Material Impact Passport

PRINCIPAL ACADEMIC TUTOR
Andrea Tuni,
Department of Management and Production Engineering, Politecnico di Torino

ACADEMIC TUTORS
Francesco Bruschi,
Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano

EXTERNAL INSTITUTIONS
BNext

EXTERNAL TUTORS
Nicholas Kaspareck

TEAM MEMBERS

Laura Ginestretti,
Biomedical Engineering,
Politecnico di Milano

Carolina Ludovici,
Biomedical Engineering,
Politecnico di Milano

Beatrice Pipperi,
Management Engineering,
Politecnico di Milano

Wendy Lorena Rodriguez Castro,
Architecture Built Environments-Interiors,
Politecnico di Milano

Chiara Torelli,
Architettura Costruzione Città,
Politecnico di Torino

Executive summary

The construction industry significantly contributes to global greenhouse gas emissions, primarily due to materials like concrete and steel. In response to the need for sustainable alternatives, the Material Impact Passport (MIP) was developed as a tool to accompany sustainable building products, ultimately aiming to **encourage the use of environmentally friendly materials like wood and mass timber** by enhancing traceability and making sustainability data more accessible and user-friendly. It features a unique database that leverages blockchain technology to securely embed social and environmental impact metrics of the items throughout their supply chain, from raw material extraction to final product distribution. In light of the increasing legislative focus on sustainability in the construction sector, the MIP not only facilitates compliance with key regulations, but it also represents a step towards greater transparency.

A survey and competitor analysis were conducted to validate and refine the MIP. The survey included architects, engineers, general contractors and private citizens, and helped identify the most desirable features to meet customer needs. The competitor analysis highlighted the MIP's innovative approach, as it goes beyond existing solutions, offering a holistic view of the entire supply chain and providing a comprehensive environmental impact assessment.

Each product with a MIP features a QR code that can be scanned to access sustainability information. **This includes a Carbon Footprint (CF)**, detailing the material's environmental and social performance across its lifecycle, **such as its geographical origin, the carbon sequestered, carbon emissions associated with production, processing, and transportation, energy consumption, logistics data, and social sustainability indicators.** The information provided is easily accessible for bio-based construction material companies, architects and engineers, but also consumers, via a user-friendly mobile interface.

A key feature is **blockchain technology integration**, to secure and ensure transparency of each product's data: once recorded on the blockchain, it cannot be tampered with, ensuring its integrity. Blockchain is exploited through **smart contracts**, which are automated programs triggering specific actions when certain conditions are met. At each supply chain step, the involved parties deploy a smart contract storing the product's data on the Ethereum Testnet platform, and then digitally sign it to verify the information accuracy. This transparency promotes more informed decision-making, empowering consumers and companies to choose sustainable products based on accurate, traceable data.

The MIP was developed through collaborations with **BNext**, an Italian wood panel manufacturer, and **Casa Congo**, an NGO supporting local communities in Nicaragua, which enabled prototyping and testing within a real-world context. A case study was conducted using BNext's Laminated Strand Board (LSB) panel: it included a CF assessment and the design of both a graphical interface accessible via QR code, and a **web page interacting with the blockchain.** The page processes the panel's data, calculates sustainability metrics through smart contracts, and then displays the results. This system ensures that the entire process is secure and verifiable, with all data and calculations managed on the blockchain.

The project culminated in a **mock-up** of the MIP mobile application, laying the groundwork for further development. Future steps include transitioning from the **Ethereum Testnet to the Mainnet, integrating carbon credits** to further incentivize sustainable practices, and **incorporating tokens** to scale the system for broader industry adoption.
Overall, the MIP represents a comprehensive, innovative solution to promote sustainable building materials and address the environmental challenges posed by the industry. By facilitating regulatory compliance, enhancing transparency, and empowering stakeholders to make informed decisions, the MIP has the potential to support this transition towards a more sustainable construction industry, aligning with both industry needs and public expectations for a greener future.

Can We Choose Sustainability?

Figure 1: Example axonometry of MIP application

Key Words
Sustainability, Construction industry, Carbon Footprint, Blockchain technology, Supply chain traceability

Project description written by the Principal Academic Tutor

The construction sector is a major contributor to global warming, being responsible for **17.5%-40%** of global greenhouse gas emissions according to different sources. The majority of these emissions arise in the construction supply chain, with 45% of emissions due to purchased goods and materials. The sector's ambitions to reach Net Zero objectives require a transformational change of the industry, which is hampered by multiple barriers including **the lack of sustainability data about materials** and the limited transparency of supply chains.

