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# CONCEPTUAL MODEL DESIGN OF SUSTAINABLE PALM SHELL SUPPLY CHAIN BUSINESS PROCESSES

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**ABTSRAK**

This study aimed to design a graphical conceptual model of the sustainable palm kernel shell processing industry in Indonesia. This study used system entity analysis and Business Process Modeling Notation (BPMN 2.0) to find out the conceptual model of sustainable palm kernel shell industrial processing including procurement of palm kernel shell to be processed into several high value-added products such as coal briquette fuel, feed mixtures livestock, and road paving materials. The conceptual model in the form of a system entity model and business process was integrated with sustainable economic, social, and environmental concepts. The conceptual model can be the basis for the development of other models at the strategic, planning, and operational levels of the sustainable palm kernel shell supply chain.

**Key words: Palm Kernel Shell, Sustainable, BPMN**

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## 1. BACKGROUND

Palm kernel shell is a waste from palm oil processing that has not been utilized optimally (Yarman 2006). Kernel shell is one source of biomass that can be processed into Palm Kernel Shell Charcoal (PKSC). PKSC is widely used to become coal. Compared to diesel and coal, PKSC requires lower costs, has a small environmental impact, and is abundantly available (Saefudin 2012). Palm kernel shell charcoal is used by the activated carbon industry, briquettes to steel smelting. Activated carbon can be used as a color and odor remover in the beverage industry, oil refining, color and odor cleaning in water treatment, dye removal in the sugar industry, solvent recovery, removal of sulfur, toxic gases, and odors in gas purification, as well as a catalyst (Subhadra, 2005). Optimal utilization of palm kernel shell into a product with high added value requires sustainable supply chain management with consideration of environmental, economic, and social impacts.

Sustainable supply chain management to ensure optimal utilization of palm kernel shell waste is a challenge in the current study of sustainable palm oil. Gatti et al (2019) stated that environmental and socio-economic challenges are important aspects to consider in sustainable palm oil waste processing. Wu et al (2017) stated that optimizing the utilization of palm kernel shell waste into potential products needs to be studied in the form of the supply chain in order to optimize the impact on the environment, society, and economy. The palm oil industry waste processing supply chain requires products to be produced, actors in the supply chain, value chain flows, economic, environmental, and social studies so that business processes run in a sustainable manner. This supply chain sustainability challenge needs attention from industry, government and researchers holistically, namely from an economic, social, and environmental approach. The sustainable supply chain approach views business activities from upstream to downstream as a unit to be connected and interact with each other to achieve the same goal. Studies on sustainable supply chain systems have become increasingly popular in recent years due to sustainability issues in various sectors (Carter and Easton, 2011).

Many studies related to supply chain sustainability have been carried out in the last few decades. Lim and Biswas (2018) conducted a study on the impact of sustainability on the integration of palm oil waste biogas processing with conventional palm oil supply chains. This study claimed that the integration of biogas processing with the supply chain can improve sustainability. Nevertheless, the challenge of waste treatment production is still an aspect that needs to be considered in future studies. Hadiguna and Tjahjono (2017) stated that performance measurement and optimization of integrated supply chains need important attention in the study of sustainable palm kernel supply chains. Pacheco et al (2020) and Munasinghe et al (2019) recommended a study on the sustainability of palm oil waste processing, especially connectivity between actors, value chain flows, system complexity, and their social, economic, and environmental impacts. These studies provide insight and an illustration that an integrated design of a sustainable supply chain for waste treatment is important in an effort to improve the sustainability of the palm oil business. Previous studies related to sustainable palm oil have not yet conducted a holistic sustainability study on the processing of palm kernel shells into a high value-added product. Increasing the added value of palm kernel shell has not been performed optimally, although several previous studies suggested conducting a study on various by-products of sustainable palm oil processing. Currently, palm kernel shell waste treatment is limited to boiler fuel and is sold directly in the form of kernel shell exports abroad. Thus, supply chain design as a strategic aspect to increase the added value of palm kernel shell is a novelty and important to be studied as a contribution to the supply chain study of the palm oil industry.

