MANUAL FOR VACUUM AND HEAT STEAM PHYTOSANITATION TREATMENT TECHNOLOGY

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Table of Contents

Table of Figures

Tables

I. Introduction

i. Overview

a. Introduction to Vacuum and Steam Heat Technology

In wood phytosanitary practices for hardwood logs, vacuum and steam treatment technology has emerged as a potential treatment method. The approach eliminates pests and diseases from hardwood logs without using chemicals, such as methyl bromide, that cause harm to the environment. By combining the principles of vacuum pressure and steam heating, this technology ensures sterilization and pest elimination, promoting healthier and more sustainable treatment for hardwood logs. The process begins with the application of vacuum pressure, which removes air and moisture from the wood's cellular structure, making it easier for steam to penetrate deeply and uniformly. The subsequent steam treatment raises the temperature of the logs to levels that are lethal to insects, fungi, and other pathogens. This method eliminates pests and diseases while preserving the hardwood logs' quality.

The vacuum and steam treatment technology is gaining traction as an environmentally friendly approach, aligning with the growing demand for sustainable forestry practices. By reducing the need for chemical practices, this method minimizes impact and enhances the safety of wood products.

b. Purpose of the Manual

The primary purpose of this manual is to serve as a guide for organizations in the hardwood industry seeking to support the transition from MB fumigation to vacuum and steam treatment technology. This manual provides detailed insights into current fumigation methods and markets for log exports, a description of how this technology works, and its acceptance, aiming to enhance understanding and facilitate its integration into existing wood exporting operations.

By offering a structured overview of the technology, historical context, and the feasibility of implementation, this manual aims to help stakeholders make informed decisions using the knowledge needed to transition from traditional chemical treatments to a more environmentally friendly method. It also includes step-by-step instructions on the treatment process, descriptions of the necessary equipment, and guidelines for monitoring and controlling the treatment environment to ensure optimal results.

Furthermore, this manual addresses performance measurement, safety protocols, and regulatory compliance, ensuring that users can achieve international standards and gain market acceptance for their treated products. Also included is an economic analysis, a feasibility study for determining a location for a vacuum and steam treatment facility in the US, and a discussion of perceptions of log importers and regulators in India and China. Finally, a summary of best practices to increase US log exports is provided. By outlining the benefits and limitations, providing case studies, and emphasizing continuous improvement initiatives, the manual serves as a resource for advancing sustainable forestry practices and promoting the integrity of hardwood logs.

ii. Background

a. Historical Context

The history of hardwood log treatment has been closely tied to the need for effective fumigation methods to eliminate pests and diseases. For many years, the solution for this problem was to use chemical fumigants, with methyl bromide being the most prevalent choice due to its high efficacy in eradicating a wide range of wood insects and pathogens. "Methyl bromide (MB) is a versatile fumigant that can be effective at killing pests, including insects, nematodes, and fungi. It's one of the most widely used pesticides in the world and is often applied to soil before crops are planted. MB is effective because it can quickly and deeply penetrate materials at normal atmospheric pressure" (Eisenberg, 2007).

Hardwood log exports play an important role in the global market, especially for the export companies in Virginia, with major importers including China, Vietnam, and Canada. These countries rely on hardwood logs sourced from the United States to meet their industrial and commercial needs. Understanding the dynamics of this trade is essential in understanding the implications for both exporters and importers. It sets the stage for a deeper exploration into specific demands and trends, particularly within key markets like China and India.

China's demand for US hardwood logs has experienced remarkable growth, attributed to the nation's strategic forest reserve protection and the rapid expansion of its furniture and interior decoration market (Snow, 2023). According to Asia Intelligence Wire, the import value of US hardwood products into China surged to an all-time high of US$323 million in 2019, marking a 3.4 percent year-on-year increase (Snow, 2023). In the first quarter of 2023, there was substantial growth, with export values for Hardwood logs reaching US$138 million—a significant rise of 36.7 percent compared to the previous year's statistics, as the American Hardwood Export Council (AHEC) reported. Among the imported species, alder led the list with an import value of US$32 million last year, closely followed by yellow poplar at US$29 million. These hardwood varieties find extensive application in furniture manufacturing and interior decoration (Snow, 2023).

The heightened demand for hardwood logs has been further fueled by the expanding housing market and the furniture industry, driving a surge in exports of hardwood logs, particularly to Asia, where China remains a prominent recipient. The Appalachian states of New York, Ohio, Pennsylvania, and West Virginia account for 80–90% of the hardwood log and lumber exports from the Northeast. In 2016, 84% of hardwood logs exported from the Northeast to China came from these four states (Jefferies, 2017).

Some countries require that hardwood logs undergo a strict fumigation process to eliminate the risk of any type of pest, fungi, or disease that could be associated with the log (Jones, 2021). Examples of insects that can be present in hardwood logs are the Asian longhorn beetle, emerald ash borer, and weevil, and examples of diseases include oak wilt and thousand canker disease. These are a concern for importers of hardwood logs because they can affect the native flora in the importing country.

To safeguard against the spread of insects and diseases, phytosanitary measures must be implemented during the importation of hardwood logs. These are methods that mitigate the risk of introducing harmful pests into new ecosystems. The preventive measures include heat or chemical treatments, quarantine protocols, and inspection procedures. These preventive methods for pest management and disease control can minimize the ecological and economic impacts associated with the importation of hardwood logs.

Fumigation is the most common method used to prevent the spread of unwanted insects and diseases in logs and agricultural products and is a currently accepted procedure by the USDA, for logs imported into the United States. Fumigants used around the world include Methyl bromide, Sulfuryl Fluoride, Phosphene, and Ethanenitrile. Methyl bromide fumigation is the most used and is the most effective (Maxwell, 2021). Methyl bromide (MB) is a fumigant that has been widely used for killing pests on plants in trade, soils, and structures worldwide due to its excellent permeability and insecticidal effect; however, MB should be replaced because it is an ozone-depleting substance (Park, 2020). The treatment process requires methyl bromide to be used at not less than 40 degrees Fahrenheit with an ideal temperature of 72 degrees and a usage rate of 2 pounds of the chemical for every 1,000 ft^3 of the volume of treated material (Maxwell, 2021). These requirements limit its use in colder temperatures, as many port locations in the United States reach in the winter months, preventing treatment during these times. Another downside of using methyl bromine is that it is a non-renewable resource, which makes its availability in the future uncertain (Maxwell, 2021). These problems lead to the need to find an alternative treatment for logs. The negative effects of MB have caused countries like New Zealand, and Australia to stop using MB and start looking into more sustainable ways of treatment (Maxwell, 2021). Also, countries in the European Union like Denmark, Finland, and Sweden have taken their commitment towards stopping Methyl Bromide more seriously, eliminating this chemical in quarantine and pre-shipment fumigations (PAN Europe, 2003).

Currently, log fumigation is usually outsourced to third parties due to the challenges faced in obtaining licenses for the treatment processes, lack of land, or the demand to justify in-house treatment being too small (Maxwell, 2021). The downside of this practice is that companies may not always be fully aware of the environmental impact that chemical treatments can have. Their primary objective is often to export logs quickly and cost-effectively.

A new technology that utilizes a vacuum chamber and steam heat to replace chemical treatments for log phytosanitation, entails placing logs or timber into a vacuum chamber and subjecting them to high temperatures and steam. The combined action of vacuum and steam heat effectively penetrates the wood, treating pests and pathogens without affecting the quality of the logs (Z. Chen and M. White, 2022). The Vacuum and Steam treatment method has been suggested as a replacement for MB for meeting international phytosanitary requirements for log export/import. This new technology aims to ensure that exported hardwood is free from pests and diseases that could harm ecosystems or other wood products in the receiving country and that logs remain protected post-treatment and are covered in ISPM No. 15 by the Food and Agriculture Organization of the United Nations (IPPC, 2017)

Early methods of hardwood log fumigation

In the early days of the hardwood industry, untreated logs often fell prey to pests and diseases during storage and transport, leading to significant economic losses and compromised wood quality. Foreign forest pests have damaged forest ecosystems and affected lumber production. Fungi, nematodes, or insects introduced through importing logs, lumber, and wood packaging have attacked forests in Northern America (USDA, 1996).

There have been several intrusions of foreign pests into the US, such as chestnut blight (Cryphonectria parasitica) from 1904 to 1955, Dutch elm disease (Ophiostoma ulmi) in the 1920's, and the Gypsy moth (Lymantria dispar) in 1870. More recently, these infestations include the Asian long-horned beetles (ALB) and Emerald ash borer (EAB) which will eventually deplete the ash tree population (USDA, 1996). To mitigate these issues, chemical fumigation became a standard practice.