The Material Impact Passport (MIP) project thus developed a tool to **uniquely record the social and environmental information of construction materials along the supply chain.** The record can be easily accessed by a variety of users through a QR code. The MIP carbon footprint follows a **cradle-to-gate** approach, capturing CO2e sequestered and stored by forests as well as CO2e emitted due to processing, production and transportation. The MIP exploits **Ethereum blockchain technology and smart contracts** to securely ensure data integrity across different supply chain actors.

The project focused on renewable materials originating from forestry, as they are a sustainable building solution and display a favourable market outlook. Two case studies were explored to validate the MIP: **a MIP prototype** for a bamboo bookcase produced by the **NGO Casa Congo in Nicaragua** and a **web-based platform for the LSB panel** industrially manufactured by **BNext in Italy.** The case studies demonstrate the applicability of MIP into different contexts as an effective tool to support sustainability communication to stakeholders. A survey conducted with potential consumers and professionals working in the construction industry supported the refinement of the MIP and the integration of desired features by stakeholders.

Project description written by the Principal Academic Tutor

The MIP has the potential to increase traceability of construction supply chains, a highly desired feature, **well-aligned with upcoming EU regulations** on Digital Product Passports. The MIP advances the current sustainable supply chain management of construction industry by going beyond the certifications practices and unveiling the actual CO2e and social performance of products, which can incentivize a wider adoption of sustainable materials in the construction industry. Future developments can further increase the marketability of the MIP, including the possibility to **unlock carbon credits for the voluntary carbon market** and the transition from to the **Mainnet of Ethereum to ensure a fully integrated operation of the tool.**

Figure 2: User-friendly interface divided by sectors

Team description by skill

The project was led by a collaborative, interdisciplinary team that strategically divided tasks based on each member's area of expertise. This approach, combined with teamwork during key phases, enabled each member to contribute more effectively to the project, ensuring the project's success and laying the foundation for further developments in the MIP initiative. The team is composed of five members:

- **Laura Ginestretti**, enrolled in Biomedical Engineering, was designated as the Team Controller, responsible for communicating with tutors and the ASP board. She focused on the development of the MIP prototype, spending a month in Nicaragua, and on the creation of the MIP user interface.

- **Carolina Ludovici**, enrolled in Biomedical Engineering, was responsible for enhancing and supporting the data retrieval process in collaboration with BNext, as well as developing the blockchain infrastructure.

- **Beatrice Pipperi**, enrolled in Management Engineering, was responsible for enhancing and supporting the data retrieval process in collaboration with BNext, as well as developing the blockchain infrastructure.

- **Wendy Lorena Rodriguez Castro**, enrolled in Architecture Built Environments-Interiors, supported both Laura in the prototype development, focusing on the graphical aspects of the user interface, and Carolina and Beatrice in developing the blockchain infrastructure.

- **Chiara Torelli**, enrolled in Architettura Costruzione Città, supported Laura in the prototype development, focusing on the graphical aspects of the user interface, and conducted a feasibility study to evaluate the potential for integrating carbon credit calculations within the MIP.

  The team embarked on a collective effort to develop an **Excel file** that served as the foundation for the Carbon Footprint (CF) of BNext's primary product, the LSB panel, and **to create surveys** that were designed to gather feedback and secure the company's support and involvement in the project.

Goal

The Material Impact Passport (MIP) project aims to revolutionize sustainability in the construction industry by disclosing information on social practices and environmental impact of materials to consumers and professionals of the sector, incentivizing their choice for eco-friendly materials like wood and mass timber. **The primary goal is to develop a tool that enhances traceability and transparency of building materials supply chains**, democratizing data by transitioning from complex certifications to accessible and consumer-friendly information, while embracing consumer demand for sustainability. The MIP provides a secure and transparent record of a product's environmental and social performance, allowing for a comprehensive evaluation of its impact, from raw material extraction to final distribution.

In order to realize this tool, the **key objectives** the team had to reach were:

- **To collect raw data** from all stages of BNext's supply chain, an Italian wood panel manufacturer, which were essential to calculate critical metrics for the material environmental and social performance evaluation.

- **To create a publicly accessible dataset** tied to a specific unit of the material, allowing stakeholders like consumers and general contractors to easily report and assess the environmental performance of materials for eco-friendly choices.

- **To develop a MIP prototype** with all necessary features, ensuring ease of use and acceptance by BNext, the project's main stakeholder.

- **To conduct a feasibility study on associating the MIP with carbon credits**, enabling manufacturers to enter the voluntary carbon market, potentially lowering costs or boosting volumes by reducing the "green premium" on sustainable products.

