree do? A tree sequesters carbon. The moment you cut down a tree, you are not yet releasing carbon. The moment you make a beam or a column, you are not releasing carbon. The moment you release carbon is when you throw it away to rot or burn. In the case of cement, for example, in clinker (Portland cement), the process requires a lot of energy, so you release carbon. In the case of steel, since the iron was captured in the mine and then the steel was made, a lot of energy is used, and then you release carbon.

Interviewee 7 comments: Environmental problems? No, quite the contrary, because any of the forestry plantations by concept are environmentally friendly. The timber industry is one of the few industries that can show a neutral carbon footprint. All the pollution or CO_2 absorption that wood has versus concrete or any metal or steel product has an abysmal difference. So, environmentally, it's only positive.

Interviewee 9 believes that: If a plantation is subject to environmental control and its production can be recycled, then I don't think there will be any problems. Some areas in the mountainous regions of Ecuador have experienced this situation, and if too many trees are planted, it may destroy a lot of land. Although trees capture a lot of moisture, they also absorb a large amount of water and do not leave enough water to grow other products. Therefore, it is necessary to analyze the land to avoid affecting other types of plantations

5. Discussion

At first glance, the interviewees mentioned an important fact about the production of raw material or forest mass in the country, namely that there are not enough trees (conifers) to mass produce the product. One of the reasons why Ecuador has not exploited its forestry potential is the lack of willingness and interest on the part of the controlling entities. This has led to a lack of knowledge of forestry characteristics, as well as inefficient processes that hinder the forestry production chain, which is not the case in other agricultural sectors. However, Ecuador has very competitive characteristics in terms of forest plantation cycles that represent an advantage in terms of production time.

The indiscriminate logging of native trees has fostered the misconception that all logging is environmentally detrimental. However, these controlled plantations are a different case. They must be managed carefully and adhere to reforestation cycles. It is important to note that the expansion of such plantations can have an impact due to their high water consumption, potentially affecting other types of plantations. Nonetheless, there is a consensus among those interviewed that, when compared to the environmental impact of other construction materials like concrete and steel, the impact of these controlled plantations is positive.

In terms of manufacturing, a process must be in place to quantify the physical capacities of the wood and to be able to use it for different purposes. It is also necessary to have a skilled labor force to handle the machinery needed to mass produce the manufacturing process. These machines must be imported, which makes training more difficult and makes the initial investment more expensive. Both the interviewees and the literature agree that, in reality, this is not a complex process, since it does require industrial machinery, but it is quite common. A major drawback is that the adhesives for assembling the parts that meet the requirements are not produced in the country, so they have to be imported, which also increases the cost of the final product.

According to the literature, the construction process is simple, since practically all the pieces are prefabricated and their installation requires basic carpentry skills. However, interviewees have diverse opinions. Some claim that upgrading to this method is tedious and no time or money will be invested in training employees. Others believe that there will be no problems because of its ease of transportation and assembly versus other methods. One issue that arises is the reaction of wood in different climates, which may require different treatments.

Regarding the economic issue, it is essential that the starting price should be competitive, as this will be one of the most attractive aspects for its introduction in the Ecuadorian market. This is important because in the coming years, there will be an increase in the cost of labor, which favors construction systems with prefabricated elements and quick assembly. Therefore, it is crucial to increase the efficiency of the construction process, in order to reduce costs and make it attractive for both formal and informal use in Ecuador.

As there is no large supply or demand in the country, some interviewees suggested that this product should be implemented first in simple social housing so that both the public and professionals become familiar with it and the initial investment is less risky. In addition, this material should be exhibited at construction fairs so that professionals are aware of its physical, mechanical, aesthetic, and other characteristics and can promote it to their clients. It should be emphasized that the aesthetic characteristics of the material are one of its greatest advantages, because it is pleasant for customers and also benefits the builders, because of the savings in finishes. This can compensate for the economic gap compared to other construction systems.

Labor and maintenance are essential to make their long-term use attractive. In terms of maintenance, the greatest threats described by the literature are: humidity, pests and fire. For the interviewees, humidity and pests were an issue of concern; while fire was an aspect they considered even less risky than in other construction methods. The opinion of the

general public may differ from that of the professionals, as the public is generally unaware of their capabilities. An issue highlighted by the interviewees, which was not given much importance in the literature, was UV discoloration. These rays have a greater impact in the equatorial zone and most of the countries that use this material are in the temperate zones (north and south) of the planet. Because of these characteristics of wood, it is important to keep in mind that the maintenance of the structure depends on the conditions to which it is exposed.

6. Conclusion

The main limitations for the implementation of glulam in Ecuador are: the updating of the Ecuadorian construction standard, obstacles and lack of incentives from control entities, the need to import machinery and training, and the industrialization of the material to make the construction system economically competitive. It was observed that there is a genuine interest among professionals in the use of new environmentally friendly materials to reduce the impact of this industry. Consequently, it can be suggested that this material is a potential solution to reduce the high CO_2 emissions in the industry. However, in order to mass-produce the product, it should be understood that the environmental benefits are irrelevant compared to the economic competitiveness of other construction methods. This preliminary study aims to identify the technical, cultural, professional, political, and regulatory conditions that may pose impediments to the introduction of a new construction system in Ecuador. This will pave the way for further research that will help determine the feasibility of implementing solid wood in the construction industry, as well as conducting studies on the environmental and economic consequences of the mass implementation of this material in Ecuador.

Contribution of the Authors

Patricio Zaldumbide and Emir Fuentes contributed equally to the article as first authors in the conceptualization, writing, methodology, research, discussion and results; Miguel Andrés Guerra, principal investigator (PI), contributed to the methodology, review and editing of the article.

Conflicts of Interest

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