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Agroforestry Biomass Recovery Supply Chain Management: A More Efficient Information Flow Model Based on a Web Platform

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Abstract: *Background*: With the increasing societal focus on sustainability and the critical need for innovative energy solutions, this research emphasizes the undervalued biomass originating from waste products of agroforestry activities. The traditional practice of disposing of these waste products through open-air burning has led to environmental challenges and a tragic loss of their inherent energy potential. *Methods*: This study adopts a multifaceted approach, integrating literature reviews, expert interviews from both the academic and professional sectors, and surveys. The central focus is on understanding supply chain inefficiencies and communication gaps that contribute to waste and addressing them through the Lean philosophy, renowned for its waste reduction benefits. *Results*: Our research culminated in the development of a unique information management model based on a web application. Additionally, the study provides a theoretical groundwork for an application that backs the proposed model. *Conclusions*: The presented strategy and web-based model offer promising avenues for managing waste products from agroforestry activities more sustainably and efficiently. This approach not only addresses the environmental issues arising from waste disposal but also taps into the significant energy potential these waste products hold.

Keywords: sustainability; biomass energy; circular economy; agroforestry waste; Lean philosophy

Citation: Bastos, T.; Teixeira, L.C.; Matias, J.C.O.; Nunes, L.J.R. Agroforestry Biomass Recovery Supply Chain Management: A More Efficient Information Flow Model Based on a Web Platform. *Logistics* **2023**, *7*, 56. https://doi.org/10.3390/logistics7030056

Academic Editor: Robert Handfield

Received: 7 July 2023
Revised: 1 August 2023
Accepted: 18 August 2023
Published: 23 August 2023

1. Introduction

In an era where energy demands are escalating and the importance of renewable sources is being increasingly recognized, biomass has gained relevance [1]. However, it is noteworthy to remember that for most of human history, it was indeed biomass and bioenergy that served as the primary energy source, before fossil energy took precedence just around 200 years ago [2]. While biomass and bioenergy have lost their significance as primary energy sources in developed countries, they still play a pivotal role in meeting the energy needs of billions of people in developing nations [3]. Therefore, the conventional notion of the growing significance of biomass and bioenergy in light of climate issues should be considered with caution. The key factor contributing to the competitive disadvantage of biomass compared to fossil fuels lies in its lower energy, and thus its lower value density. Consequently, the cost of transporting biomass per unit of energy or value is higher relative to fossil fuels [4]. However, leveraging the timely local or near-proximity utilization of biomass could effectively mitigate this issue, potentially transforming biomass into a superior energy source [5]. Besides this, biomass could contribute to the decrease in environmental deprivation [6]. Living or recently deceased species, as well as any plant- or animal-derived byproducts, are all considered to be biomass [7]. Characteristics such as carbon-neutral status, great availability, as well as the fact that it can be produced from a range of agricultural and/or livestock wastes have made this resource "desirable" [8]. Biomass can be produced in a wide range of activities; for that reason, woody and non-woody plants, forest or agricultural residues, agro-industrial wastes, or municipal solid waste are examples of biomass resources [9]. However, its production settles mostly in forestry or the upkeep of greenery, agriculture, and animals.

Leftovers such as vineyard pruning or kiwifruit biomass are described as resources with significant potential because they are undervalued and readily available. This emphasizes the possible value of agroforestry biomass, which can go from a waste to something valuable. Traditionally, in the Mediterranean region, most of this biomass type is burned or left in place, which can lead to rural fires and endanger lives. In this sense, producing bioenergy with these materials can decrease energy costs, prevent waste from occupying land and decaying into greenhouse gases, accelerate the adoption of renewable energy sources in poor nations or nations with significant forestry or agriculture sectors [10], and impact positively in the reduction of forest fires [11]. Biomass is a resource that—despite its many potentialities, such as availability, low cost, or ease of storage—faces challenges such as logistical cost overlap [12]. The dependence of logistic activities, the geographic dispersion, the seasonality, or the quality variations can be pointed as other potential threats [13,14].

The effective coordination of the biomass supply chain (SC) can be instrumental in addressing and overcoming the challenges associated with waste management and energy production. By enhancing information flow and fostering collaboration among participants, the likelihood of optimizing the benefits for the entire supply chain significantly increases. Improved coordination can lead to reduced costs, increased efficiency, and better utilization of resources in the biomass supply chain. This, in turn, can contribute to greater environmental sustainability and the promotion of circular economy principles. Although numerous studies have investigated the coordination between participants in traditional supply chains, there is limited research focusing specifically on channel coordination in biomass supply networks and the advantages it offers for all parties involved. As the demand for renewable energy sources continues to grow, understanding the unique characteristics and challenges of biomass supply chains becomes increasingly important. Future research in this area could explore innovative strategies for enhancing coordination, leveraging digital technologies, and promoting transparency and trust among stakeholders. By shedding light on the potential benefits and best practices in biomass supply chain coordination, this line of inquiry could contribute to the development of more sustainable and efficient systems for biomass production and utilization [15].