Methyl bromide and its environmental impact

While methyl bromide proved to be highly effective, its extensive use raised significant environmental and health concerns. Methyl bromide is a potent ozone-depleting substance, and its release into the atmosphere contributed to the degradation of the ozone layer, which protects the Earth from harmful ultraviolet radiation. Methyl bromide is a Class I ozone-depleting substance (ODS) that damages the ozone layer and allows more ultraviolet radiation to reach the Earth's surface (EPA, 2005).

Additionally, exposure to methyl bromide posed health risks to workers handling the chemical, prompting increased scrutiny and regulatory controls. The effect of methyl bromide on humans and other mammals appears to vary according to the intensity of exposure. At concentrations not immediately fatal, this chemical produces neurological symptoms. High concentrations may bring about death through pulmonary injury and associated circulatory failure

(MPI, 2003). The onset of toxic symptoms is delayed, and the latent period may vary between 0.5 to 48 hours, according to the intensity of the exposure and the personal reaction of the patient (von Oettingen, 1955).

The need for sustainable alternatives

The environmental and health hazards associated with methyl bromide led to international efforts to phase out its use. The Montreal Protocol, an international treaty aimed at protecting the ozone layer, mandated the gradual reduction and eventual elimination of methyl bromide. Under the Montreal Protocol countries are required to phase out methyl bromide use for non-quarantine use and New Zealand has ceased to import the gas for non-quarantine use. Official quarantine and pre-shipment use are still allowed but countries are encouraged to reduce the amount used (MPI, 2003). This global commitment underlined the need for alternative fumigation methods that are both effective and environmentally sustainable.

Development of vacuum and steam treatment technology

In response to the pressing need for safer and more sustainable wood treatment methods, vacuum and steam treatment technology emerged as a promising alternative. This innovative approach combines vacuum pressure and steam heating to sterilize hardwood logs without the use of chemicals. The vacuum process removes air and moisture from the wood, allowing steam to penetrate deeply and uniformly. The heat steam treatment raises the temperature of the logs to levels that are lethal to pests and pathogens, ensuring thorough sterilization.

b. Evolution of Vacuum and Heat Steam Treatment Technology

The development of vacuum and heat steam treatment technology has the potential to revolutionize the phytosanitation industry. Pioneering research conducted by the Department of Sustainable Biomaterials, led by Dr. Zhangjing Chen and Dr. Marshall White, has been instrumental in this innovation. This technology provides a chemical-free method for treating hardwood logs intended for export, addressing the need to eliminate chemical use in phytosanitation. These advancements not only transform the current practices in hardwood log treatment but also pave the way for future development of non-chemical treatment methods.

This technology involves heat treating the logs by utilizing a vacuum chamber and steam. This method is preferred because saturated steam contains 100 times more energy per cubic meter than hot air at the same temperature (Chen and White, 2008). Additionally, steam condensation is exothermic on surfaces, meaning it releases energy to the surface, whereas hot air vapor is endothermic, which lowers the temperature of the logs. The vacuum chamber ensures fast and uniform heat distribution to all external and internal log surfaces through the formation of pressure gradients (Chen and White, 2008).

Testing the Efficacy of Vacuum and Steam Heat Treatments on Wood Logs

A test was conducted on 6-inch diameter ash (Fraxinus spp.) bolts, which were treated to 56°C for 30 minutes at the center using saturated steam at 90°C and an initial vacuum of 200 mmHg. This process successfully killed all EAB larvae, with treatment cycle times ranging from 3.5 to 4.5 hours to reach the bolt center. No mold was generated, as the vacuum chamber effectively dried the pallet surfaces in seconds. Additionally, when heat treating naturally infested willow (Salix spp.) logs with diameters of 6 to 10 inches, using saturated steam at 90°C and a vacuum of 250 mmHg to achieve 60°C for 60 minutes at the log center, all ALB larvae and adult beetles were eradicated in an average total treatment time of 5 hours. No change in moisture content was observed after the test (Chen and White, 2008).

Veneer logs of 15 to 22 inches in diameter, including cherry, walnut, red oak, hickory, and yellow-poplar, were successfully heat treated to 60°C for 60 minutes at the log center using saturated steam at 90°C over 16 to 20 hours at 25 mm Hg, depending on the log diameter and wood species. This treatment process did not impact the yield or quality of the veneer logs (Chen and White, 2008). The energy required for the treatment varied from 1.32 to 2.17 kWh per kilogram of log mass.

In conclusion, treatments were conducted at 56°C for 30 minutes and 60°C for 60 minutes at a depth of 2 inches (5 cm) in oak and 1.5 inches (3.8 cm) in walnut, with an initial vacuum of 100 mmHg. The average treatment time for oak was 6.4 hours to reach 56°C for 30 minutes and 8.2 hours to reach 60°C for 60 minutes. For walnut, the average treatment time was 4.6 hours for 56°C for 30 minutes and 5.1 hours for 60°C for 60 minutes. The average energy consumption was 0.052 kWh/kg for 56°C for 30 minutes and 0.048 kWh/kg for 60°C for 60 minutes. All oak wilt fungus and vector insects were eradicated, and in walnut, only one out of 899 specimens tested positive for TCD, with all vector insects killed at 56°C for 30 minutes (Chen and White, 2015).

These results confirm that 56°C for 30 minutes at 5cm depth is adequate to kill all pathogens and associated vectors on hardwood logs. If the logs needed to be treated to the center of the log, it would increase the treatment time to 40 or 50 hours for some species (Chen and White, 2015). There was also no positive pathology found after treatment and no re-infestation after post-treatment inoculation. This treatment can have potential uses not only on hardwood logs but also in firewood, wood chips, pallets, and solid wood packaging.

c. Perceptions of costumers and regulators in China and India

China stands out prominently in the hardwood log import market, exhibiting a significant difference in imports compared to other major importing countries such as Canada, Vietnam, and Italy (FORECON, 2022). While some countries, including Japan, Thailand, and Spain, have seen a decline in their hardwood log imports in recent years, China's import volume continues to grow, making it a critical market for this study. Additionally, India, although a smaller market compared to China, has shown substantial growth, with U.S. hardwood exports to India reaching an all-time high in 2022, valued at USD 8.618 million for hardwood lumber and veneer exports (AHEC, 2023).

For this study, the focus is primarily on the Asian markets, particularly China and India, due to their significant growth potential and impact on annual revenue. Both countries require the use of methyl bromide for phytosanitation, making them ideal candidates for evaluating the adoption of vacuum and steam treatment technologies. Understanding the perceptions of companies in these markets is essential for facilitating the transition to the vacuum and steam treatment method.

Import volume and common species:

Import volume:

- China imports a significantly higher volume of hardwood logs monthly compared to India. This indicates a larger and more consistent demand for hardwoods in China.

- Both countries prioritize high-grade logs, but their strategies differ. The Chinese companies interviewed sourced logs from distant states like New York and Pennsylvania despite higher transportation costs due to treatment facility locations, while the Indian companies all shipped out of one Virginia port benefiting from closer treatment facilities, minimizing transportation costs.

Common species of hardwood logs:

- The species of hardwood logs imported by both the companies interviewed in China and India show considerable overlap, including red and white oak, ash, and walnut. These similarities suggest a global preference for these species due to their quality, availability, and specific properties desirable for manufacturing purposes.

Import restrictions faced by companies when importing hardwood logs from the United States:

Import restrictions and compliance:

- Both countries have strict fumigation requirements for the use of methyl bromide treatment for fumigation. This highlights a global regulatory reliance on methyl bromide for pest control, despite its environmental concerns.
- China does allow for debarked hardwood logs while India only accepts MB fumigation. Nonetheless, there is a necessity for phytosanitary certificates in both countries that emphasize the importance of pest-free assurances in international trade.

Regulatory barriers:

- China's import process, governed by the CIQ, poses significant cost and logistical challenges due to mandatory methyl bromide treatment and the potential for additional inspections. Compliance with these regulations is essential but costly.
- India faces similar challenges with its strict adherence to methyl bromide fumigation. The lack of approval for alternative treatments indicates a cautious regulatory environment that is resistant to change without proven alternatives.

Awareness and considerations of vacuum and steam or alternative treatments for hardwood logs:

Awareness and consideration of alternative treatments:

- Both Chinese and Indian companies show limited awareness of alternative methods such as vacuum and steam treatments. This lack of knowledge suggests a significant gap in the dissemination of innovative pest control methods.
- There is interest in exploring new treatment methods, particularly in China, where companies are open to alternatives that offer cost-effectiveness and efficiency. However, the adoption of new treatment methods is hindered by regulatory approval and the need for proven effectiveness in other markets.

