Proposal of a building material passport and its application feasibility to the wood frame constructive system in Brazil

M R Munaro¹, A C Fischer¹, N C Azevedo¹ and S F Tavares¹

¹ Department of Civil Construction Engineering, Federal University of Paraná, Centro Politécnico, Jardim das Américas, mail box 19.011, zip code 81531-980, Curitiba - PR, Brazil
munaro.mayara@gmail.com

Abstract. Implementing practices for a circular economy transforms the way companies do business. Obtaining and processing systematized and optimized information facilitates decision making in order to innovate, create value and adopt measures to promote energy efficiency and sustainability in construction. Building Materials Passports (BMPs) are tools for inserting circular economy in buildings. They can be crucial in managing and providing information to stakeholders in industry value chains, with the aim of promoting the construction of more sustainable and resilient cities, where materials are identified in a database, removed and reused in order to maintain, recover or even increase value and useful life. This paper presents a proposal of a BMP applied to the wood frame system in Brazil, introducing the following guidelines: general information, safety, sustainability, use and operation, assembling directions, reuse and product service history. A case study was developed in a Brazilian company in order to test the application feasibility of the tool to the system. There were some barriers found in the development of the BMP regarding LCA data, as well as the end of life information of the material. This attempt to implement the BMP encourages practices of circular economy in the construction industry and, associated with the expanding use of wood frame in Brazil, contributes to flexible and renewable buildings. In addition, the main challenges for the introduction of BMP are discussed, emphasizing the need for joint action based on political initiatives and regulations that allow and facilitate circular practices in construction.

Keywords: building material passport, wood frame, circular economy, bank of materials, built environment.

1. Introduction
The wood-based panels global market has been estimated at $ 91.05 billion by 2016 [1]. The low cost associated with properties such as high strength and durability of this type of material result in high demand from the construction industry. Brazil is among the countries with the most advanced manufacturing processes for wood panels from planted trees [2,3]. In 2016, the country was responsible
for the production of 6.4 million m³ of lumber and 7.3 million m³ of reconstituted wood panels, being 
the eighth largest producer in the world [2].

The wood products chain can make crucial contribution to the development of more sustainable 
built environments along with the construction industry, which is already the largest consumer of resources 
and raw materials and represents more than a third of the total energy consumed in the world [4,5]. 
Therefore, the adoption of construction systems that minimize waste at the construction site and that use 
renewable materials are alternatives to reduce environmental impacts. The use of planted forest wood is 
an option. Wood is a recyclable, renewable and biodegradable material, which sequesters carbon from 
the atmosphere and that demands low energy consumption in its production process, thus being 
considered an environmentally sustainable material [5,6]. Wood is a suitable material for the 
industrialization of elements to facilitate their transportation and assembly [6,7]. In addition, wood 
construction is associated with cleaner construction, as well as lighter and more flexible buildings.

In countries such as the USA, Canada, Germany and Japan, timber constructions are used on a large 
scale. In the USA, more than 80% of homes are built with the wood frame system [6]. In South America, 
Chile and Venezuela invest in the use of wood frame and prefabricated roof trusses for popular housing 
[6,7]. In Brazil, the wood frame is expanding. The system has been in process of standardization since 
2016, and the standard is expected to be sent for national consultation still in 2018 [8]. By 2016, the 
country had about 22 wood frame manufacturers [7]. Among them, the company Tecverde is a reference 
in prefabricated houses, offering the possibility of customization and exclusive production houses [9].

The light wood frame consists of a durable industrialized construction system. It is structured in 
treated wood profiles which form floor, wall and roof panels that are combined with and/or coated with 
other materials in order to increase thermal and acoustic comfort, besides protecting the building from 
weathering and against fire [6,7]. The wood frame flexibility, as well as its reuse and recycling 
possibility corroborate with the concept of circular construction, based on circular economy (CE), where 
buildings are explored as material banks, changing the way material flows need to be managed. In this 
context, the BAMB (Buildings as Material Banks), a project initiated in Europe in partnership with 
institutions from eight countries, entails a new approach on the value of materials and construction 
products by considering buildings as temporary material storage [10].