The improvement of companies frequently uses the Lean strategy, mindset, tools, and methodologies. There are numerous instances where Lean has increased efficiency and decreased lead times by getting rid of non-value-adding activities and wastes [16]. According to Redeker et al. [17], the concepts of Lean tools can be adapted to other areas and could benefit them. Concerning the information flow, the idea of minimizing waste and increasing the value of the information could be defined as Lean Information Management (LIM). According to Klimecka-Tatar and Ingaldi [18], the five big principles of LIM include aspects such as only incorporating valuable information or information availability in real time. Thus, given the need to promote coordination and communication channels between the various actors for the possible valorization of biomass resources and the potential for incorporating lean tools, as well as LIM principles, this combination can become "enticing", and a potential approach for mitigating the above-mentioned challenges.

As demonstrated, current information management practices exhibit significant inefficiencies, especially regarding waste in information flows. Despite numerous solutions proposed in the literature, the problem persists, thereby leaving a substantial research gap in this field. The novelty of our work lies in addressing this research gap through the proposal of a new information management model. This model, aimed at streamlining waste in information flows, leverages the power of a web-based digital tool, which has not been explored extensively in previous research. This study outlines the conceptual model of the proposed platform, elaborately described using UML notation, including use-case and class diagrams. This serves as the foundation for information flow processes, which are further modeled using the Business Process Model and Notation (BPMN). This novel approach can contribute to optimizing information flow management, presenting a comprehensive solution to a long-standing problem in the field. Following an introduction to the methodology employed, the study delves into data collection and results, culminating in the discussion and final remarks.

2. Theoretical Background

2.1. Biomass Energy: Characteristics and Challenges in SC Management

As previously mentioned, the potentials of biomass energy are several, and for that, it has gained popularity all around the world. Although this prospective energy source is widely available, only 7–12% of the world's primary energy consumption comes from it [19]. One type of biomass is agroforestry, also known as lignocellulosic biomass, which is made up of cellulose, hemicellulose, and lignin [20]. Forest residues, abundant in lignocellulosic material, can be divided into two groups: residues produced during forestry operations and residues produced in industrial processes. A lot of waste is produced when a plantation is thinned, or when wood is processed to make furniture or other household items [21].

The processes that can be majorly used to transform the biomass in energy include combustion, pyrolysis, gasification, liquefaction, anaerobic digestion, and fermentation. The biomass is almost carbon-neutral and has a calorific value near to the coal [22]. The inefficiency of converting biomass feedstock (such as agroforestry biomass) into energy and the value chain of whole biomass to energy are both hampered by the defects of poor grindability, high moisture content, a poor energy density and calorific value, perishability, and difficult collection, storage, and transport of biomass [23]. Another problem is the geographic dispersion, which involves not only various direct economic prices, but also various CO_2 emission levels. Thus, one of the obstacles to their widespread usage for energy production is the high cost of biomass logistics [24]. In this context, a cost-effective way to pretreat agroforestry biomass must be found, the majority of agricultural and forestry biomass residues are left or burned in the fields, which not only causes serious environmental problems but also wastes energy resources [25]. These "residual" resources have the advantage of being cheaper than the imported biomass or from biomass derived from deforestation [26]. Encouragement of the use of domestic agricultural waste for energy generation could help to lessen the nation's reliance on foreign sources of energy and also lessen the greenhouse consequences [27].

2.2. Lean Philosophy, Lean Tools, LIM, and BPMN

Lean thinking has become a growing trend among organizations, aiming for leaner management with less waste [28]. With the aim of archiving this purpose, a set of artifacts, named Lean tools, characterized by their simplicity, effectiveness, and cheapness, have become popular solutions [29]. Visual management is one component of Lean tools. Briefly, visual management consists in a set of tools that allow for easy identification, through their visual character, of the current organizational status or an eventual problem [30]. Value stream mapping (VSM), andon lights, or kanban cards are examples of visual management tools [31]. Briefly, VSM aids in illustrating the current process and the essential changes that should be made to the current processes [32]. The indication board that tells when and where a worker has halted the line is known as an "andon" [33]. The lights serve as a warning that production is either at rate (green), in danger of remaining at rate (yellow), or off-rate and in need of assistance (red). Kanban cards consist of a visual system that is frequently used in conjunction with cards or tickets, whose aim is transferring orders [34]. It has been investigated to define, measure, and monitor performance using the Lean methodology. Using KPI metrics is a popular method for performing these measurements [35]. The eight Lean wastes are transportation; motion; overproduction; inventory; waiting; over-processing; defect; and talent and creativity waste [36–38].

The LIM has five major dimensions: value, value stream, flow, pull, and continuous improvement; in these pillars, there is to be noted the need to manage only valuable information and the necessity of give information available in real time and make sure that the sequence of procedures and actions that produce information is mapped. This covers procedures that assist in the gathering, presenting, exchanging, organizing, retrieving, and visualizing of data. This makes sure that the series of procedures (network) that underpin information management are interconnected [39].