Environmental and cost considerations:

- Companies in both countries are focused on the cost-effectiveness of the treatment methods rather than their environmental impact. This reflects a market-driven approach where economic factors outweigh ecological considerations. When treating alternatives were allowed, for instance, China also accepted debarking, the availability of material or ability to ship needed material promptly often outweighed cost or quality concerns.

iii. Feasibility Study

a. Wood product industry overview

The global wood-and-wood-article trade is a $135 billion industry regulated by the International Standard for Phytosanitary Measures (ISPM) 15, which mandates using either methyl bromide fumigation or heat treatment to eradicate pests (VTECE, 2022). Efforts to eliminate methyl bromide, an ozone-depleting substance identified by the Montreal Protocol in 1992, have led to a phaseout schedule for developed countries, including the U.S., to reduce its use by 100% by 2005. However, exemptions for "critical" uses, such as quarantine and pre-shipment treatments, have allowed continued usage under certain conditions (VTCECE, 2022).

Several countries have taken steps to phase out methyl bromide entirely. The European Union banned all uses, including for quarantine and pre-shipment, in 2010. Nigeria's NAFDAC banned its import and export in 2015, preventing its use as a pesticide (VTCECE, 2022). Other regions, like the USDA's APHIS in the U.S., are exploring alternative treatment options for imported goods. In North Carolina, a bill was introduced in 2020 to outlaw methyl bromide for fumigating whole logs, indicating a growing movement towards phasing out this substance, though the bill did not pass (VTCECE, 2022).

b. Interview analysis on industry stakeholders conducted by the VTCECE

The Virginia Tech Center for Economic and Community Engagement (VTCECE) conducted 10 formal interviews and numerous informal conversations with industry stakeholders and regulatory officials to assess the current market conditions, challenges, and opportunities in timber processing and exporting. Participants included representatives from APHIS, VDACS, the Port of Virginia, Virginia Loggers Association, various forestry and timber companies, and regulatory bodies (VTCECE, 2022). The findings collected on timber processing and exporting were:

Industry trends

- **Demand:** Growing demand for timber products both domestically and internationally, with fluctuations due to regulatory changes. Optimism for the wood exporting industry in 2022-2023 was noted.

- **Costs:** Rising export costs and logistical challenges, such as securing competitive rates and container shortages.
- **Supply Chain:** Shifts in supply chain operations due to changes in processing and transportation costs, with trends toward vertical integration.
- **Political and Economic Factors:** Influence on the industry from domestic economic conditions and opportunities from the Russian embargo.
- **Export Markets:** China and India are prominent destinations, alongside Romania, Vietnam, the Middle East, North Africa, and South Korea.
- **Virginia's Exports:** A variety of wood products are exported, with 75% of logs from the Port of Virginia originating in-state.

Regulatory environment

- **Regulatory Fluctuations:** Varied regulatory conditions among importing countries, especially China, which had previously banned U.S. wood exports.
- **Inconsistent Standards:** Disparities in enforcement of wood treatment standards.
- **Methyl Bromide Ban:** A global move towards banning methyl bromide treatment, creating opportunities for alternative methods.
- **Local Regulations:** Municipal regulations affecting transportation logistics and costs.
- **Need for Uniformity:** Calls for consistent and clear regulations at all levels.
- **Interstate Transport Taxes:** Applicable taxes for logs transported across state borders, though industry-specific taxes are not a major concern.

Site and feasibility factors

- **Location Priorities:** Companies prioritize access to shipping containers and proximity to ports to minimize costs.
- **Transport Methods:** Vary by firm size, with smaller firms using trucks and larger companies using rail or truck.
- **Virginia's Suitability:** A favorable regulatory environment and control of invasive pests make Virginia more suitable for timber transportation.

- **Potential Facility Sites:** Greater Richmond region or Hampton Roads are identified as favorable for a steam-and-vacuum-treatment facility due to infrastructure and port access. A site would need 5 to 20 acres, 24/7 access, and space for container staging.

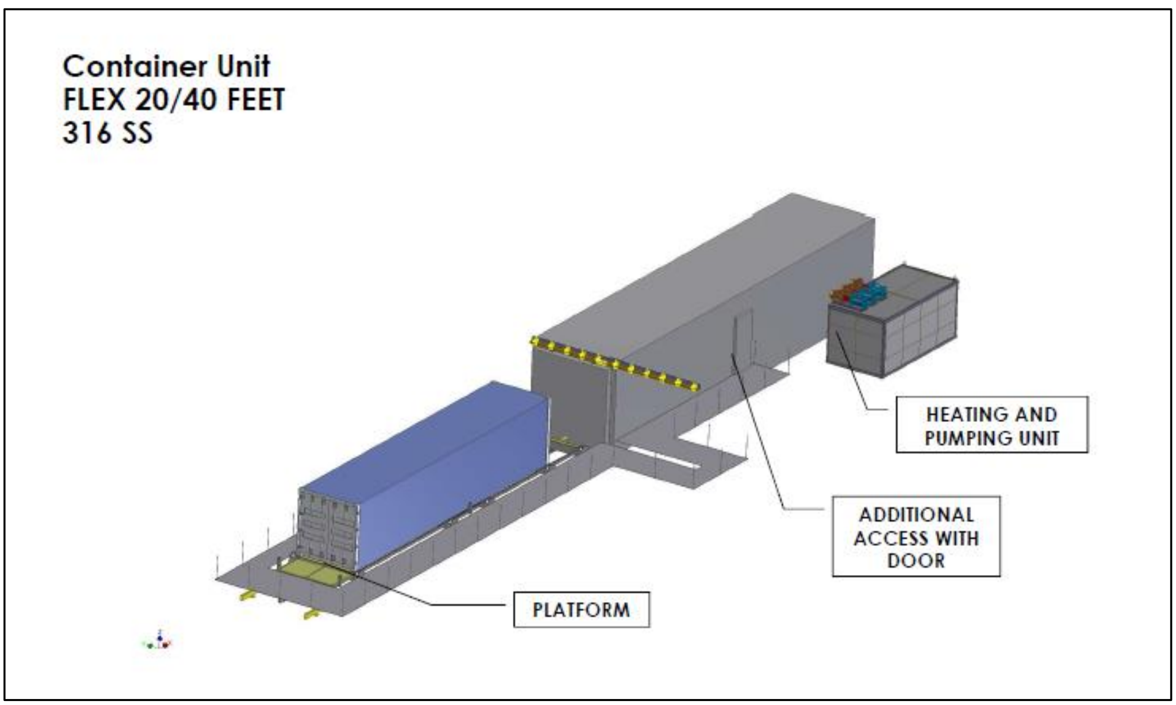
Overall, the findings highlight the complexities and evolving nature of the timber processing and exporting industry, emphasizing the need for regulatory consistency and strategic site selection for new treatment facilities.

c. Site factors

Using existing research by VT College of Natural Resources and Environment (CNRE) faculty and input from industry experts, the research team identified key characteristics for choosing a suitable site for a potential steam and vacuum treatment facility.

Facility size and operations

The site must have sufficient space to accommodate a vacuum treatment chamber, which can handle shipping containers up to 40 feet in length. This specification is based on a system developed in 2017 in collaboration with VT faculty, Phytovac, and Welker Vakuum GmbH.



Source: (Quesada, 2021)

Figure 9. Representation of treatment unit

Source: (Welker Vakuum, 2021)

Figure 10. Treatment unit onsite

Additionally, the potential site will need to have enough space for trucks transporting containers to enter, load, and unload containers and logs. Furthermore, the site will need sufficient storage space where logs that have been treated and are waiting to be transported to ship can be stored in a protected manner to prevent re-infestation (VTCECE, 2022).

Therefore, the potential site for the steam-and-vacuum treatment facility will need to be at least 5 to 20 acres in size (VTCECE, 2022).

Zoning

Permitted uses for a site are determined by local zoning ordinances, which vary by locality. The research team found that forestry and wood product manufacturing typically fall under light industrial or heavy industrial classifications. For example:

- **City of Richmond:** Permits wood and paper products, including shipping container uses, in light industrial (M1) districts.
- **City of Suffolk:** Allows sawmills with a conditional use permit in light industrial (M1) districts and by right in heavy industrial (M2) districts.

Therefore, the potential site for a steam and vacuum treatment facility must be zoned for light or heavy industrial uses or be designated as such on the locality's future land use map.

Utility needs

Vacuum treatment requires approximately half the energy of treatment at atmospheric pressure, so the energy needed for a vacuum-steam treatment facility will not restrict site selection more than that of conventional methyl bromide treatment (VTCECE, 2022).

The steam-and-vacuum treatment method is water-intensive due to the generation of steam that increases the efficiency of the method. Each treatment cycle per container uses 187.5 gallons of water (Chen and White, 2021). Thus, the potential site will require dependable access to water infrastructure.

