EXAMINATION OF SUSTAINABILITY INDICATORS IN AN ORIENTED STRAND BOARD (OSB) BUSINESS WITH SUSTAINABLE VALUE STREAM MAPPING DESIGN (SUS-VSM)

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Abstract

Sustainability in the forest products sector in Turkey depends on the sustainable management of the country's forests, but its importance has been increasing in recent years. Various practices are implemented in the sector for sustainability. However, little is known about the consequences of these practices in forest products businesses. Oriented Strand Board (OSB), an output of the forest products sector, is produced by mixing the chips obtained by chipping small-diameter round wood raw material in the longitudinal direction with glue and wax, and then pressing them under certain pressure and temperature. This study aims to examine sustainability indicators in an OSB business with Sustainable Value Stream Mapping Design (sus-VSM). The research was carried out in a business that has been producing OSB for more than 10 years in Turkey. The business has high quality efficiency (99.7%) in the economic indicator and high material efficiency (97.8%) in the environmental indicator. The safety efficiency level, one of the social indicators, is low (70%). The results showed that the business can be an exemplary business in terms of sustainable production by making improvements in the safety level. It is recommended to add efficiency regarding waste use by sector as a variable to the sus-VSM design in future studies.

Keywords: *sustainable production, sustainable value stream mapping, sustainable occupational and health and safety, board industry, forest product sector*

1. INTRODUCTION

It is known that the origin of the concept of sustainability is based on the principle of Central European foresters that "there is a long-term stable flow of goods and services necessary for the well-being of people from a forest" (Pretzch 2014). The concept of sustainability, which started with their pioneering ideas, was transferred from forestry to other natural systems over time (Diaz-Balteiro et al. 2018). With the increase in world population, industrialization and consumption habits have increased rapidly. This situation has led to the unconscious use of resources obtained from natural systems, the deterioration of the living environment of living things on earth and their existence under threat. Sustainable development is a very broad concept that has become popular and integrated into daily life. The United Nations World Commission on Environment and Development published a report called "Our Common Future" in 1987. In this report, the concept of "sustainable development" was defined for the first time as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Burton 1987). The International Union for Conservation of Nature (IUCN) provided the most well-known definition of sustainable development in 1980. According to IUCN, sustainable development is "Development that responds to today's needs without compromising the ability of future generations to meet their own needs" (Moltesen & Bjørn 2018).

Sustainability in the production process; It also includes fulfilling requirements such as the priority use of renewable resources and clean energy, optimized use and recycling of non-renewable resources, and reduced waste and energy production (Barata et al. 2016; Islam & Managi 2019). Sustainable production has been defined as "a value-added recovery process that can recover the value of the product at the end of its lifespan or throw it away" (Ngu et al. 2020). Therefore, sustainability begins in the design process of the product. When designing the product, not only the product, but also the five-part life cycle (pre-production, production, distribution, use and disposal) of the product should be taken into account, and the use of local materials from renewable resources should be prioritized (Barata et al. 2016; Djatna &

Prasetyo 2019). Accordingly, sustainability has directed businesses from traditional business policies focusing on economic goals and being socially responsible, to policies that reconsider their plans and expectations for the future and all their other activities in an environmentally friendly manner (Hartini et al. 2020). The development of this paradigm has encouraged businesses to move from traditional production systems and lean production to green production and then sustainable production (Ngu et al. 2020; Atoillah & Hartini 2021). Evaluation indicators representing the Triple Bottom Line (TBL) of the sustainability concept, that is, the interrelationships between environmental, social and economic dimensions, have been added to the structure of industrial management models and helped to change them (Junior et al. 2018; Cagno et al. 2019).