Business process management is an approach that tries to create a bridge between business and IT sections, with the objective of supporting some improvements [40]. This promotes the perception of what represents, effectively, value for customers, and allows for a major cross-sectional synchronization of the processes [41]. The Business Process Model and Notation (BPMN) is a "graphical notation for modeling business processes as collections of related tasks that produce specific services or products" [42]. This language offers a wide range of symbols that allows for easy comprehension by the public, becoming very useful [43]. It is simpler to detect wasteful information flows and use Lean concepts to enhance the results of business processes using this graphical approach [44]. For example, in the work of Yücenur and Şenol [45], this approach allows one to identify some "wastes" that were solved by the utilization of Lean tools.

2.3. The Information Systems and the Supply Chain

Information systems (IS) can make the supply chain more closed and improve its overall effectiveness [46]. They have the capacity of improve the efficiency of the operations, the visibility of information, and the connection between the various actors [47]. ISs ensure that information sources necessary to help with the decision making, and good information flow, are a "backbone" of supply chain management [48].

Some examples were found in the literature showing the value of ISs in the SC; in the context of the SMEs, Pangaribuan et al. [49] developed a platform that allowed one to reduce the work performed manually, namely the creation of invoices or inventory management, allowing one to reduce errors and increase the efficiency of the system. In the context of avoiding wasting food, money, or other resources is to integrate software. Businesses may now track sales, inventory, manufacturing, waste prevention, food quality and safety, and waste areas thanks to system enhancements [50]. Also, Walmart has implemented an IS solution to manage materials and orders, also using RFID, which allows for better previsions to the demand, which results in a decrease in inventory costs [51].

3. Materials and Methods

3.1. Methodological Approach

To comprehend the challenges faced by the chapter on forest biomass valorization, this study employed a multifaceted methodology that encompassed both theoretical and practical aspects. The initial stage of the methodology consisted of a comprehensive literature review, which aimed to provide an overview and a subsequent theoretical foundation for the study's objective, as delineated in the introduction. This method was used to consolidate the identified gap and consequently to give strength to the motivation of this study.

Subsequently, the following steps aimed to achieve a better understanding of the dimension of the problem identified in the literature in a practical context, while also trying to identify solutions that could solve the above-mentioned problem. Thus, the second stage entailed engaging in discussions with academic experts on the subject matter. A series of meetings were conducted with the intention of contrasting the various findings present in the literature, considering the wide-ranging areas of expertise that could prove valuable in addressing the research problem. Throughout this stage, certain questions emerged due to the limited literature available in this domain. To obtain a practical perspective and address inquiries that remained unanswered by the literature, as sought by the research team, the methodology's third component comprised a workshop involving experts from the biomass supply chain. The workshop included representatives from agriculture and forestry associations as well as biomass consumers in the context of supply and demand, respectively. Given the municipal implications of this issue, members of political authorities were also invited to participate in the workshop. During this event, participants were encouraged to express their opinions on the problem, provide feedback on the proposed solution, and seek clarification on any uncertainties arising from the previous stages. Following the workshop, further consultations with academic experts took place to refine the model and establish the tool's conceptual framework. Simultaneously, a questionnaire was devised to evaluate the platform's significance, examine fire risks in respondents' regions, and measure the perceived value associated with the valorization of residual materials. This process aimed to determine which requirements (identified during the meetings with academic experts) might offer added value to the ultimate solution. The development of the questionnaire was informed by the literature review and preliminary consultations with academic experts. Figure 1 provides a summary of the entire methodological process employed in this study.

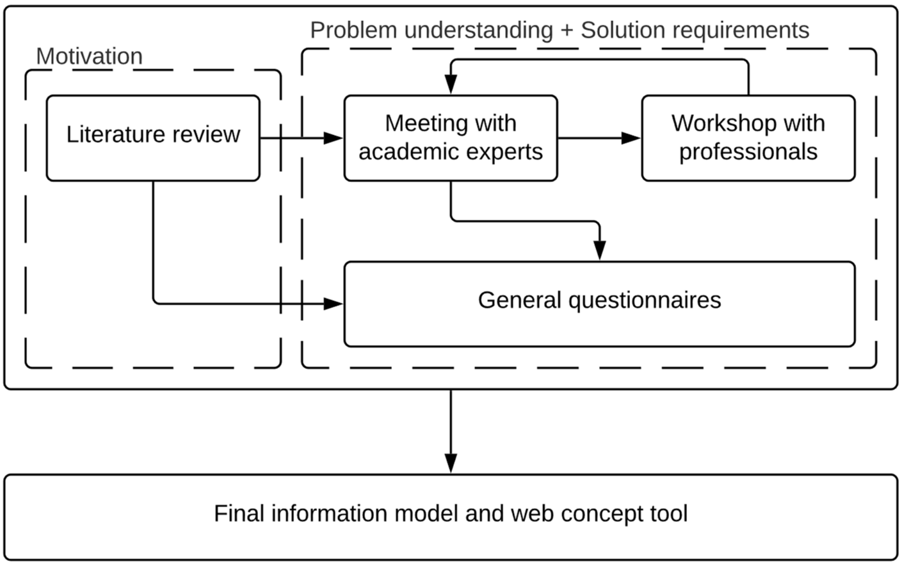

Figure 1. The methodological approach.