This study aimed to design a graphical conceptual model to find out the sustainable supply chain of palm kernel shell processed products. This study is part of a dissertation entitled "Design of Sustainable Palm Kernel Shell Supply Chain". This study is a part of a sustainable supply chain flow model for palm kernel shell agroindustry management with a

system entity approach and Business Process Modeling Notation (BPMN 2.0) in each component of continuous conflict. As an output, conceptual graphic models can be the basis for the development of advanced models such as simulations and mathematical models as well as process flows in feasibility studies so that they can have a positive impact in terms of economic, social, and environmental. The novelty claimed in this study is the complex design of sustainable palm kernel shell supply chain with a system entity approach and Business Process Modeling Notation (BPMN 2.0) as the basis for developing a business model and processing management of sustainable palm kernel shelll. The methodology section describes a framework for developing a conceptual model based on a system entity model for system requirements analysis and a business process model based on BPMN 2.0. In the next section, a comprehensive graphical model is then described.

## 2. METHODOLOGY

This part consists of a conceptual study as described in the introduction, namely the entity system and business process model. The business process modeling of sustainable palm kernel shell supply chain was used to facilitate a more comprehensive understanding of the system through a conceptual approach to the business process model graphically. This part was divided into two, namely the analysis system using the entity system approach proposed by Wasson (2016) and the business process model using the Business Process Modeling Notation version 2.0. (BPMN 2.0).

### System Analysis of Sustainable Palm Kernel Shell Supply Chain

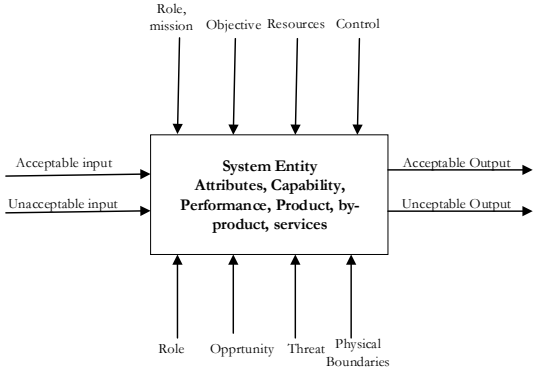


Figure 1 Representation of system in an entity (Wasson 2016)

Wasson (2016) represented a system in an entity composing a system which consists of acceptable and unacceptable inputs and outputs so that control can be carried out on unacceptable inputs and outputs; process consists of performance, product, by-product attributes; stakeholders and their respective roles, rules, resource constraints, mission, opportunities, threats, and feedback. The system is illustrated in Figure 1.

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The process in a business system is analogous to a system entity representing the top-level system, sub-systems, and other derivatives. This system entity has a limited ability to process inputs into outputs with certain performance measures. During processing inputs into outputs, the system will be influenced by factors from the environment such as stakeholders and their respective roles, rules, missions, opportunities, threats, controls, and resources. The resulting output can be either acceptable or unacceptable which will give feedback to the system.

A. Input and Output (*Acceptable* dan *Unacceptable*)

Everything enters into the system either acceptable or unacceptable. Both types of input have the possibility to enter and be processed by the system either intentionally or unintentionally. Input can be in the form of design or from the environment. Input can be in the form of stimuli, commands, cues, and everything that can be consumed by the system. Output is all the results of the value-added input process. Output can be product, by-product, service, or behavior.

B. Stakeholders

Each system functions to meet the operational needs, satisfaction, and benefits of each party involved in the system. When the relationship between the system and its stakeholders diminishes or ends, the existence of a system, product, or service has ended. In general, the stakeholders in this system are divided into 2, namely, those who carry out Command and Control operations or are called User(s) Roles and those who benefit (either directly or indirectly) from the system or are called End Users.

C. Roles, Missions, and Objectives

Roles are something that every stakeholder in the system must do in carrying out the role of Command and Control (C2). Missions are a number of tasks that must be fulfilled by a system according to the objectives in order to produce performance-based outputs set by the Higher-Order System (a higher system capable of commanding, directing, limiting, and controlling the system operation) and users. Each system has a goal that can be documented and supported by other more specific goals that can be calculated, measured, tested, and verified.

D. Resources

The resources needed by the system in carrying out operations to achieve performance-based goals. Resources are everything provided by the system environment to support the operating system, processing inputs into outputs with a certain performance. This means that in developing a system, the resources provided by the environment must be considered properly because it affects the performance of an operational system. The absence and insufficient resources from the environment will weaken the operation of the system and cause a system failure.