Circularity will provide a pathway to more sustainable and resilient cities. According to Ellen 
MacArthur Foundation [11], CE is a restorative or regenerative system, whose purpose is to keep 
products, components and materials at their highest level of utility and value. The BAMB project aims 
at systematic change in the construction industry by investigating and creating circular solutions to 
preserve the value and functionality of building materials and systems, enabling their reuse [10]. This 
concept is being added to the value chain of construction through instruments, such as the material 
passports and the reversible building design.

The building materials passport (BMP) is a set of data and indicators that describe characteristics of 
materials or systems, aiming to give them value for recovery and reuse [12,13]. It presents the material 
history documentation, such as information provided by the manufacturers and conditions of the 
material after use [14]. Therefore, it is a tool to incorporate data and information as a support for the 
circularity, focusing on the recovery at the end of life and the value maximization of the materials [12].

While glimpsing the above scenario, it is important to emphasize that management and access to 
information is fundamental to improving the quality of buildings and the construction industry. 
The implementation of circular directions and practices to obtain and process information in a systematized 
and optimized way will facilitate the decision making of the stakeholders, creating opportunities for 
sustainable innovation in construction. Under these circumstances, this paper presents a building 
material passport proposal applied to the wood frame system in order to provide the necessary 
information for the development of this mechanism, as well as to stimulate the practice of the CE in the 
Brazilian civil construction. For this, a case study was developed based on free access information 
provided by a Brazilian company specialized in the wood frame construction system.

The article presents a brief contextualization of the Brazilian wood frame system. Then, in the 
method section, the material passport concepts and a BMP model are introduced, indicating the
necessary information which should be included in the tool in order to retrieve and reuse the materials. Later, the BMP model is applied to the case of a Brazilian company specialized in the wood frame system, where it was possible to analyze information gaps for the application of the tool. In addition, obstacles were highlighted in the implementation of the BMP in the built environment.

2. The wood frame context in Brazil

Although wood is among the oldest building materials in the world, its use as a structural element in Brazil is still surrounded by unawareness and often linked to deforestation of preserved green areas [6,15]. Brazil presents many barriers, especially cultural ones, in relation to wood constructions, since it adopted the reinforced concrete and masonry as conventional constructive technique. According to Brazilian Institute of Geography and Statistics (IBGE), the percentage of wood buildings in relation to the total buildings in Brazil decreased dramatically from 20.2% in 1970 [16] to 4.6% in 2017 [17]. In early 2010, the wood frame began to be applied in the Brazilian construction. The advantages of this system caused researchers to adapt the techniques to the national level [18].

In 2011, through an initiative from the Brazilian technical community, the wood frame underwent an evaluation process and a guideline was created for its technical evaluation. The guideline is named “Constructive systems structured in light pieces of solid lumber, with wood sheathing” and it was created by the National System of Technical Assessment (SiNAT), which is a project of the Ministry of Cities to provisionally provide guidelines and evaluate products not covered by existing national technical standards [19]. Since then, the aforementioned document, also known as SiNAT Nº 005, establishes the guidelines for the characteristics and technical performance of the light wood frame in Brazil.

In Brazil, according to SiNAT Nº 005, structural lumber and the Oriented Strand Board (OSB) form the wood frame system. Due to hot and humid climate of the country, the wooden structures should receive a preservative treatment so that the wood is resistant to the attack of xylophagous organisms, thus increasing its durability. The external sheathing components may consist of chemically treated OSB or plywood panels, along with cementitious panels. For the internal sheathing, in addition to the wood panel options, it is necessary to apply a gypsum plasterboard. As for thermal insulation, rock wool, glass wool, expanded polystyrene (EPS) board or other material with equivalent properties can be used. As for waterproofing, it is necessary to apply a waterproof membrane. As for finishing, siding or mortar coating with paint and texture can be applied.

The wood frame system not only boosts the construction sector, but also the whole industry related to the wood chain. Sotsek and Santos [15] reported that the expansion of this system in Brazil is strongly dependent on government incentives, on the integration of civil construction value chain and the wood sector, on the dissemination of more information to reduce prejudice regarding the use of wood, as well as on the need to instruct professionals to work with wood construction. Despite these challenges, the system is seen as a promising market due to the favorable conditions found in the country [6,7].