- Finally, **to transfer the collected data to the blockchain environment**, to grant that the information reported are public, secure, and not modifiable.

Understanding the problem

Nowadays, the construction industry is facing several significant challenges that are more urgent than ever to address. Among the main ones, the environmental impact of materials used in the construction industry, the lack of traceability and certifications fragmentation in sustainable materials supply chain, and the increasing strictness of regulatory requirements for the building sector and its related products.

The construction industry is responsible for a huge amount of global greenhouse gas emissions, with an estimated contribution between 17.5% and 40%. The main portion of these emissions originates from the production and transportation of conventional building materials like concrete and steel, which dominate the market: **concrete accounts for around 55% of construction materials, steel makes for 25%, whereas sustainable alternatives like wood and bamboo represent only a marginal 12%.** Despite their significant environmental benefits—related to the ability of forests to sequester carbon—renewable materials remain underutilized. This low adoption is partly caused by the resistance from industry incumbents in the cement and steel sectors, who are reluctant to lose their dominant market position; at the same time, it is also due to a lack of a comprehensive tool that can highlight sustainable practices to consumers and citizens and ensure that these positive activities are rewarded.

Another core issue is that, despite the environmental benefits, the complex supply chains of bamboo and wood hinder their widespread adoption: since multiple actors and phases are involved, from sourcing and processing to distribution, **it is often challenging to accurately track the true environmental and social effects of these renewable resources.** Without a transparent system in place, both final consumers and professionals face difficulties distinguishing between sustainably sourced materials and those that are not, thus reducing the chance of adoption of these greener alternatives. Moreover, **sustainability certifications are fragmented:** each certification typically focuses on a specific dimension— whether environmental, social, or related to carbon emissions—without providing a holistic view. Additionally, these certifications are often **highly technical**, making them inaccessible and difficult to be interpreted by consumers. As a result, both consumers and companies struggle to make informed decisions about sustainable materials and to shift towards greener options.

Lastly, regulations are evolving to tackle these issues, but the new requirements aimed at solving them have introduced further obstacles for manufacturers. For example, recent European Commission regulations, such as **the Digital Product Passport (DPP)** that will be mandatory from 2026, require companies to disclose detailed sustainability data about their products. The aim is to improve transparency and traceability across supply chains by tracking and reporting the environmental impacts of materials from sourcing to disposal. However, **many companies are currently unprepared and may face significant challenges to comply with those strict requirements.**

Exploring the opportunities

Exploring the opportunities has involved a thorough competitor analysis and stakeholder survey. **The competitor analysis** revealed that while existing solutions such as Elision, Ympact, and Labgo focus on certifications, **they fail to provide transparency across the entire supply chain** and an overall assessment of a product's environmental impact. Current certifications in the construction sector are often inadequate, focusing on isolated segments and neglecting to deliver a comprehensive view of cumulative environmental impacts. This fragmented approach undermines their effectiveness in promoting sustainability and transparency. On the other hand, the MIP offers a more holistic solution. It goes **beyond traditional certifications by ensuring full transparency across the supply chain** and incorporating thorough impact assessments, thus fulfilling the sector's need for a unified tool capturing the complete environmental footprint of construction projects.

Feedback from the survey, which engaged **165 stakeholders including 138 private citizens and 25 professionals**, highlighted the need for enhanced traceability and user-friendly access to sustainability metrics. Over 90% of professionals and 87% of private citizens expressed that MIP would **significantly influence their decision to choose sustainable materials.** As a result, the survey analysis also led to the refinement of key MIP specifications, such as incorporating real-time carbon footprint data and geographical origins, alongside a blockchain-based mechanism to ensure transparency and immutability. **More than 90% of respondents also indicated their willingness to pay a premium for materials equipped with an MIP,** further validating the MIP market potential.