E. Internal Control (Constraints)

Internal control is one component of the system entity playing a role in controlling unacceptable inputs, operational limitations, and resources provided by the system environment. The existence of controls can reduce the possibility of unexpected things such as low system performance, unacceptable output, and system failure. This control can be either a set limit or a rule.

F. Threats

A threat is anything (intentionally or not) that has the opportunity to cause unacceptable outputs or system failure. These threats can arise from the system environment as a result of the operational limitations of a system. To reduce the impact and threats that have the opportunity to damage the system, good system control is needed as described previously.

G. Opportunity

Opportunities have opportunities to arise in system operational activities as a result of good system development/operations. This component can be utilized optimally for decision making and the next step in system development.

H. Operational Limits

Operational limitations are owned by the system in processing input into output. This limit is defined as the capability of the system in carrying out the task. It is also related to what the system can do and what the system cannot do (functionality).

**Business Model of Sustainable Palm Kernel Shell Supply Chain**

After conducting a system entity-based requirement analysis in the previous stage, the next stage was to design a graphical conceptual model to determine the behavior of the palm kernel shell supply chain. This graphic conceptual design makes it easier to find out the supporting strategy of sustainable palm kernel shell supply chain. This study used the conceptual diagram of BPMN 2.0 as a conceptual representation of the system design. BPMN 2.0 is a standardized graphical notation used to make it easier to understand not only actors in a system but also technical analysis and development with specific roles in configuring and supervising the implementation of a system (Sybase 2011). The notation in the business process model version 2.0 is flow objects, connecting objects, and swimlanes and artifacts.

A. Flow Object

The flow object consists of 3 objects, namely events, activities, and gateways as the main elements that make up the business process model in BPMN 2.0. Event is represented as a circle and means something that will "happen". Each notation contains a circle with a certain notation. The circle is defined as one of the event types. In general, events are divided into three, namely start, intermediate, and end events. The start event represents the trigger of a process denoted by a circle with a single line. The intermediate event represents something

happening between the start and end event and is denoted by a circle with a double line and can be used for the initiation of a process (catch) and the end of a process producing an output (throw). The end event represents the result of the process represented by a single thick line or circle with full color to be able to produce an output from the previous process (throw).

Start event none is a general start event that does not have a specific type and is generally used to start any process. The message start event is a start event starting a process when it receives a message from another process/task. Timer start event is a start event initiating a process based on a predefined time or the process starts according to a predetermined schedule. The escalation start event is a type of event that can only be used in sub-processes. Escalation start event initiating a sub-process occurs at the same or lower range. A conditional event triggers a process to run if it satisfies the condition.

The error start event can only be used in subprocesses, symbolizing that the initiation of a process must be carried out because an error is caused by a process or input in the form of a system failure. Compensation start event can only be executed on sub-process activate compensation process when a process or task is canceled or failed to execute. The start event signal is almost similar to the message event, except that a start event signal initiates a process regardless of whether the process will run or not from the signal, while the message event will initiate a specific process that will run based on an incoming message from outside. Multiple start event is used for several incoming inputs and summarized/recapitulated into one start event. The parallel start event is a multiple start event initiating 2 or more processes and running simultaneously.

Intermediate event is executed between the start and end event. Intermediate event none is a general intermediate event that does not have a specific type and is generally used to start any process in the middle of the process between the start and end events. Message intermediate event is an intermediate event starting a process when it receives a message from another process or task in the middle of the process between the start and end events. Timer intermediate event is an intermediate event initiating a process between start and end events based on a predetermined time. Escalation intermediate event is a type of intermediate event that can only be used in sub-processes between the start and end events. The conditional intermediate event triggers a process to run if it meets the conditions.