3. Method

Considering that the goal of this study was to propose a BMP model, this article was divided into two sections. Firstly, the important information that should be included in a BMP was defined and then a model was proposed. Later, in order to analyze the feasibility of the application of this model, the case of a Brazilian company specialized in the wood frame system was selected.

3.1. Proposal of a Building Material Passport (BMP) as a circular tool

As circular economy promotes the potential for recovery of materials, products and systems, the collection of useful and reliable data and information is necessary. Unfortunately, current methods and documents, such as Environmental Product Declarations (EPDs), quality declarations, security measures, lists of material and substances, performance properties, partially meet those needs [12].

The data and information stored in a BMP must be purposeful and accessible to users. They must communicate the level of information related to a product in a living and dynamic document that can suit the stakeholders according to their needs [20]. It is a tool to track value at all stages of the material
life cycle, so knowledge of the material value chain as well as its Life Cycle Assessment (LCA) is critical. In this sense, the BMP is capable of driving innovation by providing project orientation in the choice of materials and creating incentives for stakeholders to produce in a more sustainable way, and to transparently communicate the circular value of their products so that they can be reused [10,12,13].

The passport must be the connection between information and the element/material [14]. It must contain information on quality, safety, sustainability, use and operation, disassembly, reuse potential, history of checks and traceability of materials, as exemplified in Figure 1.

| Product tracking code: | Building Material Passport (BMP) | Sections description |
|-----------------------|---------------------------------|---------------------|
| **1 General data**    |                                 | Comprises the manufacturer/supplier data, the general description of the material/system, composition, recommendations and restrictions of use, performance requirements and criteria intended use period. |
| Product/commercial name | Use recommendation/restrictions  | Compromises use, performance characteristics |
| Composition/materials | Technical data (strain/weight)  | |
| Manufacturer/supplier |                                 | |
| Use period/time        |                                 | |
| **2 Security measures (safe data sheets)** |                                 | Indicates safety information from material receipt to its disposal; |
| Security information (warnings/recommendations) | Handling and storage instructions | |
| Toxicological recommendations |                                 | |
| Risk identification/fire protection |                                 | |
| **3 Sustainability**   |                                 | Involves LCA and environmental product declarations, the methodology used, the results and interpretation. |
| Environmental declaration | LCA results and interpretation | |
| Life cycle assessment (LCA) |                                 | |
| LCA boundaries and methodology |                                 | |
| **4 Use and operation** | Assembly instructions | Indicates the positioning and location of the material in the building; assembly instructions; maintenance and cleaning; connections details and systems requirements. |
| Positioning and location in the building | Maintenance and cleaning | |
| Connections details and requirements |                                 | |
| **5 Disassembly guide** | Disassembly instructions (removal/replacement of pieces) | Provides instructions for disassembly, removal, replacement of the pieces and components of the material/system. In addition, indicates best practices regarding transportation and storage. |
| Transportation and storage instructions |                                 | |
| **6 Reuse potential**  | End-of-life considerations (reuse/recycling/remodeling) | Provides information regarding the reuse, refurbishment, recycling potential as well as disposal considerations at the end of life of the material. |
| Disposal options |                                 | |
| **7 History**          | Use period | Covers tests and verifications carried out during the material or system life, indicating its use period, past uses, operations, as well as its current state. |
| Verifications made during use | Latest uses/operations | |
| **8 Other information** | References used/standards consulted | Indicates sources, references and standards consulted, as well as details and descriptions of information used in the development of the passport. |
| Complementary material |                                 | |

**Figure 1.** Proposal of a building material passport indicating the necessary information.

The data contained in the BMPs will be obtained and constantly updated by the parties involved in the material value chain. For example, the designer will specify qualitative and quantitative data; the supplier, security, sustainability, use, reuse and operation aspects; the leasing, tracking, assembling, and testing of the material/system will be the builder or specialized team responsibility. The management of this information may be performed by Building Information Modeling (BIM) [12,14]. It is important that the information is available at an accessible and identifiable database when the code or ID of any element of the digital construction model is inserted into the database [14].