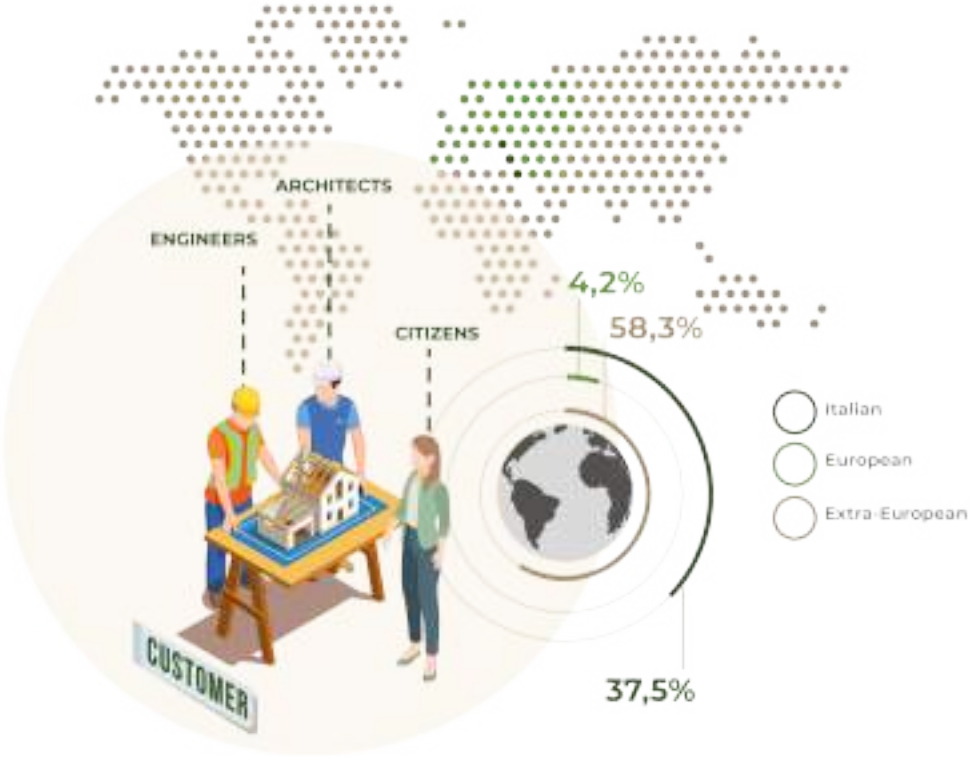

Figure 3: Target actors

Genereting a solution

The Material Impact Passport (MIP) was designed as a comprehensive tool aiming to track and provide sustainability data throughout the entire product lifecycle, offering transparency and accessibility for all stakeholders.

The core of the solution involves embedding a **QR code into products**, allowing users to access detailed environmental performance metrics through a user-friendly mobile interface, which includes several key sections, each corresponding to a supply chain stage. This data includes **the Carbon Footprint (CF)**, calculated using a Cradle-to-Gate approach that evaluates greenhouse gas emissions from raw material extraction, production, and transportation, measured in Carbon dioxide equivalents (CO_2e), as well as the geographical origin of the material, general product information, relevant from a commercial viewpoint, and social sustainability indicators, thus ensuring a full view of the product's environmental and social impact. Furthermore, the MIP system enables **document downloads** for stakeholders like general contractors, architects, and companies that require comprehensive data for reporting and analysis.

To guarantee data security and immutability, **blockchain technology** is integrated into the MIP, with **smart contracts** implemented to verify and record sustainability data.
This approach allows all participants—from upstream suppliers to downstream consumers—to trust the integrity of the data, while also providing a reliable record of the material's lifecycle.

Each blockchain participant—namely forest managers, manufacturers, and logistics operators—deploys and digitally signs a smart contract containing the product's data at the corresponding supply chain stage: forest management, production, and logistics. At the same time, **the MIP team deploys three smart contracts** with formulas and assumptions used to perform the Carbon Footprint (CF) Assessment, each correlating to its respective counterpart in the previous set of contracts. For example, the "Logistics Assumptions" contract is applied to the "Logistics" one to evaluate carbon dioxide emissions associated with logistics operations. The contracts are deployed on the **Testnet of Ethereum**, a well-established public blockchain platform, using the **Metamask wallet** to interact with it. All these features enable the MIP to provide easy access to critical sustainability information, allowing end-users to verify the accuracy of the data directly on the blockchain.

An initial prototype, tested on a bamboo bookcase produced in Nicaragua, demonstrated the concept's feasibility by displaying real-time data through a user-friendly interface.

Genereting a solution

Showcased to the public, the prototype received critical feedback on its design and functionality to ensure it met the expectations of partners and potential users.

Building on this, a more advanced version of the MIP was developed for BNext's flagship product, **the LSB panel:** first, we created a comprehensive **Excel file** used to evaluate its Carbon Footprint, along with other relevant data. Additionally, we developed a fully functional and u**ser-friendly graphical interface accessible via a QR code**, which directs users to a web-based platform for interacting with MIP data. Although currently a mockup, it operates online, demonstrating how users can easily access sustainability information with a simple scan.

Furthermore, we developed an **HTML page** that communicates directly with the Ethereum blockchain. This platform enables seamless management of data and smart contracts, laying the foundation for replicating this infrastructure across other products and companies, significantly enhancing transparency and sustainability in the construction industry.