Intermediate event errors can only be used in subprocesses symbolizing the initiation of an intermediate process that must be carried out because an error is caused by a process or input in the form of a system failure. Compensation intermediate event can only be executed on the intermediate sub-process activating the compensation process when a process or task is canceled or fails to execute. Cancel intermediate events can only be executed on sub-processes and handle interrupts. This intermediate event is used to cancel a process or task and trigger an active compensation intermediate event. The intermediate event signal is almost the same as the message intermediate event, except that a signal start event initiates a process regardless of whether the process will run or not from the signal, while the message intermediate event will initiate a specific process running based on the incoming intermediate message from outside. The multiple intermediate event is used for multiple inputs to be summarized/recapitulated into a single trigger on the intermediate event. The parallel intermediate event is a multiple intermediate event initiating 2 or more processes and running simultaneously on the intermediate process.

End/terminated event is used to end a process on the lane. In contrast to start and intermediate, this event does not have interrupting or non-interrupting, catching, or top-level classifications. End events can be at the top-level or sub-process which functions are both ending or limiting a process by stopping it. Based on the type, end events are classified into none, message, escalation, error, cancel, compensation, signal, multiple, and terminate.

Activities in BPMN 2.0 represent a process in the business process model. Activities in BPMN 2.0 can be decomposed into more detailed processes into a sub-process. Activities in BPMN 2.0 consist of 13 notations. The

notations are abstract task, send task, receive task, user task, manual task, business rule task, service task, script task, transaction task, call activity, sub-process, event sub-process, ad hoc subprocess. The abstract task is the basic unit of a task. The send task sends a message to a participant or actor out of the location of the send task. Receive task waits for a message to arrive from a participant outside the process. When the message has been successfully received, the task is complete. User task shows a process with the help of tools developed by the developer. The user task requires the user to perform a procedure on the device so that the system can run. The manual task is done without the help of any device or system software.

The business rule task sends inputs to a device/process containing a number of rules and receives outputs from that device/process. A service task is a task consisting of automation processes. Script task executes a script interpreted by a business process engine. A transaction task contains a number of activities logically as a unit following a protocol or transaction rule. The call activity wraps a globally defined sub-process or task for reuse in the currently running process. The sub-process shows the internal details of a process in the form of a model composed of activities, gateways, events, and sequence flows. The sub-process event is assigned to a process or sub-process and is activated when the start event is triggered and can terminate the context of high-level processes or run in parallel (non-interrupting) depending on the start event. An ad hoc sub-process is a special sub-process in the form of a group of activities that do not have a sequential relationship where the order and amount are determined by the actors in a process.

Gateways control the sequential flow of a process and can combine or separate an input/output stream according to gateway conditions. In simple terms, a gateway is an if-else conditional. There are 7 types of gateways, namely basic/exclusive gateways, parallel gateways, inclusive gateways, event-based gateways, exclusive event-based gateways, parallel event-based gateways, and complex gateways. On splitting, the basic/exclusive gateway directs a flow to a single output branch. On merging, the basic/exclusive gateway waits for one stream branch to complete before triggering or activating the output stream.

On splitting, parallel gateway activates all branches out of the gateway in parallel. On merging, the parallel gateway waits for all branches to come to the gateway to complete. On splitting, inclusive gateway activates one or more gateway external branches. On merging, inclusive gateway waits for all input to the gateway branch to complete before merging. The event-based gateway is followed by receiving the tasks and flow routes that occur first. An exclusive event-based gateway starts a new process event for each continuation event that occurs. A parallel event-based gateway starts an event process for all continuation events to occur in parallel. Complex gateways perform complex merges or branch out behavior that other gateways cannot do

B. Connecting Objects

Flow objects are connected to each other using connecting objects consisting of three types, namely sequences, messages, associations. A sequence flow is represented by a solid line with one arrowhead at one end and shows the sequence of activities carried out.

Sequence flows may also have a small kite-shaped symbol indicating the conditional flow of an activity, while diagonal slashes indicate the default data flow of a decision or activity with the conditional flow. The message flow is represented by a dotted line, a circle at the beginning, and an open arrow at the other end. This line informs the message flows across organizational/actor boundaries (between pools of swimlanes).

This message stream cannot be used to link activities or events to the same pool. Association is represented by a dotted line to connect an artifact or text to an object stream, indicating the object flow with an open arrowhead at the end of the line flow representing the results and input of an artifact. This flow can be directionless (without arrowheads) when an artifact is associated with a sequence or message flow.