### 3.2. Case study definition

As previously stated, Brazil has not developed an official national standard for the wood frame yet. Therefore, the SiNAT Guideline Nº 005 was created to present a technical evaluation document establishing the minimum requirements for the application of the system. This guideline provided the basis for the creation of a Technical Assessment Document - DATec - that certifies a system after material testing, according to the SiNAT [21]. The achievement of a DATec document occurs when the proponent requests the evaluation of their product of interest at an Evaluation Technical Institution [19].
In light of this, the company Tecverde, which has a technological solution for the wood frame, adapted to the Brazilian reality, proposed its DATec 020 - Tecverde Light Wood Systems [22]. This document describes the entire system including the materials used, technical tests carried out and constructive details. The main materials used by Tecverde are dried Pinewood treated in autoclave; OSB panels; gypsum plasterboard (internal walls); cementitious board (external sheathing); glass wool and a waterproof membrane. The structural pieces of wood come from planted forests of *pinus sp.*, mainly *taeda* and *elliottii*. The chemical preservative treatment is made of Chromated Copper Arsenate (CCA) in order to guarantee durability of more than 50 years.

Based on the aforementioned pieces of information, in order to analyze the application feasibility of the proposed BMP model, the technology of the wood frame developed by Tecverde, as described in DATec 020, was selected as the case study.

4. Application of the BMP model to the selected case
The application feasibility of the BMP model proposed was studied for the Brazilian wood frame system. It was conducted based on the available information in free access documents by the Tecverde company. Table 1 shows the information covered by the passport and the data obtained. Much of the information was obtained at DATec 020, other in support materials made available in the Tecverde database, and historical information in the SiNAT Guideline Nº 005.

The data related to the sustainability, disassembly and reuse guidelines items were not obtained in the documents and materials consulted and were identified as gaps in the elaboration of the BMP, since they are essential requirements for the circularity of the wood frame. Sustainability reports, LCAs, EPDs and environmental licenses are examples of documents that can be used to obtain information for BMPs.

| Passport requirements | Obtained information                                      | Source       |
|-----------------------|-----------------------------------------------------------|--------------|
| 1 General data        | Product description; manufacturer; composition of the system; recommendations/restrictions of use; technical evaluation; structural performance; impact resistance; resistance to xylophagous organisms; watertightness, thermal and acoustic performance; system durability | [22]         |
| 2 Security            | Fire resistance; reaction to fire evaluation               | [22]         |
| 3 Sustainability      | -                                                          |              |
| 4 Use and operation   | Implementation/execution procedure; transport; assembly process; methods of component evaluation | [09, 22, 23] |
| 5 Disassembly Guide   | -                                                          |              |
| 6 Reuse               | -                                                          |              |
| 7 History             | The requirements for the evaluation of the material and components characteristics of the wood frame system are indicated in Sinat-005/2017 | [19]         |
| 8 Other information   | Information sources; complementary technical documents     | [22]         |

5. Discussion
Regarding the general data required for the passport, the company does not disclose the suppliers of the materials, which impairs obtaining information for some subsequent items, such as item 3, Sustainability. The DATec document mentions that the wood materials come from planted forests and have environmental certification. However, in Brazil, suppliers are not yet required to create EPDs that disclose more detailed product information, particularly in relation to impacts obtained through LCA studies. Therefore, studies that address the life cycle analysis of all wood frame components are lacking.

The lack of information on disassembly and reuse at the end of life of the wood frame components brings about a great challenge to the stakeholders on implementing principles of circularity in the construction chain. Consequently, the creation of new business models focused on the possibilities of reuse of the system components according to its specific conditions is also impaired. It should be noted, therefore, that the system is not yet designed for the reuse or recycling of its components at the end of its life cycle. Diyamandoglu and Fortuna [24] analyzed the greenhouse gas (GHG) emissions reduction
and energy savings in the deconstruction of wood frame houses for resale purposes, pointing out the recycling scenario in reducing GHG. Other forms of reuse address:

- reinstalling elsewhere in the building for the same use;
- reusing as is in another product or for another purpose;
- disassembling and reusing in other buildings;
- disassembling and reconditioning for reuse (change waterproofing and coating/finishing);
- sending the components for recycling.