3.2. Data Collection and Data Analysis

Concerning to the data collection of the first of two methods that had provided practical visions (workshop and questionnaire), and since the experts were invited to answer questions and give opinions in a freeway, the session was recorded to posterior analysis. The session was two distinct parts, in which in the first one, experts from the supply side participated, and in the second part, the demand-side ones participated. Concerning the questionnaire, the primary purpose was to gather input from users in order to understand the value of the solution, and at the same time, comprehend the potential impact that the requirements might have on the final solution; thus, the structure of the questions set is presented in Table 1. To achieve the first objective, three questions were posed to the respondents, and to accomplish the second objective, respondents were invited to rate the importance they attributed to each requirement.

This questionnaire was made to 10 key respondents, specialists from SC, of which 7 were producers, 3 were transporters/consumers/receivers, and 4 were members of political authorities. At the data analysis level, as the collection resulted in textual information, the authors proceeded to a content analysis, considering the specific goal of each method, explained in Section 3.1. In the following section, the main contributions of each method are explained. Note that the contribution of the literature review is detailed in Section 2.

Table 1. Questionnaire.

(a)	What do you consider to be your level of motivation to contribute to the valorization/reuse of agroforestry leftovers?
(b)	Please indicate the degree of importance you give to the valorization of agroforestry leftovers.
(c)	Please indicate the degree of importance you give to the implementation of a project with the characteristics of this one in your municipality.
Requirements for producer:	
(d)	Enter the characteristics of agroforestry leftovers from his/her properties (e.g., species, type of leftovers, and quantity).
(e)	Enter the data that characterizes the way his/her agroforestry leftovers is available (e.g., place and date).
(f)	Request cleaning services for my land/forest.
(g)	Visualize on a map the location of the consumption centers of this type of waste.
Requirements for transporter/consumer/receiver:	
(h)	Visualize the collection points and availability of agroforestry leftovers (e.g., google maps).
(i)	View the characteristics of the leftovers available for collection.
(j)	Enter on the platform the receipt of the agroforestry leftovers when it was delivered to him.
(k)	Having an agile communication channel with the producers of agroforestry leftovers
Requirements for member of political authority:	
(l)	Knowing the state of cleanliness of the properties in your municipality.
(m)	Contribute to the management of the platform by registering users of the platform.
(n)	View indicators on the agroforestry/biomass supply chain.
(o)	Have an agile channel to communicate with the owners of potential sources of agroforestry leftovers.

4. Practical Vision (The Workshop Notes and Questionnaire Conclusions)

4.1. The Workshop Notes

4.1.1. Supply Perspective

Regarding the participants with experience in the supply area, they proposed potential requirements that would be relevant in a solution such as the one intended to be developed, further stating that in the context of municipalities, it could be beneficial because they are responsible for collecting leftovers and this platform could facilitate the process. Another positive aspect from the supply perspective is the fact that the majority of small biomass producers do not see value in their leftovers. The last point worth highlighting is that associations can be an asset in promoting the use of this resource, as a large portion of farmers are excluded from accessing information.

4.1.2. Demand Perspective

Regarding biomass consumers, they also see value in the proposed solution because it can bring together various stakeholders. Additionally, given that new businesses requiring biomass are emerging more frequently, the valorization of agroforestry leftovers could be an added value. It might also be beneficial to provide other types of incentives to producers. They also mention that this solution can only achieve a significant impact if it is well-promoted by political authorities. Biomass collection plays a crucial role in reducing fuel load; however, there is a substantial amount of leftover material in the forest that cannot be collected due to infrastructure limitations. Another idea that could improve this system is to establish off-site collection parks for waste, which could also be utilized by municipalities.

4.2. Questionnaire Insights

The answers highlight the importance of all aspects, referring that all aspects/requirements were "relevant" or "very relevant", which emphasizes the value that this disruptive solution could have to the potential users and consequently to the entire supply chain.

5. Results

5.1. Actual Scenario of the Residual Biomass Supply Chain

The residual biomass supply chain aggregates various steps. The biomass is generated through forest management or agricultural management activities, which are transported to a final destination or may be transported to a temporary destination and then loaded to a final destination. These activities could increase value to the final product, as well as reduce humidity. Besides this kind of energy being renewable and promising concerning the transition to clean energies [52], the potential negative impacts of the transportation and the production of this energy cannot be neglected [53]. The main difficulty in bioenergy supply chains is supply-side unpredictability. In terms of the logistics issue, it is necessary to convey bulky, low-density materials from widely dispersed manufacturing and collecting sites to centralized processing facilities before delivering them in their finished state to customers. In actuality, the economic and environmental effects of transporting huge amounts of biomass by road are significant [4].