C. Swimlanes dan artifacts

Swimlanes are a visual mechanism for organizing and categorizing activities, based on cross-functional flow diagrams. Swimlanes consist of two types, namely pools and lanes. Pools represent major participants in a process, specifically separating different organizations/actors/stakeholders. A pool consists of two or more lanes. A pool can be open (showing details of the internal processes taking place in it) depicted as a large rectangle consisting of one or more lanes or closed (not showing visually the internal details of the processes contained within it) depicted as an empty rectangle with a certain width and length. Lanes are used to organize and categorize activities in the form of a pool based on their function or role described as a rectangle with a certain width and length in a pool. Lanes consist of flow objects, connecting objects, and artifacts. Artifacts allow a business developer to provide some additional information into the developed business process model, making the business process diagram easier to read and understand. There are three types of artifacts, namely data objects showing data required or generated for an activity, groups represented as squares with rounded corners and dotted lines for visually grouping activities without affecting the process in BPMN, and annotations to provide an overview and make it easier for readers to understand the business model.

## 3. RESULTS AND DISCUSSION

Based on field studies, there are three main entities in the sustainable palm kernel shell supply chain, namely raw material procurement, production, and sustainable supply chains.

**Table 1. The result of the analysis entity subsystem of raw material to input, the process and output**

| Process/Entity | Input | Output |
|---|---|---|
| **Raw material transportation** | The quantity of palm kernel shells, mode of transportation, travel time, transportation costs | Palm kernel shell arrived at the manufacturer on time, the quality of the palm kernel shell has not changed/damaged |
| **Quality control** | Standard palm kernel shell quality | Quality palm kernel shell |
| **Raw material storage** | Quantity of palm kernel shells, storage space size | Raw materials are stored well |
| **Procurement of palm kernel shell raw materials** | Demand quantity, demand location, supply quantity, palm kernel shell price, supply source | Demand and quantity of industrial raw materials per period |
| **Raw material handover** | Handover time, raw material receipt transaction data | Raw materials are available on time, quantities and types of raw materials received |

Table 2 The parties involved in the raw material procurement entity and their respective roles

| Stakeholders | Role |
|---|---|
| Collector | Purchase palm kernel shell, maintain quality, and carry out the transportation process |
| Raw material exporter | Purchase palm kernel shell from PKS and export raw materials |
| Processing industry procurement department | Buy and check the quality of palm kernel shell |

**Sub-System Entity of Procurment**

Based on field observations and literature review (Ngamel, 2011; Batoa et al, 2008), this subsystem has 4 main processes, namely raw aterial transportation, quality control, raw material storage, procurement of palm kernel shell raw materials, and raw material handover. This process plays a role in supplying palm kernel shell raw materials from FFB processing factories and collectors to semi-finished factories as well as for export processing in the form of commodities.

The sub-entity consists of 6 main processes as tabulated in Table 1. The raw material transportation process transports palm kernel shells with certain quantities, modes of transportation, time, and costs. Quantity, mode, time, and cost will be input in this process to transport palm kernel shells to producers of semi-finished products, finished products, and

| Threat | Control |
|---|---|
| Palm kernel shell is exposed to rain and dirt in the post-harvest process | Drying with protection/roof, keeping from contamination with soil/sand |
| Unavailability of transportation facilities and occurrence of a disturbance | Scheduling and planning the transportation of raw materials |
| High quantity of dry palm kernel shell that does not meet standards such as high moisture content, dirt, and defects during the raw material procurement process | Conducting training on harvesting, drying, storage, and sustainable supply chain operations in handling palm kernel shell |
| Non-conformance of the product with the contract | Checking before delivery |

| Process | Input | Output |
|---|---|---|
| Raw material storage | Raw material storage | Dry palm kernel shell quantity, storage time, raw material warehouse |
| Semi-finished product production process | Semi-finished product production process | Quantity of dry palm kernel shell, quantity of auxiliary materials for each product process, labor, machinery and production equipment, amount of energy (electricity, diesel & gasoline) and production costs |
| Semi-finished product packaging | Semi-finished product packaging | Polythiene, polypropyline and label plastic packaging |
| Semi-finished product delivery | Semi-finished product delivery | Mode of transportation, quantity and quality of semi-finished products, time, cost and place of delivery |
| Finished product production process | Finished product production process | Quantity of dry palm kernel shell, quantity of auxiliary materials for each product process, labor, machinery and production equipment, amount of energy (electricity, diesel & gasoline) and production costs |
| Finished product packaging | Finished product packaging | Primary, secondary and tertiary packaging and labels |
| Finished product delivery | Finished product delivery | Mode of transportation, quantity and quality of finished products, time, cost, and place of delivery |

exports with the condition of palm kernel shell quality being maintained.