Another end-of-life issue is that the wood components applied in the Brazilian wood frame receive either a CCA or CCB (Chromate Copper Borate) preservative treatment. For some European countries, waste containing these chemicals is considered hazardous and its destination follows strict legislation [25,26]. Yet, in Brazil, both the use and the disposal of treated wood are not given the necessary importance. The Resolution 307 by the National Council for the Environment (CONAMA), which establishes guidelines for the construction waste management, does not differ the natural wood residue from the treated wood one [26]. This resolution needs to be updated in order to reclassify this residue due to the environmental danger it represents [26]. The reuse or recycling of the wood components applied to the Brazilian wood frame need to take into account the type of treatment they receive in order to reduce the environmental impacts of chemical compounds at their end of life and, consequently, to reduce the use of industrial landfills, creating opportunities of business models for recycling [28].

The separation of wood frame components increases reuse and recycling possibilities. Lepage [28] suggests as reuse potentials of treated wood:

- extension of the life cycle with periodic maintenance;
- reuse of discarded wood in the manufacture of other goods;
- incorporation of the discarded wood or its leftovers in composite materials;
- pyrolysis of treated wood by the "Chartherm" process, already available on an industrial scale and capable of operating with any contaminated or non-contaminated wood waste;
- disposal in legalized class I industrial landfills (hazardous industrial waste).

### 6. Challenges of the BMP in the built environment

The introduction of the BMP in construction can make easier the understanding of the complex and multidimensional nature of materials, products and systems. This tool can generate opportunities for stakeholders involved in the productive chains by providing guidance to projects; clarity and authenticity in information; increasing the traceability of materials; facilitating handling and repair operations; reducing the environmental impacts and by providing comfortable and more sustainable environments for users [10,12,13,15]. However, there are many barriers to achieving this paradigm shift in the construction chain. Table 2 presents the main challenges for the insertion and implementation of the passport of materials in buildings as material banks.

Although companies are the primary means to promote change to a CE, governments are instrumental in facilitating or restraining this transition. A systemic reformulation of the production and consumption model requires alignment between supply and demand, being that governments need to shape market conditions [30]. A restructuring process of the built environment is necessary in order to link existing and emerging design principles and approaches to construction, in a collaborative and comprehensive way by the circular functionality of the entire value chain.

**Table 2. Main challenges for the implementation of BMP in buildings as material banks.**

| Challenges                                      | Related aspects                                                                 | Source          |
|------------------------------------------------|-------------------------------------------------------------------------------|-----------------|
| POLITIAN                                        | Complex and fragmented supply chain                                           | [10,11,12]      |
| Complex and fragmented supply chain             | The lack of integration of the construction segments can increase the wastage and costs of buildings, and jeopardize deadline fulfillment | [10,11,12]      |
| Conflicting environmental and energy policy measures | Prioritization of energy efficiency and high-energy performance of buildings can result in construction projects and materials that are not suitable to deconstruction and reuse | [10]            |
7. Conclusion
The article explored possibilities of creating value in the built environment by associating the building material passport with the wood frame construction system, aiming at inserting circular principles in the value chains of the sector. This tool highlights the importance of data and information management as a possibility of innovation and creation of value. It also reconsiders the concept of waste to increase the usefulness of materials through the potential for recovery and reuse. It is important to emphasize that information on LCA and end-of-life studies are crucial to facilitate the reinsertion of materials into new business models. It is noted that there are many barriers to the application of the BMP tool in civil construction, which requires systemic thinking about value chains and flows, leading to increased collaboration between stakeholders and government support, based on laws and tax incentives, both of which are important to the transition to a circular economy.

Finally, the application of the BMP tool to the wood frame in Brazil would make it possible to add value to the materials used right now. In addition, it would stimulate circular thinking for this construction system since its inception, considering that it is still emerging in Brazil. The currently available data do not allow the full potential of the tool to be exploited and, in this sense, incentives to generate and make this information available could be required right away, for example through the wood frame standard that is under development.