An industrial site with access to electric power, water, and sewer systems is sufficient for the facility. Industry experts expressed that the boiler used for wood treatment will need either electric or natural gas power sources.

Transportation and port access

Interviewees consistently highlighted the importance of proximity and access to ports and highways for transporting logs to be treated. Local road weight limits and regulations can impact demand for services in certain regions, so it's crucial to ensure that local regulations do not impose additional restrictions or fees beyond state requirements (VTCECE, 2022).

Proximity to shipping ports is a key consideration. Efficient and quick transport of treated logs to ports is essential to avoid re-infestation and degradation. Thus, proximity to ports and highway access is vital. Ports of interest outside Virginia include Charleston and Baltimore, though interstate transport taxes might decrease Virginia loggers' demand if the facility is out of state. Norfolk, Virginia's port, and the Inland Port are also logical areas of interest.

Additionally, stakeholders are considering supplementing wood vacuum and steam treatment services with additional services, such as quarantine treatment for other imported non-wood goods. If ports receive contaminated containers, the facility could offer treatment or disposal services. This diversification could provide a steady revenue stream, as log trade can be seasonal (VTCECE, 2022).

d. Indirect factors

Workforce

Interviewees noted that wood treatment operations require less labor than sawmills or timber harvesting, making workforce availability a lower priority when selecting a site. Job postings data from Lightcast for Virginia's logging industry revealed that 43% of jobs required a high school diploma or GED, while 15% required at least a bachelor's degree (VTCECE, 2021). Proximity to higher education institutions is an advantage but not a primary consideration.

Since the steam-and-vacuum treatment method is newly adopted, there may be limited specialists experienced in operating and maintaining the necessary machinery. This concern should be considered when selecting a site, favoring proximity to companies or contractors skilled in the technology, such as those at Virginia Tech in Blacksburg, VA.

Tax environment

The tax structure of a potential site community is a secondary or tertiary factor in site selection, with lower property tax rates reducing development costs. Service pricing for the facility should consider that logging companies will incur transportation costs, including interstate transport taxes, which could affect companies transporting logs from states outside of Virginia.

Regulatory factors

Traditional treatments like methyl bromide are regulated for outputs and waste, but the proposed steam-and-vacuum treatment method generates no waste except steam, making discharge regulations largely inapplicable. However, site selection must consider local water runoff regulations due to condensation from the treatment process. Most Virginia localities require a stormwater management plan, such as Richmond’s comprehensive stormwater management ordinance. Operators must also comply with federal, state, and local garbage disposal laws, including prohibitions on waste disposal into water bodies.

Additional regulatory factors include federal and state pest control regulations for infestations like the gypsy moth and emerald ash borer. Operating in Virginia has advantages due to existing quarantine zones, reducing the risk of transporting logs from infected areas.

e. Site Inventory: Feasibility and Siting Recommendations

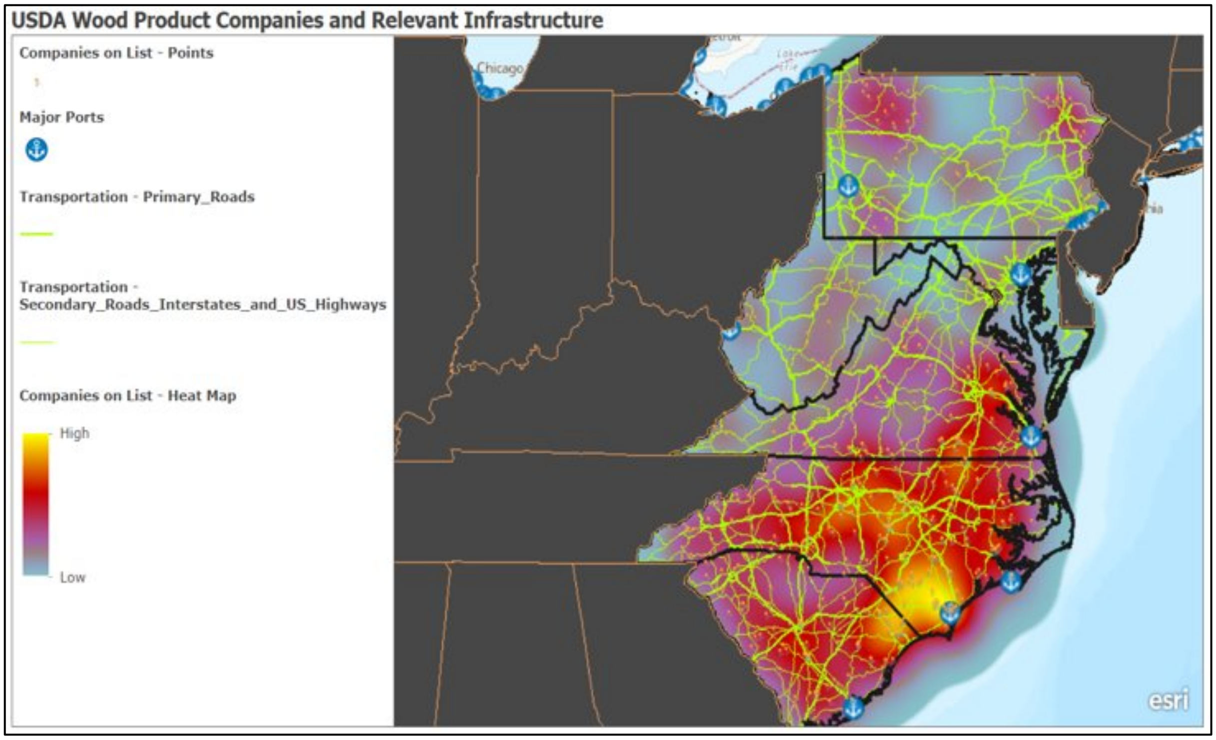
The VTCECE utilized key findings from interviews with stakeholders, regulatory agencies, and technology developers to rank site selection factors and filter available vacant sites using the Virginia Economic Development Partnership's database.

Key Findings:

- **Port Usage:** Approximately 75% of logs exported from the Port of Virginia are from within the state, with the rest from North Carolina, South Carolina, Maryland, and West Virginia.
- **Suitability of Virginia:** Virginia is more suitable for timber transportation compared to nearby states due to its regulatory environment and past exposure to invasive pests, reducing the risk of new infestations.
- **Facility Requirements:** A potential steam-and-vacuum-treatment facility should be close to a port, have 24/7 access, and have sufficient space for container staging (5 to 20 acres).
- **Site Selection Focus:** Emphasis should be on locations within Virginia because of the state's predominance in log exports and favorable pest quarantine rules.

Top factors impacting site selection:

1. **Proximity to a Port for Foreign Export**
2. **Size of Site**
3. **Water and Sewer Infrastructure**
4. **Transportation Access (Highways, Potentially Rail)**
5. **Zoning (Industrial Uses Permitted)**
6. **Regulatory Factors, Especially Wood Pest Control and Quarantine**



Source: (VTCECE, 2022)

Figure 11. Tentative figure of layers, infrastructure, etc.

The figure illustrates the overlap of transportation infrastructure, port locations, and logging industry concentrations in Virginia. Significant logging activity is concentrated in the central and southeastern parts of the state, particularly the Greater Richmond and Hampton Roads regions, which align with proximity to major ports. These regions also feature junctions of highway infrastructure and some rail, enhancing their suitability for logging industry operations and transport (VTCECE, 2022).

From the site inventory, the research team identified one top site per region that best matched the siting criteria for a potential steam-and-vacuum treatment facility:

1. **Front Royal Warren County Industrial Park, Front Royal, VA (80 Acres):**
   - Location: Within 10 miles of the Inland Port of Front Royal and 3 hours from the Port of Virginia in Hampton Roads.
   - Features: 80 acres, subdividable into 5-acre lots, with options for build-to-suit or sale, providing flexibility for facility developers.
2. **Tri-Point Terminals, Chesapeake, VA (8.4 Acres):**

- Location: In the Hampton Roads region, 22 minutes from the Port of Virginia.
- Features: Pad-ready site zoned for industrial use.

3. **West Site (U.S. 360) (51 Acres):**
    - Location: 15 minutes from the Richmond Marine Terminal.
    - Features: Well-served by highway and rail, zoned for industrial use, potential for redundant power to ensure reliable operations.

II. Cost Analysis of the Plan Location Proposal

Technological Requirements and Cost Estimation

The next step in this plant location proposal is to determine the technological requirements and resources needed to establish a fully functional plant at the Inland Port in Front Royal Warren County Industrial Park, Front Royal, VA. This involves identifying the costs associated with the necessary equipment, specifically the vacuum chamber with PLC software and the gas-fired boiler. The detailed costs are presented in Table 1.