In lean production, any use of resources that does not directly contribute to creating value for the customer is considered waste and is aimed to be eliminated. Lean production can therefore be seen as a prerequisite for achieving sustainable production (Verma & Sharma 2021). It has been pointed out that it would be more effective for businesses to start any lean transformation initiative by applying the value stream mapping (VSM) technique (Ben Fredj-Ben Alaya 2016). VSM is a lean management tool that visualizes the process from a product to its delivery to the customer and provides opportunities for improvement by identifying where waste exists (Rafael et al. 2022). VSM monitors the flow of materials, information and organizational decision-making and provides the basis for redesigning the production system by making improvements in non-value-added activities (Singh et al. 2011; Forno et al. 2014; Vinodh et al. 2015). Sustainable value stream mapping (Sus-VSM) is a tool that assesses the economic, environmental, and social impacts of business activities (Faulkner & Badurdeen 2014; Djatna & Prasetyo 2019). Examining how sus-VSM is implemented in different businesses, the obstacles to implementation and its impact on business performance is presented as an interesting research area (Atoillah & Hartini 2021).

The forest products industry works with wood, a unique raw material. The forest products industry is a worldwide industry and sources raw materials from all over the world. This shows that the industry must be environmentally responsible for the production of forest products to be sustainable (Tuppura et al. 2013). This sector, which relies on renewable natural resources from forests, is well-equipped to provide products that promote long-term environmental, economic, and social sustainability. However, forest products businesses need to internalize economic and social development institutionally in order to perceive the concept of sustainability and apply it in their management (de Souzaa et al. 2019).

In order to measure and control sustainability performance accurately and effectively, businesses present lack of time, reduced workforce and limited financial resources as reasons (Tremblay & Badri 2018). Businesses that want to improve themselves in this regard are directed to reveal their sustainability goodness levels. There are very few studies examining the issue of sustainability with sus-VSM in the forest products sector. Hartini et al. (2018) developed a VSM method in which environmental and social dimensions were added to ensure sustainable production, and with this technique, they visualized and evaluated the production process performance on a furniture business from a sustainability perspective. In this previous study, wood consumption efficiency was found to be 54.5% in a furniture business. In another study examining sustainability indicators with sus-VSM in an MDF business, the time efficiency level was found to be 81%, the quality level was 93.5%, the material consumption efficiency level was 59.3% and the worker health level was 75.75% (Atoillah &Hartini 2021).

Oriented Strand Board (OSB), an output of the forest products sector, is produced by mixing the chips obtained by chipping small-diameter round wood raw material in the longitudinal direction with glue and wax, and then pressing them under certain pressure and temperature. OSB production is a complex process. OSB businesses use wood, a natural material obtained by deforestation that causes global warming, as raw material. Although some OSB businesses can use wood waste from furniture businesses, they also produce waste themselves. In these businesses, in addition to evaluating material efficiency among environmental dimension indicators, it is also important to evaluate the efficiency of economic and social dimension indicators. A sustainable OSB production can improve the activities of businesses in economic, environmental and social dimensions and increase their efficiency. However, there are no studies on the efficiency, waste production and occupational health and safety level of OSB businesses in Turkey. In this direction, this study aims to examine sustainability indicators in an OSB business with sus-VSM.

2. MATERIALS AND METHODS

The business where the study was conducted is an approximately 50-year-old institution located in Turkey, built on an area of more than 650,000 m2, and has been producing OSB for more than 10 years. The business uses advanced technologies in OSB production and leads the sector in this regard. The business carries out its production activities without creating waste, with minimal environmental impact and a high level of raw material efficiency. The business has an average footprint of -1,047,646.48 tons of CO2 eq per cubic meter in its products with its wood-based panel production. In general, the production process in this business is raw material and chip production, OSB drying, OSB preparation, gluing, laying and pressing and sizing.

2.1. Stages of the study

In the first stage of the study, the production process was determined to examine sustainable production with the sus-VSM design in the OSB business. At this stage, the researcher made a field trip for the production process (Figure 1). After starting OSM production, 5 main processes are carried out: raw material and chip production, OSB drying, OSB preparation, gluing, laying and pressing and sizing.

Fig. 1. Production process

In the second stage of the study, sustainability indicators of economic, social and environmental dimensions were determined through an interview with the top manager. The indicators selected based on the top manager interview are time efficiency, quality efficiency, material consumption, health level and safety level. The formulas used to evaluate the performance of the indicators are given in Table 1. In the economic dimension time efficiency (TE) calculation, the ratio of value-added time (VAT) in the total process time (TT) was calculated. In the calculation of quality efficiency (QE), another economic indicator, it was calculated by subtracting the ratio of the number of defective materials (ND) to the total material (TM) from 1. In calculating the environmental dimension material efficiency (ME), the ratio of value-added material (VAM) to the total material (TM) was calculated. In the social dimension, health efficiency (HE) was calculated by subtracting the ratio of number employees absent (NA) to the total number employee (NE) from 1. In the social dimension, risk efficiency (RE) was calculated by subtracting the ratio of number of activities with risks (NR) to the total number of activities (Nac) from 1.

