Efficient agri food supply chain in a sustainable transportation perspective

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Abstract. Transportation is an essential part of the supply chain. Transportation in a supply chain is the movement of a product from origin to destination, especially the warehouse’s movement from the warehouse to the end-user. At present, the success of managing a supply chain is measured by its low cost and its environmental and social impact, which is what is called a sustainable supply chain. Because transportation is the most crucial part of supporting the supply chain to achieve a sustainable supply chain, transportation must also have a sustainability orientation. The sustainability context includes three central pillars (often referred to as the three Es): social equity, economic efficiency, and environmental responsibility. Based on this background, this paper will discuss transportation sustainability in support of a sustainable supply chain, especially in agri-food products. The study results show that implementing multi-mode concepts can improve the sustainability of the supply chain.

1. Introduction

Discussion about sustainable transportation emerging in 1990’ [1] and is a primary interest in the agri-food supply chain has changed the paradigm for the stakeholders to find the effective agri-food supply chain. Transportation in various scale and product have significantly contributed to agri-food system performance and sustainability in environmental impact. For example, energy consumption in the transportation sector at the Spanish agri-food system is 25.8%, higher than energy consumption in the agricultural, which reported in 24.2% [2]. Food miles terms explored by scholars discussed the consequences of the distance travelled by food commodities [3,4]. In addition, they concern about environmental impacts caused by long-distance transportation, such as carbon emission and greenhouse gasses which challenged the sustainability issue [5,6].

Transportation plays a crucial role in supply chain efficiency. If transportation problems can be overcome, then the supply chain will run well, even to the point of lowering product prices [7]. Especially for agricultural products, efficient transportation will significantly help realize sustainable food agriculture, where products will arrive at consumers in a fresh and healthy condition. Transport efficiency in the agri-food supply chain can also reduce the waste generated (green logistics) [8,9].

Regarding sustainability, a sustainable agri-food supply chain is an agri-food supply chain that prioritizes public health and benefits for the company. It does not have a negative impact on the environment [10]. To ensure that agri-food products remain in a healthy condition until they reach consumers, the right delivery time (on-time delivery) is in accordance with the product’s durability. It will certainly provide benefits for entrepreneurs and will not cause waste because the product becomes rotten or damaged. Punctuality can be achieved by using adequate modes of transportation, with short...
load times, high speeds (low travel times). This mode is still dominated by road transportation such as trucks or cars [11].

Road transportation has advantages in many ways, such as speed and flexibility. However, it has a high level of pollution compared to other modes (railway and water) because it is still dominated by the use of fossil fuels [12–14]. This condition is contrary to green transportation, which requires environmentally friendly, safe, and favouring the community's economy. This condition is in stark contrast to one of the indicators of the success of a sustainable agri-food supply chain, namely timely delivery to customers by fast transportation. In contrast, fast transport harms the environment.

This paper will discuss how to achieve a sustainable agri-food supply chain that still considers the concept of green transportation by identifying what can be a bridge between the two concepts.

2. Materials and methods
This research is a comprehensive review of several previous studies. They were finding gaps and links between sustainable agricultural food distribution and green transport. This study needs to be carried out because of the different objective functions of each domain. Sustainable agri-food requires timeliness of delivery to ensure products reach consumers in new conditions, while green transportation prioritizes low pollution and safety. Timeliness of delivery requires speed of delivery time, while vehicle speed usually causes high pollution.

2.1 Green transportation
Green transportation or sustainable transportation is a transportation service that does not rely on natural resources (fossil fuels). However, green transportation mode relies on renewable energy resources, adequate and efficient use of natural resources, reduced negative impact on human health and the environment, and less impact on the use of land and the generation of noise [15]. In this context, green transportation must consider three major dimensions: environment, economic, and social (Figure 1). From an environmental point of view, transportation have not adverse impact on the environment. From an economic perspective, because transportation is the main factor for growth, development, and employment, transportation must use energy efficiently and at a price that is friendly to the community. Finally, transportation must be safe for the community and not harm public health [16].