In conclusion, the MIP is designed to provide seamless access to environmental sustainability related information that is both verifiable and immutable. This accessibility is crucial in delivering the MIP's benefits to stakeholders at various levels: consumers gain the ability to make more sustainable choices, and companies can optimize their operations and enhance their brand credibility, while easily aligning to sustainability standards.

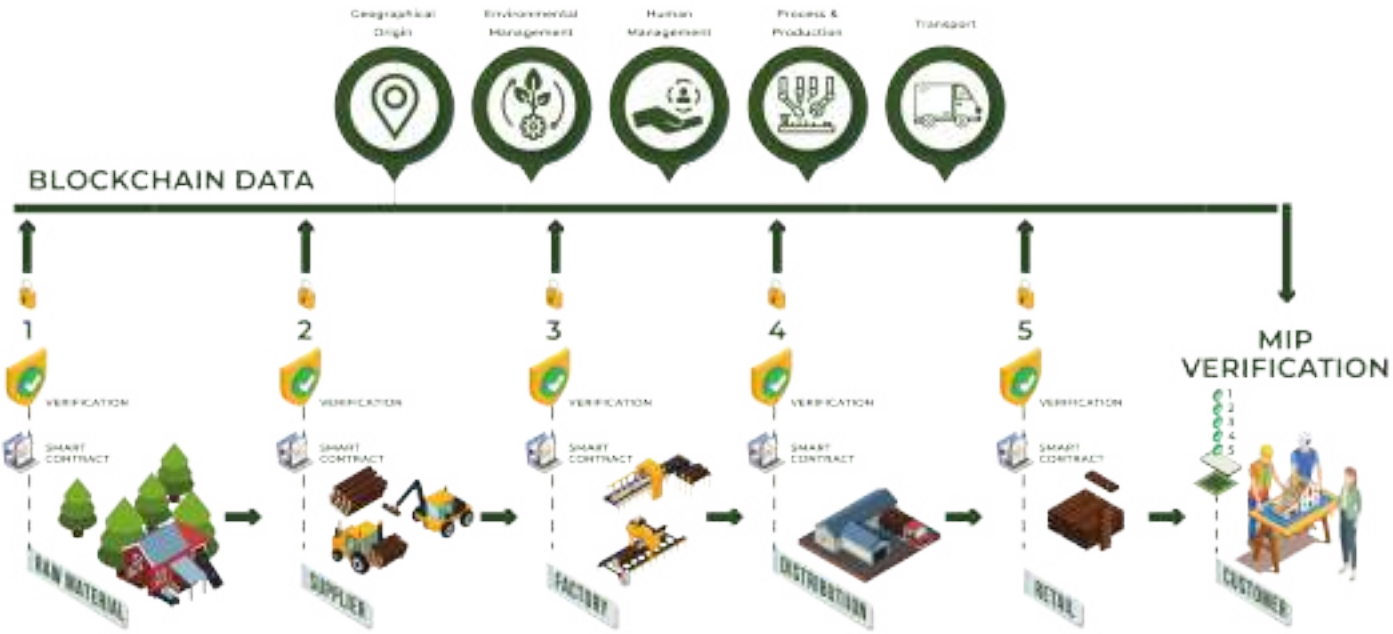

Figure 4: Building materials Supply chain with MIP

Main bibliographic references

A. Gurtu and J. Johny. Potential of blockchain technology in supply chain management: a literature review. International Journal of Physical Distribution & Logistics Management, 49(9):881–900, 2019.

J. Andreotti and R. Giordano. Strumenti per la decarbonizzazione: contabilizzazione dell'embodied carbon nel ciclo di vita di un manufatto edilizio, 2023.

L. H. E. Cosimo, M. Masiero, A. Mammadova, and D. Pettenella. Voluntary sustainability standards to cope with the new European union regulation on deforestation-free products: A gap analysis. Forest Policy and Economics, 164:103235, 2024.

M. Hanifa et al. A review on co2 capture and sequestration in the construction industry: Emerging approaches and commercialised technologies. Journal of CO2 Utilization, 67, 2023.

Main bibliographic references

M. R. Munaro and S. F. Tavares. Materials passport's review: challenges and opportunities toward a circular economy building sector. Built Environment Project and Asset Management, 11(4):767–782, 2021.

S. Wang, D. Li, Y. Zhang, and J. Chen. Smart contract-based product traceability system in the supply chain scenario. IEEE Access, 7:115122–115133, 2019.

World Green Building Council. Bringing embodied carbon upfront: coordinated action for the building and construction sector to tackle embodied carbon, 2019.