In this sense, several techniques have been developed that try to increase the potential use of energy, such as physicochemical conversion, thermochemical conversion, or biological conversion [54]. There is still a great lack of coordination among the various actors, a result of the lack of information to convert biomass into energy [55], coupled with the lack of literacy of many of the producers of this type of biomass that waste raw material.

As already seen in the literature, this is an existing problem, which is reiterated from a practical perspective, as seen in the workshop notes, where biomass producers were pleased with the valuation of leftovers, which shows that currently, this valuation does not exist, and for that reason, it can meet the literature regarding the burning and consequent energy waste of leftovers. The competent authorities also mention that they sometimes have problems in terms of collecting leftovers, which shows that the information is not the most relevant either. The questionnaire also showed the magnitude of the problem in the practical context, given the importance that potential users saw in the solution, once again showing that the lack of lines and information flows is a very clear problem in this area, in the practical chapter.

5.2. Conceptual Model of the Proposed Solution

With the aim of connecting the various actors in the supply chain in terms of information flows and given the benefits of information systems at the SC level, a platform concept was created that could function as a mediator in this context, and which is explained below. The platform will feature four key stakeholders: the producer, the transporter, the processor/receiver, and the political authority representative. Individuals interested in becoming members of this platform can initiate the pre-registration process, which will be subject to validation at a later stage. The final detailing of the requirements is presented in Table 2.

The primary goal of the application is to connect producers with final consumers to valorize leftovers that are typically burned. Producers can easily communicate their leftovers by selecting the species, inputting the quantity, and specifying the availability date. They can also view financial data related to the materials they provided. At the other end of the supply chain, receivers must indicate the type of leftovers they accept, their available time windows for receiving them, and any allocated loads. They can also view their unloading history, communicate financial data about the leftovers, and access indicators to help in decision making.

Table 2. Key high-level features of the platform.

Stakeholder	Requirements
Internet user	Make pre-registration in the platform
Producer	Communicate agroforestry leftovers Visualize financial transaction data
Transporter	Visualize the collection route Visualize the collection route history Visualize indicators Communicate the collection availability window Communicate the transport type (capacity, fuel usage. . .) Visualize the collection points and their leftovers
Processor/receiver	Insert what type of leftovers are accepted Communicate the discharge availability window Visualize the "loads" history Insert financial transaction data
Member of political authority	Visualize indicators about the region's status Register new members in the platform Validate pre-registration made by possible users

The connection between supply and demand is facilitated through transporters, who must be informed of their routes. To optimize routing, transporters need to provide their availability dates and transportation characteristics. This information enables the system to select the most efficient transport option and distribute the route accordingly. Transporters can also view collection points and the availability of leftovers. Color-coded information highlights unallocated leftovers, allowing interested parties to make use of them if necessary. Lastly, the platform's management is overseen by political authorities, who handle user management and can view regional indicators. Figure 2 illustrates the use case diagram with all requirements and actors.

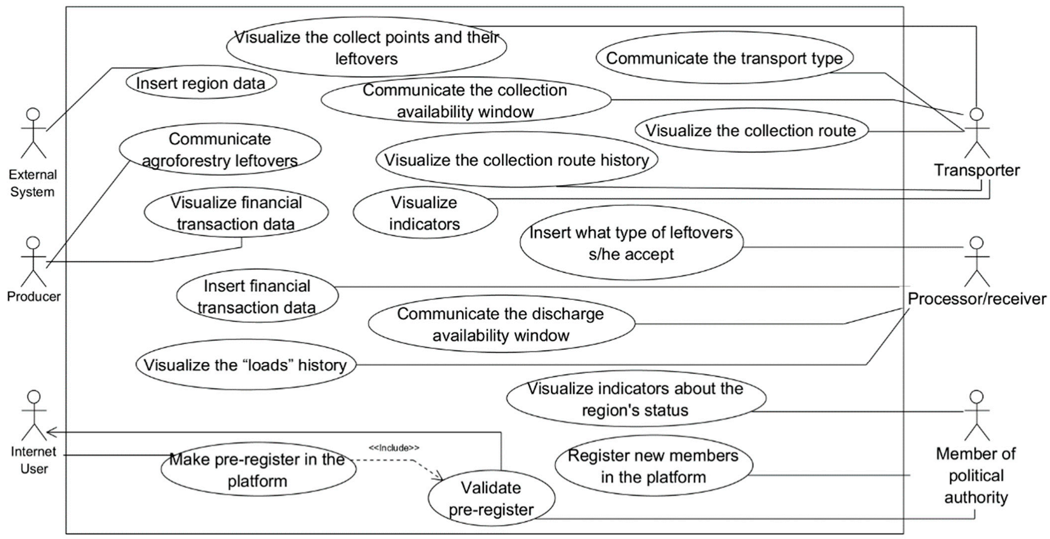

Figure 2. Key high-level features of the platform based in use-case diagram from UML.