Dimension	Indicator	The related metrics	Equation	References
ECONOMY	Time Efficiency (TE)	VAT: Value Added Time NVAT: Non-Value-Added Time TT: Total Time	TE=VAT/TT	Faulkner & Badurdeen 2014
	Quality Efficiency (QE)	ND: Number of Defects TM: Total Material QE: Quality Efficiency	QE=1-ND/TM	Huang & Badurdeen 2018; Hartini et al. 2020

ENVIRONMENTAL	Material Efficiency (ME)	VAM: Value Added Material NVAM: Non-Value-Added Material TM: Total Material	ME=VAM/TM	Faulkner & Badurdeen 2014
SOCIAL	Health Efficiency (HE)	NA: Number employees absent NE: Number employee	HE=1-NA/NE	Lee et al. 2014; Huang & Badurdeen 2018; Hartini et al. 2020
	Risk Efficiency (RE)	NR: Number of activities with risks Nac: Number of activities	RE= 1-NR/Nac	Lee et al. 2014; Huang & Badurdeen 2018; Hartini et al. 2020

Table 1. Scoring formulas for the indicators

In the third stage of the study, evaluations were made through direct observation and measurement. Production time measurements were carried out with 30-day observation results in each process.

3. RESULTS

3.1. Evaluation of economic dimension sustainability performance

Indicators related to time and quality efficiency within the scope of the economic dimension sustainability performance of the business are given in Table 2. When the time efficiency of the business is examined, it is 89% in the raw material and chip production process, 94% in the OSB drying process, 97% in the OSB preparation process, 96% in the gluing, laying and pressing line process and 98% in the sizing process. Time efficiency is at a high level in all processes, and the average time efficiency in all processes of the business is 95%. The final product quality efficiency of the business is 99.7% and the defective product rate is 0.3%.

Process	TT (s)	VAT (s)	NVAT (s)	Efficiency (%)
Raw Material and Chip Production	1440	1275	165	89.0
OSB Drying	1440	1359	81	94.0
OSB Preparation	1440	1394	46	97.0
Gluing, laying and pressing line	1440	1385	55	96.0
Sizing	1440	1416	24	98.0
Average Time Efficiency (TE)				95.0
Average Quality Efficiency (QE)				99.7
Defect product rate				0.3

Table 2. Time and quality efficiency

3.2. Environmental dimension sustainability performance evaluation

Indicators regarding the material efficiency level of the business within the scope of its environmental sustainability performance are given in Table 3. When the material efficiency level of the business is examined, it is 97.3% in the first week, 98.9% in the second and third weeks, and 96% in the fourth week. The 4-week average material efficiency level of the business is 97.8%. In addition, the business transforms waste materials into value-added products at the rate of approximately 2% of raw materials monthly.

Week	TM (tons)	VAM (tons)	NVAM (tons)	Efficiency (%)
1	1385.92	1348.39	37.53	97.3
2	1385.72	1371.53	14.19	98.9
3	1212.56	1199.67	12.89	98.9
4	1164.94	1118.06	46.88	96.0
Average	1287.28	1259.41	27.87	
Average Material consumption Efficiency (ME)				97.8

Table 3. Material consumption efficiency

3.3. Evaluation of social dimension sustainability performance

Indicators regarding the health level and safety level of the business within the scope of its social dimension sustainability performance are given in Table 4. Within the scope of the social dimension sustainability performance of the business, the number of workers absent for 30 days and work accident data for 2023 were taken from the occupational health and safety unit. In this regard, the average monthly health efficiency level is 95%. The noise level of the business 63 at dB(A) level. Total particle suspension 228 g/m3.