A quality control process is carried out to ensure that the palm kernel shell shipped is in compliance with processing and export standards. The storage process is carried out to keep the palm kernel shell unprocessed in order to maintain its quality in a storage room with a certain size and storage conditions so as to produce a palm kernel shell that is well preserved. Procurement of palm kernel shell raw materials

by the processing industry is carried out by collectors taking into account the demand quantity, demand location, supply quantity, palm

kernel shell price, supply source. This process produces data on the supply of palm kernel shells, demand for palm kernel shell,s and the amount of raw material needed by the industry per period. The handover process for palm kernel shell raw materials is carried out in the processing plant area by considering the time of handover, the statement of raw material receipt transaction data to ensure that raw materials are available on time, according to the quantity and type received.

In the procurement system entity, several threats may occur, namely the damage to the palm kernel shell due to rain and dirt during the harvesting process, thereby reducing the quality. This threat can be controlled by drying with protection/roof, keeping from contamination with soil/sand. The unavailability of transportation facilities and the occurrence of disturbances hamper the continuity of the flow of goods between stakeholders. This disturbance can be controlled by scheduling. The number of dry palm kernel shells that do not meet factory standards such as high moisture content, dirt, and defects during the raw material procurement process due to poor post-harvest handling can be controlled by standardizing shipping, drying, storage, and operations of sustainable palm kernel shell supply chain. Non-conformance of products with contracts that may occur during the supply of raw materials is controlled by conducting inspections before delivery. Threats and controls on the sub-entity of the raw material procurement system are tabulated in Table 7.

Table 5. The Stakeholders and their role in entity sub-systems processing/sustainable supply chain

| Stakeholders | Role |
|---|---|
| Semi-finished industrial raw material warehousing department | Storing and maintaining the quality of palm kernel shell raw materials |
| Semi-finished product packaging department | Packaging semi-finished products of palm kernel shell processing |
| Department of semi-finished products transportation to finished product factory | Delivering semi-finished products to finished product factories |
| Finished product raw material warehousing department | Storing and maintaining the quality of raw materials (semi-finished products) |
| Finished product process department | Processing semi-finished products into finished products |
| Finished product packaging and warehousing department | Packaging finished products and labeling |
| Finished product transportation department | Delivering finished products to local and export markets |

Based on the process, input, and output, this study determined the parties involved in the raw material procurement entity, namely the FFB processing mill as a producer of palm kernel shells. Collectors buy palm kernel shells from PKS then maintain the quality of palm kernel shells and carry out the transportation process to factories as well as exporters of raw materials. The parties involved and their respective roles are tabulated in Table 6

According to Sulaeman (2015); Ngamel (2011), Batoa et al. (2008), the rules for operating the raw material procurement sub-system include the delivery method of palm kernel shell, the quality and quantity according to the palm kernel shell contract on quality control, as well as rules for storage and transportation in the form of material handling, temperature and humidity. Opportunities that may occur are the increasing demand for palm kernel shells, the fulfillment of the quality and quantity of raw materials

according to the warehouse contract agreement (Ngamel, 2011; Batoa et al., 2008).

**Sub-System Entities of Internal Sustainable Palm Kernel Shell Supply Chain (*Plant Site*)**

The internal sustainable supply chain subsystem occurs in the dry palm kernel shell processing industry. Based on field observations and Sade et al. (2006), this subsystem consists of seven main processes, namely storage of palm kernel shell raw materials, production of semi-finished products, packaging of semi-finished products, delivery of semi-finished products, storage of raw materials in finished product factory warehouses, production of finished products, packaging finished product and finished product delivery (**Error! Reference source not found.**).