8. References
[1] Grand View Research 2018 Rep. Wood Based Panel Market Size & Share, Industry Report, 2018-2025. goo.gl/hjnwYd. Accessed 02 sept 2018
[2] IBA 2016 Brazilian Tree Industry. Report 2017 (Brazil: IBA) p 80
[3] Ferro F S, Silva D A L, Lahr F A R, Argenton M and González-García S 2018 J. of Cleaner Prod. 185 710-9
[4] IEA 2013 International Energy Agency. Transition to sustainable buildings (Paris: IEA) p 290
[5] Tonelli F, Evans S and Taticchi P 2013 Int. J. Bus. Inov. Res.7 143-63
[6] Molina J C and Junior C 2010 Conf. Exact and Technological Sciences (Londrina) 31 143-56
[7] Araújo V A, Cortez-Barbosa J, Garcia J N, Gava M, Laroca C and César S F 2016 Rev. de la construcción 15 78-87
[8] ABNT 2018 Associação Brasileira de Normas Técnicas Wood Frame Study Committee resumes activities. goo.gl/LT2H83. Accessed 24 sept 2018
[9] Tecverde 2018 Business Models. http://www.abnt.org.br/noticias/5789-comissao-de-estudos-de-wood-frame-retoma-atividades. Accessed 22 aug 2018
[10] BAMB 2018 Building as Material Banks. Rep. D1 Synthesis of the state-of-the-art p 103
[11] EMF 2015 Ellen MacArthur Foundation. Rep. Growth within: a circular economy vision for a competitive Europe p 98
[12] Luscure L M 2017 J. Waste and Resource Management 170 25-28
[13] Luscure L M 2016 Conf. Sustainable Inovation (Eindhoven) 176-9
[14] 3XN ADEPA 2016 Building a circular future (Denmark: GXN Innovation) p 284
[15] Sotsek N C and Santos A D P 2018 Ambiente construído 18 309-26
[16] IBGE 2018 Brazilian Institute of Geography and Statistics Estatísticas do século XX: Estatísticas populacionais, sociais, políticas e culturais. Habitação e infraestrutura. Prédios - por tipo de material da cobertura, segundo a si do piso — 1970. https://goo.gl/hTUwg. Accessed 30 sept 2018
[17] IBGE 2017 Brazilian Institute of Geography and Statistics Pesquisa Nacional por Amostra de Domicílios Contínua - PNAD Contínua. https://goo.gl/Br6ppr. Accessed 15 may 2018
[18] Espíndola L R and Ino A 2014 1st CLB-MCS 2014 (Guimarães) 209-17
[19] BRASIL, Ministério das Cidades 2017 Diretriz SINAT nº 005 - Revisão 02 - Sistemas construtivos estruturados em peças leves de madeira maciça serrada, com fechamentos em chapas - Sistemas leves tipo “Light Wood Framing” - (Brasília: PBQP-H) p 73
[20] EPEA 2015 Environmental Protection Encouragement Agency. Circularuty passport (Hamburgo: EPEA) p 11
[21] Espíndola L R 2017 O wood frame na produção de habitação social no Brasil (São Carlos: Federal University of São Paulo) p 331
[22] BRASIL, Ministério das Cidades 2018 DATec Nº 020-C - Produto "Sistema de vedação vertical leve em madeira - Tecverde” (Brasilia: SNH, PBQP-H, SINAT) p 49
[23] Moreira P V and Monich C R 2016 Rep. Panorama do sistema construtivo Tecverde (Curitiba: Tecverde) p 31
[24] Diyamandoglu V and Fortuna L M 2015 Resour. Conserv. Recycl. 100 21–30
[25] Ferrarini S, Souza H, Miranda L, Azevedo C, Pires R and Maia S 2012 Quim. Nova 35 1767-71
[26] Hoerlle C, Brehm F and Maciel E 2015 4th Conf. Innovat. and Technol. IFsul (Sapucaia) 1-15
[27] CONAMA Resolução n° 307 2002 Conselho Nacional do Meio Ambiente (Brasilia: MMA)p 95
[28] Lepage E 2010 Destinación Final de Madeira Tratada com CCA - Informativo Técnico (São Paulo: Montana Química) p 1-5
[29] WEF 2014 World Economic Forum. Towards the Circular Economy: Accelerating the scale-up across global supply chains (Geneva: WEF) p 64
[30] Accenture 2014 Circular Advantage - Innovative Business Models and Technologies to Create Value without Limits to Growth. https://goo.gl/YBpRfi. Accessed 30 sept 2018

Acknowledgments
The authors thank Universidade Federal do Paraná (UFPR), Programa de Pós-Graduação em Engenharia de Construção Civil (PPGECC), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for financial support.