This diagram summarizes the entire set of requirements mentioned above, with emphasis on the interaction of an external system that enables various members of the municipality to view indicators.

Regarding the data model to support the application, Figure 3 represents a class diagram using UML.

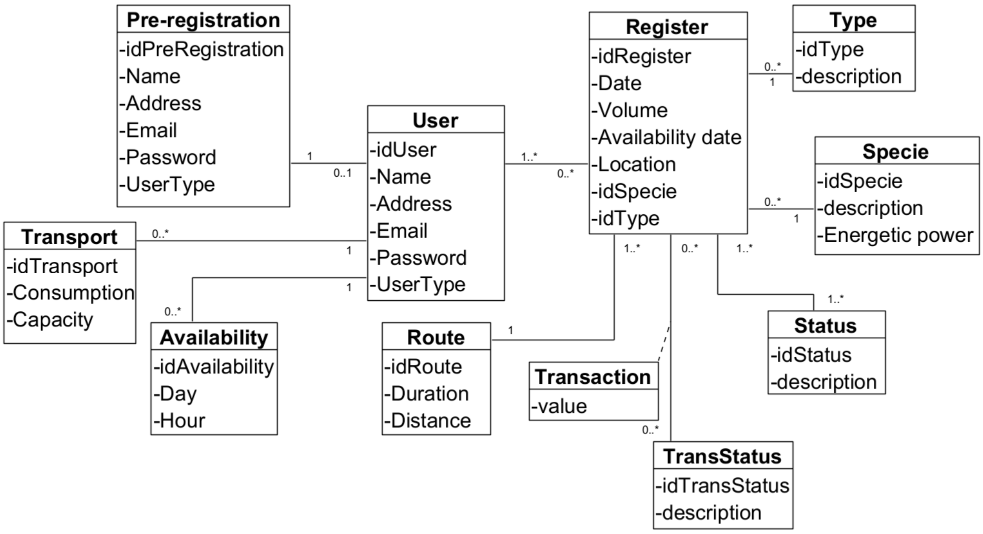

Figure 3. Data model based in the class diagram representation from UML.

As previously noted, individuals who seek to join this platform must first undergo a pre-registration process. The relevant information will be stored in a "Pre-registration" table, and upon validation by the appropriate entities, an object will be created in the "User" table. Each entry in this table, in addition to personal information, will possess an attribute named "UserType", which denotes the user's profile (one of the four outlined in Table 2). Users classified as "Producers" must complete a "Registration" process, during which they specify the species and type (e.g., bark or crowns) of surplus they possess, along with the volume and availability date of said leftovers. To standardize data and minimize errors, the species and type fields cannot be open-ended text fields; instead, they must be presented as predefined selections for users to choose from. These selections will be stored in the "Species" and "Type" tables, respectively. A registration may be assigned one of three statuses: "on-site", "being collected", or "collected". This information, along with the type and species, will be stored in a table functioning as a repository, named "Status", and will be associated with each record. Furthermore, each record will possess a transaction status ("TransStatus") that can take one of three forms: "Outstanding", "Scheduled" or "Paid". These data will be stored in an auxiliary table called "Transaction", where the transaction value is also kept. Each record will be integrated into a route ("Route") that will also display the total time and distance of the route, in addition to indicating various collection points. As for the "Transporter" and "Processor/Receiver" users, they may specify their preferred time windows for picking up and receiving goods, respectively. This information will be stored in the "Availability" table. Transporters must also input the characteristics of their transport vehicles to be assigned to the appropriate routes.

5.3. The Information Process Flow—To-Be Model

As evident in the theoretical background, one notation that proves highly useful in process mapping is BPMN 2.0. Accordingly, this section will depict the entire process flow. One of the primary drivers of this model is the potential to valorize agroforestry leftovers, making it crucial to establish mechanisms that facilitate easy and immediate communication regarding these leftovers. Consequently, whenever a producer has a new load, they must report it by registering the load on the platform. Unregistered users must initiate the process with a pre-registration, which will be validated by members of the political authority. To create a more efficient flow, a notification is generated and sent following pre-registration and subsequent accepted registration. Figure 4 illustrates the various actors involved in this minor process. It should also be noted that the communication of leftovers is represented by a single activity because the platform and the proposed model must be simple to compensate for the lack of digital skills.