Table 6. Equipment Costs for the New Treatment Method

Parameter	Description	Quantity	Cost per unit	Total per unit	Useful life (year)	Depreciation (per year)
Equipment	Chamber	1	$ 657,460.00	$ 657,460.00	10	$ 65,746.00
		1		$ -	10	$ -
	30 BHP gasfired boiler	1	$ 40,000.00	$ 40,000.00	10	$ 4,000.00
		1		$ -		

Source: P. Philipp, 2021

To achieve optimal operation, the plant will require at least one chamber equipped with PLC software to monitor and control the processes within, as well as a 30 BHP gas-fired boiler. The total cost of this equipment, excluding permits and installation, is $697,460. Both the chamber and boiler are developed by PHYTOVAC, a company that has been collaborating with Virginia Tech on innovative, sustainable wood sanitizing technologies for years.

Capacity and Operational Efficiency

To determine the plant's treatment capacity, it is necessary to calculate how many chambers are required and the operational hours. After including permits, installation, and electrical maintenance, the cost of one chamber is $777,460. The plant is expected to operate 24 hours a day, 7 days a week. Each treatment batch requires approximately 6 hours, with an additional 10% set-up time per batch. This results in 8,400 available operational hours per year, allowing for the treatment of approximately 1,272.73 containers annually.

Table 7. Inputs to Determine Volume of Containers Treated Annually

Inputs			
1	chambers	$	777,460.00
24	hours per day		
7	days per week		
50	weeks per year		
10%	set up time		
8400	total available hours/year		
1272.73	Containers/year		

Source: Elaborated

- **Operational Hours:** 24 hours/day, 7 days/week, 50 weeks/year
- **Total Available Hours/Year:** 8,400
- **Set-Up Time:** 10% of each batch's 6-hour treatment time
- **Annual Treatment Capacity:** ~1,272.73 containers

Given this capacity, the plant can treat approximately 106 containers per month. The treatment cost per container varies by log type: $859.40 for oak logs and $518.40 for non-oak logs.

Table 8. Monthly Volume and Consumption

Volume						
Containers per month	106.1					
Price						
Per container	$ 859.40	30%	Oak weight			
Per container	$ 518.40	70%	Non oak weight			
Electricity consumption	Time consumption		Quantity		Price	
Per cycle	6	hr	4.666666667	kwh	$ 0.063	kwh
Water consumption	Quantity		Price			
Per cycle	300	gallon	$ 0.0005	gallon		
Natural gas consumption	Price					
Per cycle	$ 9.74					
Salary						
Fumigator	$ 25.00	hour				
Supervisor	$ 35.00	hour				
Utilities						
Water	$ 199.00	month				
Electricity	$ 65.00	month				
Building	$ 3,500.00	month				

- **Monthly Treatment Volume:** 106 containers
- **Treatment Costs:**
    - **Oak Logs:** \$859.40/container (These are the average prices for MB fumigation treatment, not vacuum/steam treatment. Since the survey was conducted, fumigation costs have increased by an average of 50%. The current cost is approximately \$1289.10/container for oak.)
    - **Non-Oak Logs:** \$518.40/container (Similarly, the current cost for non-oak is approximately \$777.60/container.)
- **Utility Consumption:**
    - Electricity: 4.67 kWh/cycle at \$0.063/kWh
    - Water: 300 gallons/cycle at \$0.0005/gallon
    - Natural Gas: \$9.74/cycle

The annual cost of utilities (electricity, water, and natural gas) totals approximately \$43,132.20.

Financial Projections

Based on the estimated treatment volume, the plant is projected to generate around \$789,981.82 in sales annually. The annual utility costs are expected to be \$43,132.20, with variable costs primarily for water, electricity, and natural gas. After accounting for administrative expenses, the plant's total earnings are estimated at \$548,112.89. Considering a 10% deduction for interest and taxes, the net annual revenue is projected to be \$48,608.85.

Table 9. Annual Income Statement for One Chamber

Annual Income statement		
Sales		
Vacuum treatment	$	789,981.82
Cost		
Electricity consumption	$	374.18
Water consumption	$	190.91
Natural gas consumption	$	12,392.12
Fumigator salary	$	15,909.09
Rent	$	14,400.00
Gross margin	**$**	**746,715.52**
Depreciation	$	43,266.30
Chamber	$	65,746.00
30 BHP gas fired boiler	$	4,000.00
Administrative Expenses		
Administrative salary	$	50,000.00
Marketing	$	29,868.62
Utilities	$	43,980.00
Training	$	5,008.00
Earnings before interest and taxes	**$**	**548,112.89**
Interest	$	31,098.40
Taxes	$	27,405.64
Earnings after taxes and interest	**$**	**489,608.85**

Source: Elaborated

III. Vacuum and Heat Steam Treatment Process

i. Equipment

a. Providers

The vacuum and steam treatment technology for hardwood logs requires specialized equipment to ensure effective pest control and wood preservation. Developed with the expertise of Welker, a company renowned for its quality, sturdy construction, and efficiency, this technology benefits from a long-standing tradition of excellence. Since its inception in 1856, Welker has been a key player in the textile sector, producing heavy-duty machines for conditioning and heat-setting.

The company, now solely owned by the KOCH family since 2001, has undergone significant modernization and product improvements. These advancements have solidified Welker's position as a technology and quality leader in the field, extending their expertise to the realm of vacuum and steam treatment technology for wood. Welker's commitment to innovation ensures that their equipment meets the highest standards, providing reliable and effective solutions for the industry.

b. Description of the equipment

The vacuum and steam treatment system for hardwood logs is comprised of several key components, each designed to ensure the effective and efficient processing of wood. The centerpiece of the system is a rectangular, rigid vacuum chamber capable of accommodating an entire container of untreated wood logs. This chamber is equipped with a powerful vacuum pump that ensures the desired pressure levels are achieved, facilitating optimal treatment conditions.

Integral to the system is the steam generator, or electric boiler, which plays a crucial role in the steam production process. The boiler is designed with a water tube that continuously feeds water, allowing for the generation of steam. Capable of producing up to 4200 kW of power, the boiler supplies sufficient steam to permeate the entire chamber. To enhance the treatment process, the vacuum chamber is fitted with internal fans that ensure an even distribution of temperature throughout the chamber. This uniform heat distribution is essential for the consistent and thorough treatment of the wood logs.

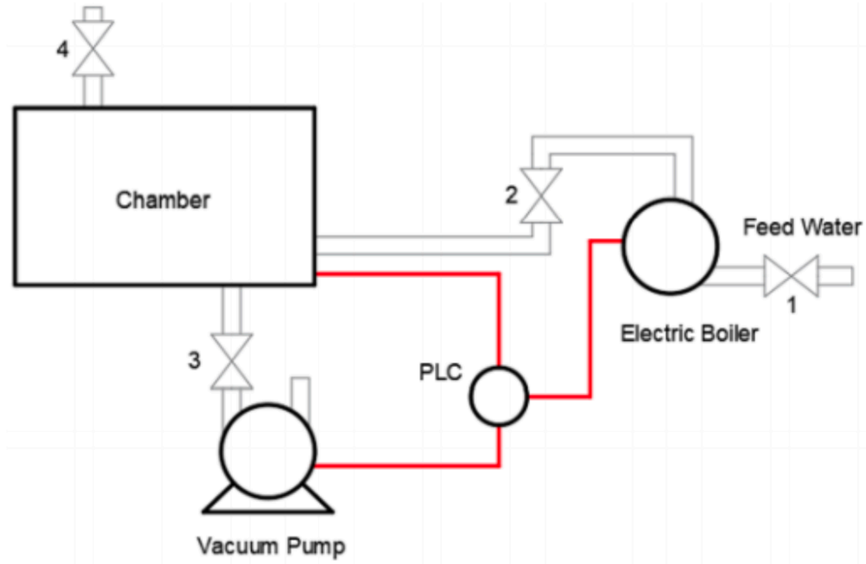


Figure 12. Vacuum/Steam equipment and setup.

All system components are controlled by PLC (Programmable Logic Controller) software. This software not only ensures that each part of the system operates as intended but also provides workers with real-time updates and notifications when the process is complete. This level of automation enhances the treatment process's reliability and efficiency. For a visual representation, refer to the sketch of these components found in Figure 4, which illustrates the layout and integration of the vacuum chamber, steam generator, and control systems.

ii. Process steps

a. Treatment procedures

Upon arrival at the treatment facility, untreated hardwood logs are delivered in a container, which is then offloaded from the truck onto a specialized platform. This platform is equipped with a conveyor belt system that seamlessly transports the container into the vacuum chamber. Once the container is positioned inside, the vacuum chamber securely closes, and the air is evacuated to achieve a pressure of 100 mmHg. This low-pressure environment is essential for the subsequent stages of the treatment process.