After the raw materials are sent through the procurement process, then the raw materials are stored in the finished product warehouse until they are ready for processing. The considerations in this process are the quantity of dry palm kernel shell ready to be processed, storage time, and warehouse conditions of raw materials so that the condition of raw materials can be maintained to be processed into semi-finished products. The semi-finished product packaging process is carried out to protect the product during delivery with plastic packaging and product labels so as to produce packaged processed products. The delivery process is carried out after the semi-finished product is packaged for further processing at the finished product factory.

The internal sustainable supply chain process at the finished product factory is carried out by storing semi-finished products such as powder to be molded into briquettes, feed mixtures, asphalt mix powders as well as raw materials for processing finished products. The packaging and shipping process is carried out as an intermediary between consumers and the export process.

Based on this explanation, the actors involved in the seven processes are semi-finished industrial raw material warehousing department for storing and maintaining the quality of palm kernel shell raw materials, semi-finished and finished product process department for processing raw material into products, packaging department for packaging and labeling products so as to facilitate the transportation process, the transportation and export department is in charge of distributing semi-finished products and finished products. Table 5 is a list of stakeholders and their respective roles.

Several threats arise during the sustainable supply chain process, namely the quality and condition of the process. These quality problems include differences in storage temperature and humidity conditions, impurities, decreased quality due to shelf life, shortage of raw materials, and coding errors in packaging. Controls carried out on these quality problems are controlling temperature and humidity, adjusting production schedules with the availability of raw materials, maintaining the quality of raw materials with a standard foreign material content of < 5%, moisture content of 30 - 35%, and checking the packaging code. The next threat is the damage to the grinding/refining machine and the unsuitability of process conditions. This threat is controlled by controlling the process and performing regular machine maintenance. Table 6 is the threats and controls identified based on

Table 6. Threats and controls on the internal sustainable supply chain subsystem

| Threat | Control |
|---|---|
| Differences in temperature and humidity conditions, expired, dirty, decreased quality due to shelf life, lack of raw materials, and coding errors in packaging | Controlling temperature and humidity, avoiding contact with the floor, adjusting the production schedule with the availability of raw materials, maintaining the quality of raw materials with foreign material content standards < 5%, meeting raw material standards, ensuring the moisture content of raw materials and checking packaging codes |
| Broken grinding machine and unsuitable process conditions | Carrying out process control and perform regular process machine maintenance |

the condition of the sustainable palm kernel shell supply chain. Opportunities that may occur during operations are an investment, high demand for palm kernel shell processed

products, new product development, and development of palm kernel shell production process technology..

**Entity Subsystem Sustainable supply chain Processed Palm Shell Products (Finish Good)**

This subsystem is the physical boundary from the warehousing of finished products, to the distribution of products to exporters and final consumers. The processes (entities) in this subsystem are storage, transportation, export, and distribution packaging (Gudehus and Kotzab (2012). The processes in this subsystem entity are mainly finished product storage, product transportation, packaging distribution, local marketing and product export. This sub-system entity must exist if the government is to develop a sustainable supply chain system based on downstream palm kernel shell processed products. This sub system will ensure that more products are processed in the form of finished products before being sold or exported abroad.

Proses penyimpanan produk jadi dilakukan dengan input berupa number of warehouse facilities, storage space, stored products. The purpose of warehousing is to increase the effectiveness and efficiency of sustainable supply chain processes so that products are ready to be distributed by the transportation department. The product transportation process has input in the form of type, capacity, and number of modes, number of products, distance to product recipient locations. Central distribution locations must be established and products arrive at consumers and export ports. Before being transported, the packaging process is needed so that the product is maintained during the distribution process. The marketing and export process is the final process of this sub-system with inputs in the form of product exporters and product demand so that the product can be well received by consumers of the same location and price. A sustainable supply chain system is able to meet demand on time, quality, quantity, time, and place. Processes, inputs, and outputs are tabulated in Table 7.

| Stakeholders | Role |
|---|---|
| **Finished product warehousing** | Finished product warehousing operations |
| **Inventory control** | Carrying out stock/product inventory control |
| **Quality control** | Controlling and supervising product quality throughout the continuous supply chain process of finished products |
| **Product marketing** | Designing palm kernel shell product marketing strategy |
| **Transportation** | Delivering palm kernel shell to retail and end consumers |
| **Exporter** | Exporting the palm kernel shell processed products |