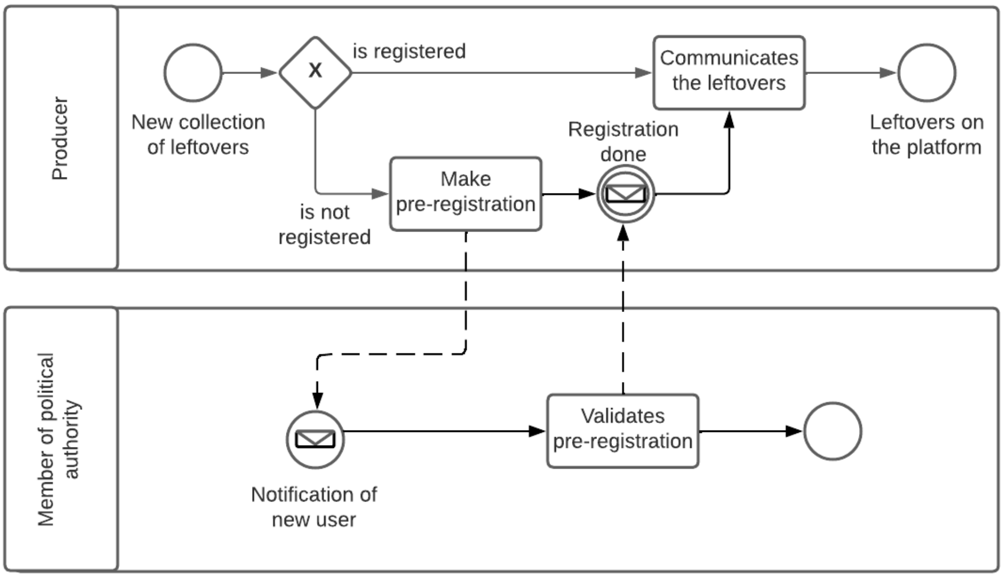

Figure 4. Mapping the producer communication in the platform.

Concerning the collection of leftovers, the platform aims to create routes, taking into consideration the locations, quantity of materials, availability dates, and transporter characteristics, with the goal of optimizing them. Therefore, whenever there is a route available for a specific time slot, the system notifies the transporter, who then initiates the route. Once started, each collection is logged in the system, and upon completion of the collections, the materials are unloaded at the processor/receiver location, which concludes the cycle. The processor/receiver is responsible for validating everything that has been delivered (Figure 5).

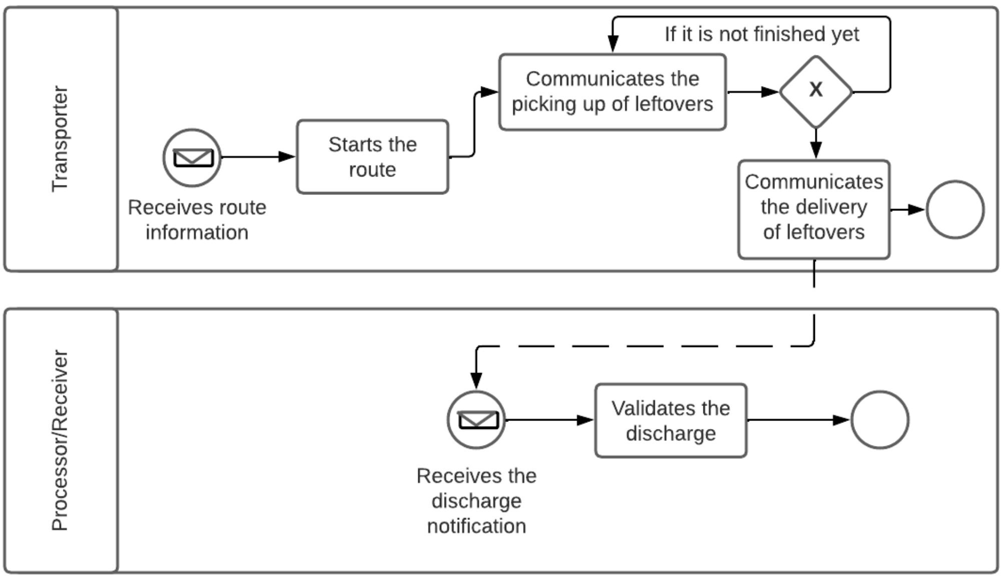

Figure 5. Information process in the collection route.

6. Discussion

As seen in the previous sections, the new energy needs to emphasize the possible value that biomass can have in this sense. The biomass energy from deforestation could be more expensive [56], which makes this resource less interesting. The leftovers from agricultural and forestry activities can present an added value by being an energy source at a lower price; although they could have a valorization mechanism, it is less than the biomass type cited above, and at the same time, it avoids the creation of new fires, since most people burn this waste in the open air. Although the biomass supply chain presents many challenges, although some technologies have been developed to increase the efficiency of the of the utilization of this leftovers [57], the coordination of the various actors is one that can be solved with this information management model proposed in this work.