Next, the electric boiler activates, injecting a steady flow of steam into the chamber. The steam is maintained at a constant temperature of 90°C. The goal is to ensure that the core temperature, specifically 2/3 of the way to the center of the logs, reaches 56°C and is held at this temperature for 30 minutes. This precise thermal treatment is crucial for effectively eliminating all larvae and other pests within the logs. The entire treatment cycle typically spans 5.2 to 6.8 hours. Throughout this period, the system ensures that the logs undergo thorough pest eradication without compromising their quality or causing any degradation. This treatment process can be seen in Figure 5.

Source: (Phytovac and Welker, 2018)

Figure 13. Treatment process

Once the treatment process is completed, the vacuum chamber opens, and the container is moved back onto the conveyor belt system. The platform then transfers the container back onto the truck, ready for transport to the ports for export.

b. Monitoring and control systems

To ensure the smooth operation of the vacuum chamber and the electric boiler, at least one operator should continuously monitor the system. This monitoring guarantees that all components function as intended throughout the treatment process.

A dedicated heating and pumping unit houses all essential components, including the PLC. This unit provides operators with a centralized location to oversee and manage the entire process in real time. The PLC interface allows operators to monitor critical parameters such as temperature, pressure, and steam flow, ensuring that any deviations are promptly addressed. This real-time oversight is crucial for maintaining the efficiency and effectiveness of the treatment system, safeguarding the quality of the hardwood logs.

IV. Characteristics of Vacuum and Heat Steam Treatment

i. *Benefits*

a. **Pest control:** Vacuum and steam treatments effectively eliminate pests such as insects, larvae, and fungi that may be present in the wood. This helps prevent the spread of invasive species to new regions and protects native ecosystems.

b. **Quality preservation:** Steam treatment can also help preserve the quality of the wood by killing any existing fungi or bacteria that could cause decay during transit or storage. This can extend the lifespan of the wood and maintain its structural integrity.

c. **Time consuming:** Vacuum and steam treatments typically take less time compared to chemical treatments, which can impact production schedules and lead times for export shipments.

d. **Environmental impact:** Compared to chemical treatments, vacuum and steam treatment is considered more environmentally friendly since it does not involve the use of potentially harmful pesticides or chemicals.

ii. *Limitations*

a. **Cost:** Implementing vacuum and steam treatment technology can be expensive, both in terms of initial setup costs and ongoing operational expenses. This cost may be passed on to exporters or consumers, potentially affecting the competitiveness of the exported wood products.

b. **Compliance:** Many countries have strict regulations regarding the importation of wood products to prevent the introduction of pests and diseases. Vacuum and steam treatment is not accepted but countries such as China and India are some of our biggest hardwood log importers.

c. **Effectiveness:** While vacuum and steam treatments are generally effective at controlling pests, there may be limitations in terms of reaching the center of the wood faster than chemicals, especially for larger or denser logs.

d. **Regulatory compliance:** While vacuum and steam treatments could meet international regulations, the requirements and standards vary between countries. Exporters need to make sure that vacuum and steam treatment technology is accepted by the importing regulatory agencies.

Overall, vacuum and steam treatment technology offers significant benefits for hardwood log exports, particularly in terms of pest control and regulatory compliance. However, exporters should carefully consider the associated costs, time requirements, and logistical challenges to effectively implement these treatments into their operations.

V. Performance Measurement System

i. Establishing the need for measurement

Implementing a performance measurement system for hardwood treatment represents an opportunity for exporting companies to meet stringent quality requirements. To ensure the successful adoption of this technology, it must align with the overarching goals and objectives set by the importing companies. These objectives include reducing environmental impact, enhancing treatment efficacy, and most importantly, meeting quality requirements set by the importing companies.

To effectively understand the extent to which the vacuum and steam treatment technology align with these objectives, it is imperative to establish a robust performance measurement system. By measuring key performance metrics, such as treatment effectiveness, treatment time, resource utilization, and cost efficiency, companies can track progress toward their goals, identify areas for improvement, and demonstrate the benefits of implementing this technology.

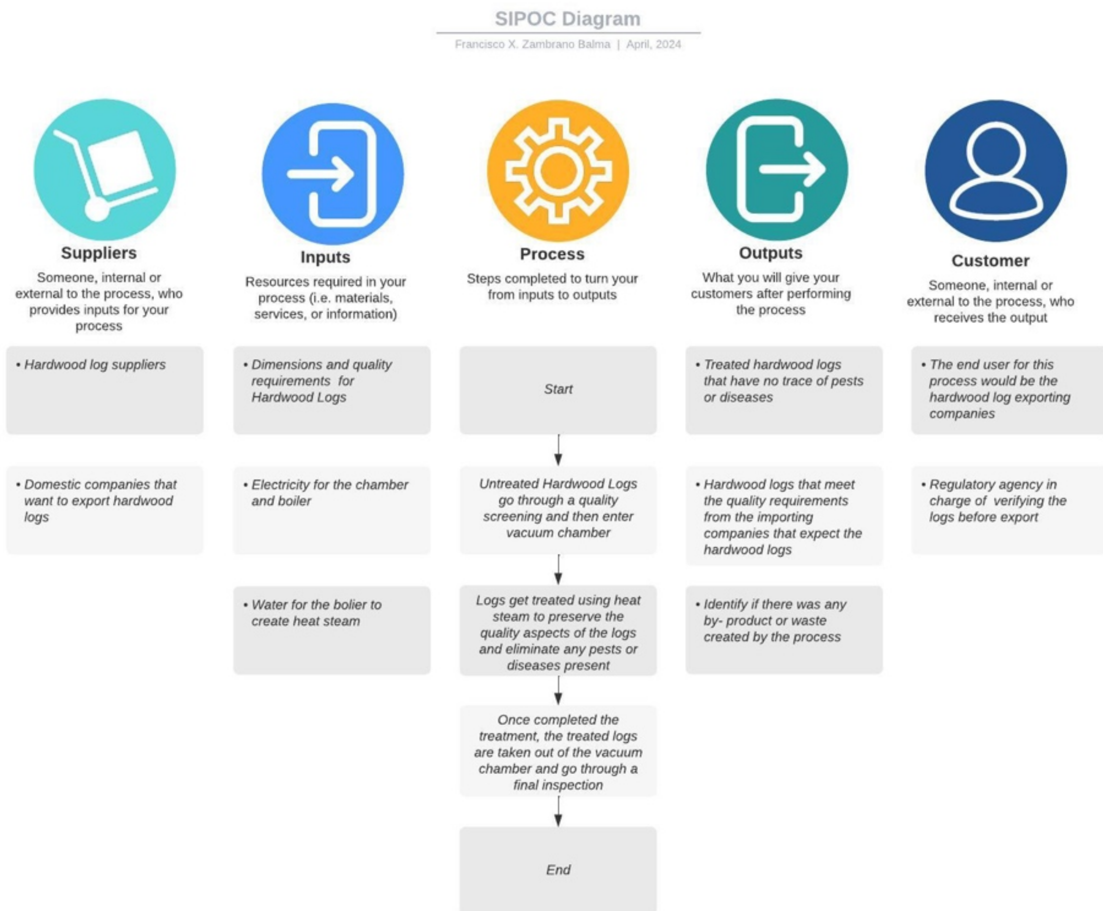


Figure 14. SIPOC diagram of the vacuum and steam process

The development of the SIPOC diagram serves as a comprehensive framework for understanding the vacuum and steam treatment process by detailing the key stages and stakeholders involved. From the suppliers providing hardwood logs to the treatment process, and finally to the customers receiving the treated logs, the SIPOC diagram represents the entire process chain. By illustrating the inputs, outputs, and interactions at each stage, the diagram facilitates a holistic view of the treatment process, enabling stakeholders to identify opportunities for optimization and improvement.

Furthermore, measuring performance metrics serves as an important tool for validating the effectiveness of vacuum and steam treatment technology in meeting quality requirements and delivering treated hardwood logs on time and at a competitive cost. By understanding the areas of improvement, the inspection areas for quality control, and the operational steps necessary to achieve optimal treatment of hardwood logs, importing companies can make informed decisions regarding its adoption and integration into their supply chain processes.

The need for measurements for vacuum and steam treatment technology is indispensable for ensuring its successful implementation and acceptance by importing companies. By establishing clear performance metrics and tracking progress towards predefined objectives, companies can optimize their treatment processes, meet quality standards, and drive operational excellence in the hardwood import industry.

ii. Overview of the hardwood treatment process

The treatment process plays a crucial role in the integrity of hardwood logs and in ensuring compliance with regulatory requirements in destination countries. It has the responsibility of eliminating pests and diseases that pose a threat to local flora, this process serves as a vital safeguard in the international trade of hardwood logs.