![Figure 1. Dimension of green transportation [16]](image)

2.2 Sustainable agri-food distribution
Sustainable Agri-food is an agri-food system that meets the needs of society (people), economy (profit), and environment (planet) over time: Environmental sustainability. One part that must be considered in achieving agri-food sustainability is the problem of product distribution. Products are distributed to customers and arrive in new conditions so that they remain healthy for the community. One indicator to
achieve sustainable agricultural food distribution is the timeliness of delivery [17,18]. The timeliness of delivery depends on road and traffic conditions, climate, transport time, and distance [19]. The strategy to achieve the timeliness of delivery is selecting agri-food travel routes, depending on the mode to be used. Policy support is also very influential on this success [20].

3. Results and discussion

3.1 Sustainable agri-food distribution and green transportation

Based on the definition of green transportation described previously, green transportation must prioritize the use of non-fossil fuels to reduce emissions or pollution. However, in reality, transportation still contributes high emissions, especially road transportation. Road transportation still contributes the most significant emission, 71.7% of the total emissions generated from the transportation process [21], it shows that the use of road transportation is still dominant. Likewise, in the process of logistics systems, for example, in the European Union, 50.4% of logistics used land transportation in 2011, even slightly increased to 50.9% in 2016 [12]. Logistics vehicles (road transport) such as trucks also produce significantly higher emissions than rail transport, 2.42 times [14].

![Figure 2. Share of greenhouse gas emissions by mode of transport (2017)](image)

Sustainable agri-food distribution requires that the product arrive at its destination in a fresh condition. If it does not go through a special treatment, the product must arrive at its destination on time (on time delivery). Agri-food business actors will choose a mode that can meet the needs of the speed of the product to the customer. By not considering the cost of travel (price), the vehicle that it will select will of course, be in accordance with the pattern of travel time and travel distance in Figure 3 is road transportation (car/truck). Land transportation has high flexibility and shorter travel time on short to medium distances [11].

![Figure 3. Travel time versus travel distance of different transportation modes [11]](image)
3.2 Multimode as solution for green agri-food supply chain
The use of multimodal is the most rational consideration to meet green transport and sustainable food agriculture objectives in terms of travel costs (prices) (Figure 4). Figure 5 showing the relationship between price and hauling distance for different modes of transport of goods (truck, rail, water), truck, rail, and water prices are denoted by $P_t$, $P_r$, and $P_w$. This cost will move along a linear function. In short distance conditions, road transportation has a lower price than rail/water transportation, but increases faster than rail/water transportation with a gradient function $\beta_1$. When the distance reaches a certain point ($D_{tr}$), the cost of rail transportation will be balanced with road transportation, so the cost of road transportation will continue to increase along with the distance. while the cost of rail transportation will be below the cost of road transportation with a slope of line $\beta_2$. At this point, the possibility of switching modes begins to be considered. Likewise, when rail transportation costs begin to meet the balance point with the cost of water transportation ($D_{rw}$), switching modes of water transportation must be considered.

![Figure 4. Bridger between sustainable agri-food distribution and green transportation](image)

The constants are assumed to be terminal costs or preparation costs before goods are transported. The assumption of the rail transport preparation cost will be a percent of the road transport preparation cost ($\beta_1$). For example, if the rail transport preparation costs are 10% of the road transport preparation costs, then the constant for rail transport is $1.1 \times \beta_1$. The gradient function shows the difference in the increase in price per unit distance. The values of c and d, show the difference in the price difference between rail transport and water transport with road transport.

With the concept of multimodal transportation, food agribusiness entrepreneurs can choose the mode according to the price and distance between them. Short-distance shipments use road transportation, medium-distance shipments use rail transportation, and long-distance shipments use water transportation. Of course, the packaging system must also be considered to remain in good condition until it reaches the consumer.

![Figure 5. Multi-mode concept](image)
4. Conclusions
The discussion results found that multimodal transportation planning would be an alternative bridge between the concept of a sustainable agri-food supply chain and green transportation. Products will reach consumers according to the planned time, and the transportation system will not be too burdensome for the environment.

Based on study results, policies recommendation should accommodate multimodal transport design, especially shipping systems mixed between toll policy and local land transport for land transports subsystem. Coastal container multimodal transportation system which also integrates with land transport subsystem also recommended for inter-island transportation. The approaches should emphasise two priority goals, for reducing cost coincide with reducing carbon emission.

Furthermore, it is still necessary to study the distance and price range between modes of food transportation. Its, of course, depends on the type of product and the durability of the product in transit. Later, it can be determined the suitability between the type of product and the type of mode recommended for use in product delivery to its destination.

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