Health Level (HL)	NA (n)	NE (n)	Efficiency (%)
Average Health Efficiency (HE)	2	41	95.0
Safety Level (SL)	**NR**	**Nac**	**Efficiency (%)**
Average Safety Level Efficiency (SE)	77	255	70.0

Table 4. Health and safety efficiency

According to the hazard and risk analysis carried out in the business during the year, the number of high-risk actions in 255 activities was 181, while the number of high-risk actions became 77 after the measures taken. The safety efficiency level of the business was found to be 70%.

Safety risks and risk categories according to the production processes of the business are summarized in Table 5. There are high risks of injury in the vehicle during the raw material and chip production process, a boiler explosion risk in the OSB drying process, a burn risk in the OSB preparation process, dermatological/allergic risks in gluing, laying and pressing process, and crushing and injury risk of in the sizing process. The riskiest processes in OSB production are, respectively, OSB preparation, gluing, laying and pressing, sizing, raw material and chip production and OSB drying.

Proses	Safety risks	Category
Raw Material and Chip Production	- Crushing, injury	- Low
	- Fractures	- Low
	- Limb compression	- Low
	- Impact of wood chips	- Moderate
	- Injury in vehicle	- High
OSB Drying	- Boiler explosion	- High
	- Injury	- Moderate
	- Finger fractures	- Low
	- Burns	- Low
OSB Preparation	- Injury	- Moderate
	- Hand severed	- Moderate
	- Getting stuck in the machine	- Moderate
	- Respiratory risks	- Low
	- Burns	- High
	- Dermatological/allergic risks	- Low
	- Death	- Low
Gluing, laying and pressing	- Injury	- Moderate
	- Hand severed	- Low
	- Dermatological/allergic risks	- High
	- Burns	- Low
	- Respiratory risks	- Moderate
	- Death	- Low
Sizing	- Respiratory risks	- Moderate
	- Crushing, injury	- High
	- Limb compression	- Moderate
	- Death	- Low
	- Fractures	- Low