Based on the analysis of the processes, inputs, and outputs, this study identified *stakeholders* and their functions. The main stakeholders in this sub-system are warehousing of finished products in charge of finished product warehousing operations, inventory control that controls stock/product inventory, quality control to maintain finished products in warehouses, product marketing to process domestic market activities, transportation to transport products to retail for the domestic and export markets, as well as exporters in charge of

Table 7 Process, input, and output subsystem of palm kernel shell finished goods

| Process | Input | Output |
|---|---|---|
| **Product storage** | Product storage | Number of warehouse facilities, storage space, stored products |
| **Product transportation** | Product transportation | Type, capacity, and number of modes, number of products, distance to product recipient locations |
| **Product marketing** | Product marketing | Product sales price, sales amount, sales location |
| **Product export** | Product export | Number of product exporters |
| **Distribution packaging** | Distribution packaging | Demand palm kernel shell |

exporting products to foreign countries. Stakeholders need to be in this subsystem to ensure that the downstream process planned by the government can be implemented. In addition, the existence of this sub-system not only guarantees that palm kernel shells are processed domestically, but can increase the

competitiveness and efficiency of the sustainable supply chain of palm kernel shells, both export-oriented and domestic sales. Stakeholders and their respective roles are tabulated in Table 8.

Threats arise in this process, namely low warehouse performance which has an impact on product expiration, costs, and inventory planning which can be controlled by efficient warehouse and inventory management operations, as well as product transportation processes. The threat of negative consumer responses to products can make consumers switch to other products that can be controlled by ensuring consumers receive the right product in terms of time, quantity, and quality

The threat of export products not meeting the standards can be controlled by providing training and applying product standards according to the export destination country so that Indonesian products can compete in the global market. Threats and controls are tabulated in Table 9.

Palm kernel shell product derivatives have high added value and have the potential to improve Indonesia's position in the world market competition for palm kernel shell processed by increasing the efficiency and responsiveness of the finished product supply chain system so that the product can reach final consumers both domestically and for export.

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Tabel 9 Threat and control Sustainable Suppl Chain subsystem Finished Products

| Threat | Control |
|---|---|
| Low warehouse performance has an impact on product expiration, costs, and inventory planning | Carrying out efficient management of warehouse and inventory operations, as well as product transportation processes |
| Negative consumer response to the product | Ensuring consumers receive the right product in terms of time, quantity, and quality. |
| Export products do not meet export standards | Implement product standards according to export destination countries |

Situational analysis is carried out using the system entity approach proposed by Wasson (2016) as the basis for the design of business process models at the next study stage so that the behavior of the palm kernel shell agro-industry sustainable supply chain system is easier to understand, identify and solve problems as well as design and develop.

## 4. CONCLUSION AND RECOMMENDATION

An analysis of system entity-based needs, a conceptual model based on a business process model, and a map of the potential for palm kernel shell development in Indonesia have been carried out in this study. Based on the identification of system entity-based systems in Indonesia and expert opinion, this study divided the sustainable palm kernel shell supply chain system into three subsystems, namely the procurement subsystem entity, the internal sustainable supply chain subsystem (plant site), and the sustainable palm kernel shell supply chain subsystem entity (finished goods). The business process model based on system entity analysis was in the form of the conceptual model of a sustainable palm kernel shell supply chain in Indonesia. The raw material procurement subsystem consists of harvesting and post-harvesting, transportation of raw materials, quality control, storage of raw materials, procurement of palm kernel shell raw materials for industrial production processes, and handover of raw materials. The main process in the internal sustainable supply chain subsystem is the production process of palm kernel shell derivative products. Storage of raw materials is carried out after the handover process is carried out in the previous subsystem. Raw materials are stored and quality control is carried out during storage until there is a request from the production department to prepare raw materials.

The quality control department evaluates each quality control activity carried out. The sustainable supply chain subsystem of palm kernel shell processed products consists of eight business process lanes consisting of distribution packaging processes, warehousing, and inventory operations, quality control, marketing, transportation and distribution, consumers consisting of retailers and end consumers. The main activity in this sub-system lies in the business process lane for warehousing of finished products and distribution processes.

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