To effectively fulfill its mandate, the treatment process must follow strict quality standards and performance benchmarks. This includes ensuring that all pests and diseases are thoroughly eliminated from the hardwood logs, thereby mitigating the risk of introducing harmful organisms into importing countries. Apart from this, the treated logs must meet regulatory requirements imposed by destination countries, including specifications related to treatment methods, quarantine periods, and documentation. To understand better the initial process, an As-Is Diagram was developed and can be accessed in Figure 5.

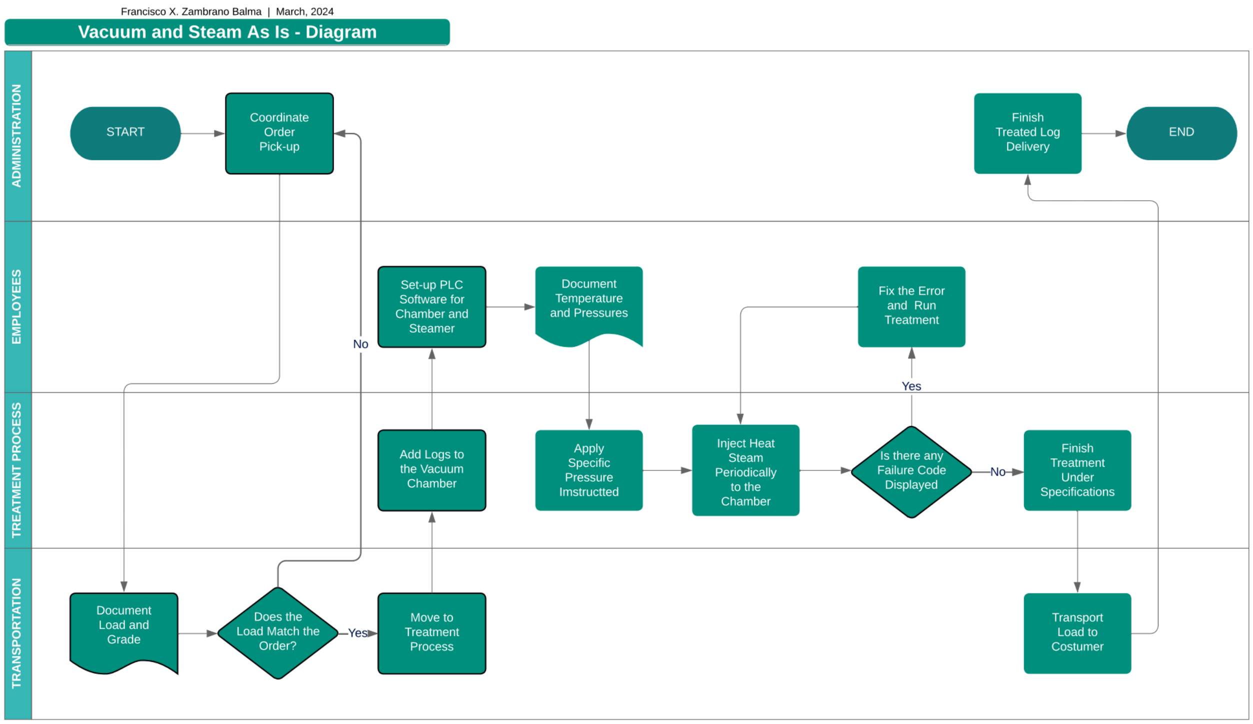


Figure 15. As-Is Diagram

To validate the efficacy and reliability of the treatment process, it is essential to establish a robust system of measurements and performance metrics. By quantifying key parameters such as treatment effectiveness, treatment duration, pest eradication rates, and compliance with regulatory standards, stakeholders can assess the performance of the treatment process and identify opportunities for improvement.

Furthermore, measurements in the treatment process serve as a means of accountability and transparency, assuring importing countries and regulatory authorities that all necessary precautions have been taken to safeguard their ecosystems. By demonstrating adherence to the performance metrics and quality standards, companies can instill confidence in their ability to deliver treated hardwood logs that meet or exceed regulatory requirements.

iii. Key areas for success

Achieving excellence in the treatment process entails delivering high-quality treated logs to customers that are not only cost-effective but also environmentally sustainable. This commitment to excellence is driven by the need to surpass conventional treatment methods and establish vacuum and steam technology as the preferred choice for hardwood treatment.

The purpose of this study is to deliver treated logs that meet or exceed customer expectations in terms of quality, cost-efficiency, and timeliness. By optimizing treatment processes and leveraging technological innovations, companies can streamline operations and reduce treatment costs, ultimately offering customers a more competitive pricing structure.

By minimizing reliance on chemical treatment methods and adopting environmentally sustainable practices such as vacuum and steam technology, companies can significantly reduce their ecological footprint and contribute to the preservation of natural resources. Furthermore, by prioritizing sustainable treatment practices, companies can differentiate themselves in the marketplace and appeal to environmentally conscious customers seeking responsibly sourced products. Ultimately, excellence in the treatment process is synonymous with delivering superior value to customers while upholding the highest standards of quality, efficiency, and environmental sustainability.

iv. Measuring success metrics

To ensure our success in delivering high-quality treated logs that are cost-effective, and environmentally sustainable, we will implement a comprehensive strategy focused on optimizing every aspect of the treatment process. Central to this strategy is the establishment of clear, measurable performance metrics that will serve as benchmarks for success. These metrics will include quality controls to ensure the efficacy of treatment methods, treatment time to minimize unproductive times, treatment efficiency to maximize resource utilization, and final cost per treated batch to maintain cost-effectiveness.

To begin, we will create quality control measures at every stage of the treatment process to guarantee the highest standards of quality and efficacy. This will involve implementing rigorous inspection protocols, utilizing testing equipment, and adhering to industry best practices to identify and eliminate any potential defects or inconsistencies in the treated logs. By prioritizing quality assurance, we will instill confidence in our customers and ensure that our treated logs meet or exceed their expectations.

Additionally, we will focus on optimizing treatment time by streamlining processes and standardizing the steps that need to be followed. By minimizing downtime and maximizing throughput, we will reduce unproductive times and enhance operational efficiency, allowing us to meet customer demand more effectively and maintain a competitive edge in the market.