Table 5. Safety risks

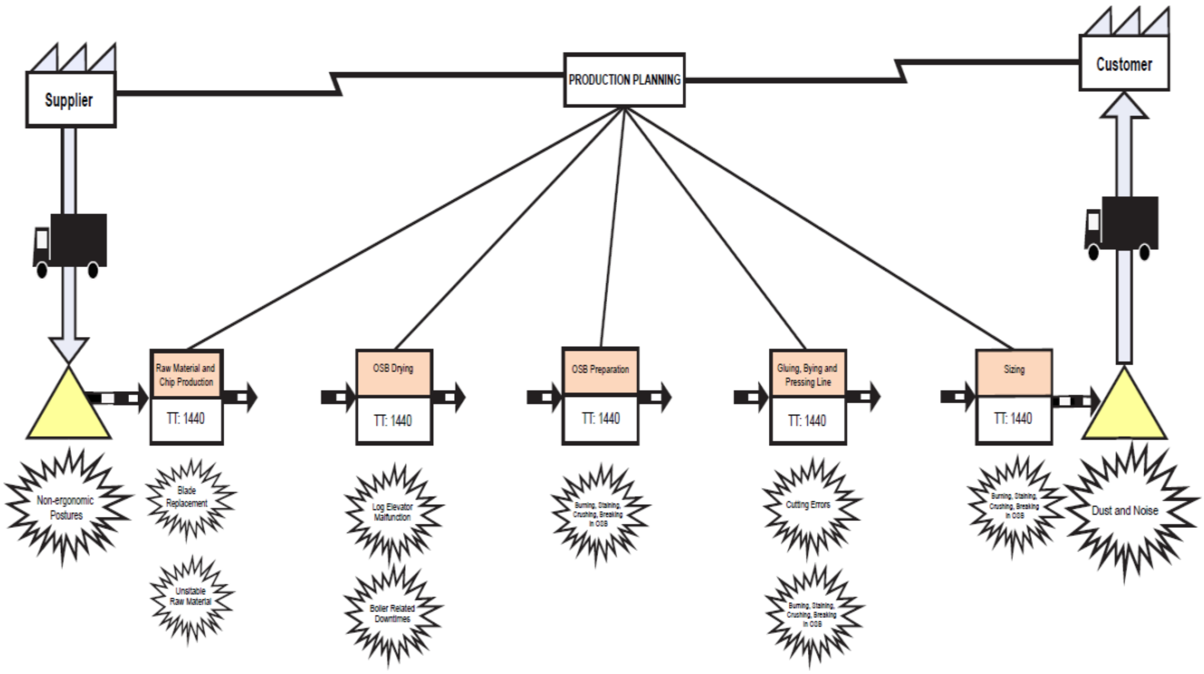
3.4. Sustainable value stream mapping

Suggestions for improving the sustainability performance of the business are given in Table 6. In order to increase the time efficiency of the business, the use of longer-lasting blades and more durable elevator pistons in the raw material and chip production process has been recommended. Routine maintenance of sensors used in OSB pressing and sizing processes is recommended to increase quality efficiency. In order to increase material efficiency, it is recommended to cooperate with SMEs on the recycling of wood waste and to develop products based on wood waste. It is recommended to continue occupational health and safety training and safety and health certification studies for equipment in order to increase the safety efficiency, which is low due to high-risk actions in OSB production. In order to increase the health level, the use of ergonomic tools and equipment, periodic health checks of employees and supervision of the use of personal protective equipment have been recommended.

Performance type	**Adverse effects**	**Improvement suggestions**
Time	▪ Downtimes due to blade replacement and log elevator malfunction in the raw material and chip production process ▪ Unsuitable raw material and boiler related downtimes in the drying process	▪ Use of longer-lasting blades ▪ Using more durable pistons in the elevator ▪ Balancing the moisture content of the wood by making arrangements in the wood area ▪ Use of quality control systems that control the moisture of wood ▪ Using a boiler suitable for capacity
Quality	▪ Burning, staining, crushing, breaking in OSB during the pressing process. ▪ Cutting errors in OSB during the sizing process	▪ Routine maintenance of production sensors ▪ More frequent replacement of saw hub bearings
Material		▪ Cooperating with SMEs regarding the recycling of wood waste ▪ Developing products based on wood waste
Safety	▪ High risk as wood saws, boilers and heavy materials are used in OSB production	▪ Continuing Occupational Health and Safety training for workers ▪ Maintaining standardization by providing safety and health certification facilities for machine operators (forklifts and boilers)
Health	▪ Non-ergonomic working postures, dusty and noisy working environments	▪ Use of hydraulic chairs with adjustable height ▪ Maintaining periodic health checks ▪ Maintaining regular maintenance of filters to minimize the number of dust particles ▪ Supervising the use of personal protective equipment and equipment (mask, earplugs, gloves and shoes, etc.) by employees

Table 6. Performance type, adverse effects and improvement suggestions

The sus-VSM design of the current state of the business's sustainability performance in OSB production is shown in Figure 2. This business has a production flow consisting of 5 sub-processes, from receiving the logs from the supplier to delivering the OSBs to the customer. The business has time efficiency (95%) and high-quality efficiency (99.7%) in the economic indicator, high material efficiency (97.8%) in the environmental indicator, and high health efficiency (95%) in the social indicator. The safety efficiency level, one of the social indicators, is low (70%).



Time Efficiency	VA=1275, NVA=165, Ratio=89%	VA=1359, NVA=81, Ratio=94%	VA=1394, NVA=46, Ratio=97%	VA=1385, NVA=55, Ratio=96%	VA=1416, NVA=24, Ratio=98%	Ratio=95%
Quality Efficiency	Ratio=99.7%					Ratio=99.7%
Material Efficiency	TM=1287 ton, VAM=1259 ton					Ratio=97.8%
Health Level	NA=2, NE= 41, Ratio=95%					Ratio=95%
Safety Level	NA=77, NE=255, Ratio=70%					Ratio=70%

Fig. 2. Current value stream mapping

4. DISCUSSION

Sustainability efforts of businesses have become important management tools to create conditions for education and competitiveness (Tachizawa 2002). In this study, sustainability indicators in an OSB business were examined with sustainable value stream mapping design (sus-VSM). The fact that the business has a sustainability policy has made a significant difference in the time and quality efficiency indicators related to its economic sustainability and on the material efficiency related to its environmental sustainability. In Brazil, the sustainability level was evaluated as higher than 0.600 (0.000–1.000) in 75.8% of Rio micro and small-scale furniture businesses. Sustainability effectiveness was found to be higher in economic and social dimension indicators and lower in the environmental dimension (Feil et al. 2022).