As any chain and any sector has waste, in the light of Lean's eight wastes, this scenario presented above can be framed as excessive storage, waiting, necessary transportation, or even the non-utilization of people. Although these two points could be an added value to the raw material [58], this could be optimized and controlled if the information be in one common information repository, as stated by Budholiya et al. [59], which refers that information systems could improve the supply chain efficiency, as the proposed platform. The last Lean waste, concerning the people, is applicable because as there is no tool for this purpose, those who want their waste to be collected will have to spend a lot more time calling the authorities, as stated by the participants in the workshop. With Lean being a theme that values the reduction of waste and that can be applied in different contexts, this work was based on LIM principles, such as avoiding the creation of activities in this area that do not offer any type of added value and the mapping of the entire activities [60], visible in the final model presented in BPMN, which has a very high degree of simplicity. Also, in this model, it is possible to see that there are no waiting times throughout the model; this is justified by the fact that the application that will support the model (presented in this work) allows for the achievement of another LIM principle: information available in real time.

As visible in the literature, there are many benefits of the use of information systems in the context of the supply chain; the increase in efficiency and the decrease in human errors are examples. In this industry, although there are not yet many information channels that allow us to claim that this is the way forward, supply chain management can benefit greatly from the introduction of platforms like this. This information available in real time given by the proposed IS could be a "backbone" of this supply chain; as referred by Lee and Lee [61], this platform could also provide crucial information to the decision-making processes. The diminishing of manual work and the reduction of stocks goes in line with the minimizing of Lean wastes, and could improve the elimination of these wastes in the agroforestry biomass. In the chapter of application, other pillars of Lean are visible in the data model, the incorporation of only relevant information [62], since the model is quite simple, and only the essentials are kept. The second is the number of requirements based on KPIs that are used in Lean approaches [63]. The incorporation of BPMN with Lean concepts is through the graphical character of this notation; for this reason, for this mapping, in this context, as the information flow is not yet a reality, it is impossible to make an identical approach [64]. However, this mapping in the BPMN presented could be a good graph for an eventual future study on Lean tools. Another challenge facing the biomass supply chain is the issue that it is often the poor energy powers of the leftovers; however, this model, given the fact that it incorporates this into the Web platform, could be a breakthrough in this regard. Analyzing the theoretical framework of the biomass supply chain, it seems clear that there are many challenges, particularly with the mixtures, or even with the difficulties of transport; this could have a reflection at the application level, resulting in an addition of requirements, and consequently, a complication of the proposed model, going a little in shock with the Lean principles (simplification). Also, challenges such as moisture content, although not discussed throughout the article, can be incorporated into the platform at the route-planning level.

7. Conclusions

In an era characterized by escalating energy demands and a heightened awareness of sustainability, it is essential to valorize materials often incinerated or discarded, such as leftover biomass. Beyond energy valorization, mitigating fire hazards is crucial. One challenge that diminishes the appeal of utilizing these leftovers lies in the complexities of the supply chain, particularly at the information transaction level. Therefore, enhanced coordination among various supply chain actors could yield significant improvements. This research contributes to the existing literature by introducing a novel information management model anchored on a web platform. A key feature of this model is the integration of Lean thinking, aiming to establish a more efficient model in terms of waste reduction. The creation of a streamlined model was accomplished via a mixed-methods approach, amalgamating theoretical insights and practical viewpoints. Owing to its graphical nature, the model was crafted using BPMN notation, which allowed for the seamless incorporation of Lean concepts. The implementation of Lean Information Management (LIM) in this setting became evident through adherence to several foundational principles of this philosophy, thus leading to an innovative theoretical application of LIM in a unique context. Practically, the proposed application could serve as a valuable tool in connecting diverse actors within the supply chain. Future work could enhance the tool's capabilities by incorporating additional features while maintaining its simplicity. In relation to the route detail discussed in the paper, future work may include the development of an algorithm to optimize collection and the entire chain using the minimal information obtained. One limitation of the study is the low response rate to the questionnaire.

Author Contributions: Conceptualization, T.B., J.C.O.M., L.C.T. and L.J.R.N.; methodology, J.C.O.M., L.C.T. and L.J.R.N.; validation, T.B., J.C.O.M., L.C.T. and L.J.R.N.; formal analysis, T.B., J.C.O.M., L.C.T. and L.J.R.N.; investigation, T.B., J.C.O.M., L.C.T. and L.J.R.N.; resources, J.C.O.M., L.C.T. and L.J.R.N.; data curation, T.B., J.C.O.M., L.C.T. and L.J.R.N.; writing—original draft preparation, T.B., L.C.T. and L.J.R.N.; writing—review and editing, J.C.O.M., L.C.T. and L.J.R.N.; visualization, T.B., J.C.O.M., L.C.T. and L.J.R.N.; supervision, L.C.T. and L.J.R.N.; project administration, J.C.O.M., L.C.T. and L.J.R.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the FCT—Fundação para a Ciência e Tecnologia/MCTES, through national funds, and when applicable, co-financed by the FEDER, under the new partnership agreement PT2020, grant number PCIF/GVB/0083/2019. L.J.R.N. was supported by proMetheus—Research Unit on Energy, Materials and Environment for Sustainability—UIDP/05975/2020, funded by national funds through FCT—Fundação para a Ciência e Tecnologia.

Data Availability Statement: Data are available upon request to correspondent author.

Conflicts of Interest: The authors declare no conflict of interest.

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