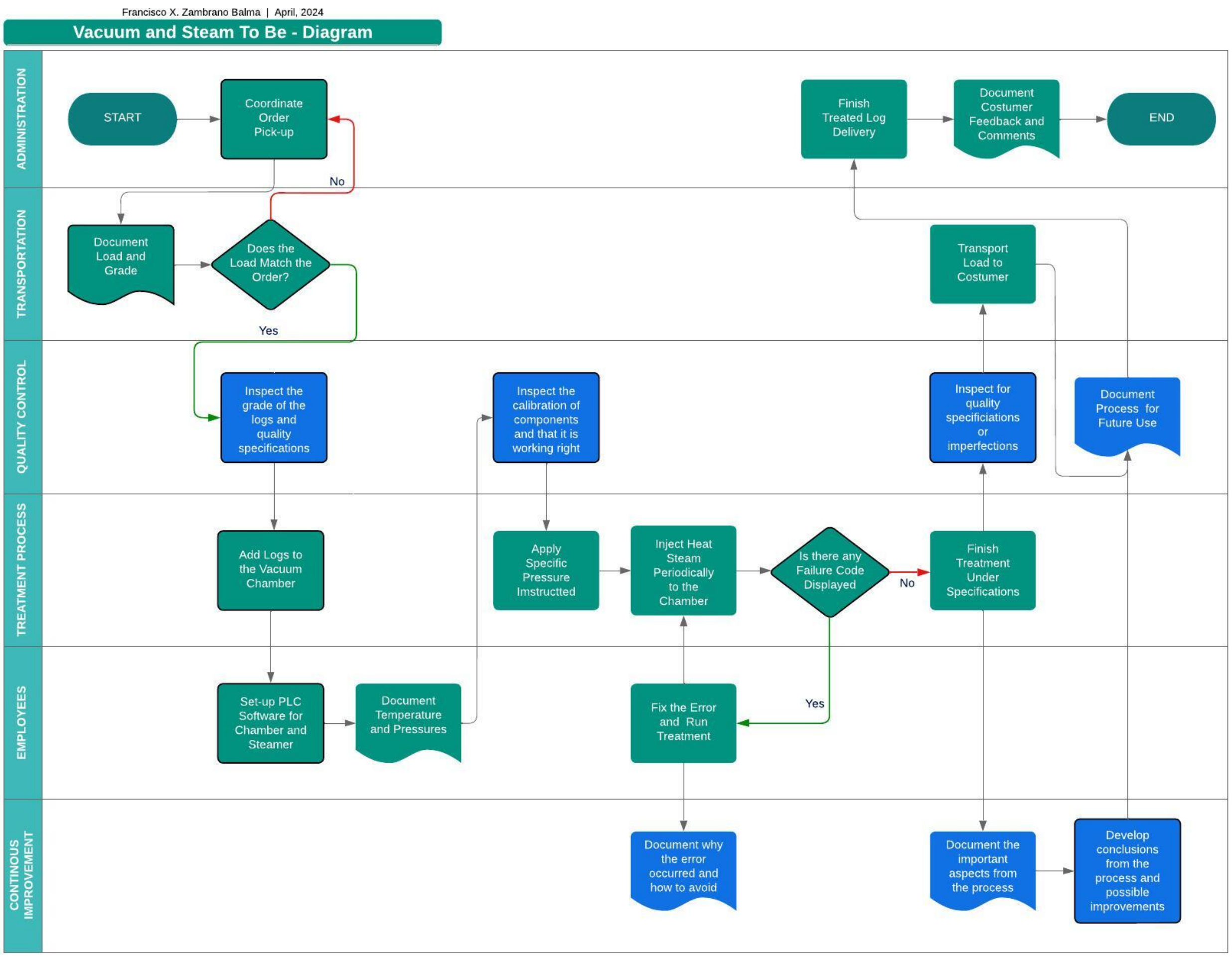


Figure 16. To-Be diagram

Furthermore, we will prioritize treatment efficiency by implementing lean principles and continuous improvement initiatives to identify and eliminate inefficiencies in our processes. This will involve analyzing workflow patterns, optimizing resource allocation, and leveraging data analytics to identify opportunities for enhancement.

By enhancing treatment efficiency, we will minimize waste, reduce costs, and improve overall productivity, enabling us to deliver treated logs at a lower cost and with a reduced environmental footprint. To understand these steps better, we have developed a To-Be diagram (Figure 4) to visually map out the application of these performance metrics within our treatment process. This diagram will provide a clear, structured overview of how each metric will be monitored and measured, facilitating ongoing performance evaluation and continuous improvement efforts.

In the redesigned To-Be diagram, enhancements to the phytosanitation treatment process include the integration of two new specialized departments aimed at elevating treatment quality and fostering continuous improvement initiatives. Firstly, a Quality Assurance department is established to conduct thorough inspections at critical junctures of the treatment process. Upon receipt of hardwood logs from suppliers, an initial inspection ensures adherence to specified quality grades and identifies any imperfections that could impact log value. Subsequently, just before entry into the vacuum chamber, another inspection verifies the calibration and functionality of all chamber components. A final inspection post-treatment assesses for any new imperfections, such as knots or color changes, and confirms the eradication of larvae and insects.

Additionally, a dedicated Continuous Improvement division is established to systematically gather feedback from process stakeholders and analyze treatment performance data. This department documents any deviations or errors encountered during the treatment process and formulates comprehensive reviews and recommendations for process enhancement. By leveraging insights gleaned from these analyses, the Continuous Improvement team ensures ongoing optimization of treatment protocols for subsequent batches.

Incorporating these new departments into the treatment process underscores our commitment to upholding treatment quality standards and driving continual process refinement. For detailed process steps and inspection protocols, refer to the accompanying documentation provided in the appendix.

v. Summary of the performance measurement system

- ***Optimizing Treatment Processes:*** The implementation of vacuum and steam treatment technology presents a promising innovation for optimizing treatment processes in the hardwood import industry. With these technological innovations and prioritizing sustainability, companies can enhance productivity, reduce treatment costs, and enhance treatment efficiency.

- ***Meeting Quality Standards:*** The establishment of robust quality control measures is essential for ensuring that treated logs meet or exceed regulatory and customer quality standards. Through inspections and quality protocols, companies can create confidence in their ability to deliver high-quality treated logs that comply with regulatory requirements.

- ***Driving Continuous Improvement:*** The integration of specialized departments focused on quality assurance and continuous improvement underlines a commitment to drive operational excellence in the company. By systematically gathering feedback, analyzing performance data, and implementing process enhancements, companies can continually improve treatment protocols and enhance overall operational efficiency.

- ***Enhancing Environmental Sustainability:*** Prioritizing environmentally sustainable treatment practices, such as vacuum and steam technology, is crucial for minimizing ecological footprint and preserving natural resources. By reducing reliance on chemical treatment methods and adopting sustainable practices, companies can differentiate themselves in the marketplace and appeal to environmentally conscious customers.

- ***Strategic Decision-Making:*** The insights gained from performance measurement systems, SIPOC diagrams, and process mapping tools provide valuable guidance for strategic decision-making processes within the hardwood import industry. This way we can align technology adoption with overarching goals and objectives, and companies can enhance competitiveness, and meet the evolving needs of the market.

VI. Implementing Measurement System

To effectively implement this measurement system, a company must adhere to a detailed set of steps to ensure the successful integration of new technology and the delivery of optimal processes for their customers. These steps are outlined in the table provided below.

Table 10. Steps for measurement systems

Step 1	**Development of Standardized Treatment Process**	First, there is a need to identify the key stakeholders that are going to oversee implement this performance measurement system. There is a need to create a quality assurance team, management, as well as qualify personnel that know how to operate the machines and the software. Also outlines the specific steps that must be follow by the stakeholders that will assure optimization with the need for measurement and the objectives that we want to accomplish. Develop a plan detailing the milestones as well as indicators that will let us know that the process is working as it is intended to be.
Step 2	**Specification of Tools and Data Collection Methods**	When it comes to apply tools for working with the machines and detailing all the aspects of the treatment process, we must be certain that the people are qualified to work those tools and that they can provide feedback in case something happens throughout the treatment process.
Step 3	**Definition of Reporting and Communication Processes**	Define clear communication channels and protocols to share performance updates that would allow anyone, regardless of status, to express their insights in a productive setting. This will ensure transparency when reporting the process and will create more trust.
Step 4	**Stablish a Continuous Improvement System**	Implement a system for continuous improvement monitoring that will allow for a clear and easy way for the personnel to review data after every batch of treated logs that would help with decision making and for improvement in terms of efficiency. Anyone should be able to contribute with their insights but the people actively working on the system possess the best insights.

VII. Summary of Best Practices

The findings from our research provide a pathway to increase U.S. hardwood log exports, emphasizing the adoption of vacuum and heat steam technology. Based on interviews with industry stakeholders and analysis of the collected data, we recommend the best practices to increase the hardwood log export transitioning from methyl bromide to non-chemical treatments are the following:

Adoption of Vacuum and Steam Technology by Government Agencies:

- Engage with government agencies to promote the benefits of vacuum and steam treatment technology.
- Advocate for regulatory changes to support the adoption of this environmentally friendly and efficient treatment method.

Reduction of Treatment Costs:

- Implement the vacuum and steam heat technology to lower the overall cost of hardwood log treatments because it uses natural resources instead of chemicals.
- Highlight the long-term economic benefits and efficiencies gained through the adoption of this technology.

Overcoming Political Trade Barriers:

- Collaborate with trade organizations and government bodies to address and reduce political trade barriers.
- Strengthen diplomatic efforts to ensure smoother international trade relations and market access.

Maintaining Log Quality:

- As we discussed in this manual, the implementation of the new treatment method does not compromise the quality of the logs.
- Ensuring that the quality of the logs is not compromised throughout the process, is going to facilitate companies accepting a new treatment method.
- Develop and adhere to stringent quality control measures to maintain the high standards expected by international buyers.

VIII. Appendix

Appendix No. 1. Quality assurance documentation.

Ref. No.	Audit Question	Score (1-5)	Standards met (Yes/No)	Improvement needed (Yes/No)	Notes/ Recommendations
1	How was the supplier hardwood log delivery?				
2	Do the hardwood logs batch have a correct grade and size?				
3	Are there any noticeable issues or diffects in the batch?				
4	How was the transport from recived logs into the process?				
5	Is the setup for the treatment software correct for the batch?				
6	Was the inspection before the treatment done correctly?				
7	Was any error detected and was it fixed propertly?				
8	Where the values and errors collected from the software?				
9	Did the treatment process finished correctly?				
10	How was the process of taking the logs out of the process?				
11	How was the inspection once the treatment ended?				
12	Was there any new diffects detected on the batch?				
13	The documentation process was done according to protocol?				
14	How was the delivery of the treat logs to the costumer?				

Guidance for Completing the Table

1. **Score (1-5)**: Rate the performance or outcome, with 1 being poor and 5 being excellent.
2. **Standard Met (Yes/No)**: Indicate if the process meets the required standards.
3. **Improvement Needed (Yes/No)**: Specify if areas need improvement.
4. **Comments**: Provide additional notes, concerns, or recommendations.