If time efficiency can be improved, productivity increases and the relative cost of production per unit decreases. Reducing the production cost will increase the economic performance of the business. Process time affects the amount of production financing and accuracy of product delivery (Faulkner & Badurdeen 2014; Costa et al. 2018). The main reasons for stoppages during raw material and chip production are blade replacement and log elevator malfunction. The main reasons for stopping the drying process are unsuitable raw materials and problems with the boiler. Product defects generally occur in the form of burning, staining, crushing, or breaking during the pressing process, and these situations may vary depending on the thickness of the OSB. Other product defects are caused by cutting errors in the sizing process. Failure to optimize the amount of materials used for a particular process results in increased energy consumption and waste products. Often, the largest material waste in production relates to the amounts lost during cutting operations leading to increased waste material (Faulkner & Badurdeen 2014). Wieruszewski et al. (2023) showed that depending on the log size and the advanced processing technology used, the economic efficiency is 170%-290% and optimization is the determining factors affecting cost efficiencies in the timber processing process. SMEs in the Australian wooden furniture manufacturing sector have shown that between 7% and 40-50% of the annual wood raw material supply becomes waste during processing, and the costs directly associated with this waste have been determined to represent 2-8% of turnover (Daian and Ozarska 2009).The amount of material used is directly linked to the process time required to create a product, as well as the energy consumption of this process, and is therefore linked to both the economic and environmental performance of a process line (Verma & Sharma 2021). Sygulla et al. (2011) reported that 50% of the costs in production come from energy consumption and raw material use to produce the product. In a study in the forest products sector, it was determined that 52% of businesses use woody waste as fuel to produce heat energy, thus providing both energy and economic sustainability (Türkoğlu et al. 2015).

It is necessary to examine the impact of sustainability on the social environment, taking into account all relevant stakeholders. While the health efficiency of this business regarding social sustainability is sufficient, the safety efficiency is low. The good health of workers is greatly affected by environmental conditions in the work environment, such as air quality, dust and noise levels. In order to increase safety efficiency, it is recommended that the business support the safe behavior of employees and the use of protective equipment and continue improvement efforts in risky areas. Despite the risk level of the business, occupational accident rates are low. Risks to employee health and safety should be measured and monitored regularly, regardless of whether these risks are daily hazards to the employee or potential hazards to the employee during a specific period (Kumar & Antony 2008; Khan et al. 2019). Overall, prioritizing employee safety is not just a social responsibility; it's also essential for achieving overall business sustainability. This ensures a healthy and productive workforce, which in turn contributes to the business's long-term success.

5. CONCLUSIONS

This study revealed time, quality, material consumption, occupational health and safety indicators with the sus-VSM application in an OSB business and offered suggestions on how to improve them. The highest efficiency level among all dimensions is quality efficiency (99.7%), followed by material efficiency (97.8%). Time and health efficiency (both 95%) ranked third. The performance of the business in these four sub-dimensions is quite high. There are 77 risky actions in the business and the safety efficiency level of the business is low (70%). Suggestions have been presented for the business to maintain its performance in dimensions with high productivity levels and to increase its performance in dimensions with low productivity. Sus-VSM is a useful tool in demonstrating sustainability in OSB businesses. The design put forward in this study can be applied to OSB businesses with different characteristics to create a general profile of this industry. In addition, conducting similar studies using sus-VSM in businesses in different sectors of the forest products industry may enable comparisons between sectors. In addition, it is recommended to add efficiency regarding waste use by sector as a variable to the sus-VSM design in future studies.

ETHICAL APPROVAL

For the study to be conducted, written permission was obtained from the Scientific Research and Publication Ethics Committee of a state university (Date: 17.10.2023, Decision No: 07-2023/20). Before the interviews and data collection, OSB business managers were informed about the nature of the study and written consent was obtained in line with the principle of volunteering.

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