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RESEARCH ARTICLE

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Fresh agricultural product logistics network governance: insights from small-holder farms in a developing country

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ABSTRACT

Fresh agricultural products (FAPs) require special handling to maintain product quality, especially during socio-economic crises. In developing countries, there is a compelling need for a robust supply chain governance strategy to regulate the supply chain actors involved in the logistics and distribution system. This paper proposes an innovative way to design FAP logistics governance to address specific problems in the FAP logistics networks of developing countries, where FAP supply chains are not well integrated. Three logistics governance scenarios were modelled using discrete-event simulation. The results revealed that the fully distributed governance could effectively reduce process delay and consequently minimise logistics costs, especially within the logistics networks serving multiple markets. This is due to that fact that the distributed governance allows the actors involved in the network to have some autonomy to manage their resources. The paper contributes to improving the fundamental understanding of the governance for FAP logistics networks consisting of small-holder farms. Our work also offers valuable insights for policymakers and practitioners into how to improve FAP supply chain management.

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1. Introduction

Fresh agricultural products (FAPs), including those derived from livestock and marine sources, are products sold to end customers with little or no processing in their value chains (Sun et al. 2020). This means that FAPs have short lifetimes and are perishable (Yan et al. 2020). The shelf life of FAPs is influenced by climatic conditions, so good temperature control along the supply chain is required to extend the shelf life (Sun et al. 2020; Wang and Yip 2018). As consumer awareness of the quality and safety of FAPs increases, the FAP supply chain tends to become more complex than that of other products, such as fast-moving consumer goods (Shukla and Jharkharia 2013).

The impacts of the COVID-19 pandemic have been particularly detrimental to the global FAP supply chains of developing countries (Karwasra et al. 2021), including Indonesia (Perdana et al. 2020; Achmad, Chaerani, and Perdana 2021). At the downstream points in supply chains, panic buying (Sharma et al. 2020) has increased market demand and created distribution barriers

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(Hobbs 2020; Kumar and Kumar Singh 2021). Many farmers have been unable to access FAP markets, as many have been closed due to social restrictions (Siche 2020). At the upstream points in supply chains, labour unavailability due to illness and (again) social distancing measures has caused FAPs to be left to rot and ultimately wasted (Altieri and Nicholls 2020; Kumar and Kumar Singh 2021; Poudel and Subedi 2020).

Interestingly, the disruption of global FAP supply chains has somehow increased the export demand for Indonesian FAPs. The demand for fresh vegetables during the pandemic has in fact increased by more than 65% compared to that in the January–September 2019 period (Statistic Indonesia 2020). This strong demand indicates the compelling need for more robust FAP supply chain management (Rizou et al. 2020) that focuses on ensuring food safety and product availability, affordability, and accessibility (Perdana et al. 2020). The Indonesian FAP supply chain networks undergo continuous improvement to maintain the right level of productivity to minimise waste and losses and meet both the domestic and export market demands in terms of quality, quantity, price, and security.

Tackling the disruption in the global FAP supply chains is critical to improving the supply chain governance. This is due to the fact that the FAP supply chain governance is an institutionalised decision-making process to regulate the numerous supply chain actors involved (Perdana et al. 2020; Sharma et al. 2020; Kumar and Kumar Singh 2021), especially within logistics and distribution systems (Tsolakis, Zissis, and Tjahjono 2021). There is also a need for robust FAP governance strategies that enable the management of more effective and efficient logistics systems and improve the sustainability of FAP supply chains (Ren et al. 2021; Cai et al. 2020; Sharma et al. 2020). This includes the management of integrated operations and the strategic decision parameters that improve the efficiency of processes, reduce logistics costs, and increase product availability (Pujawan et al. 2015).

Logistics governance, which incorporates the strategic and operational aspects of logistics, has so far been developed using various approaches. Mathematical models have been developed to optimise the inventory system of FAPs (Xu et al. 2019). Optimisation algorithms are often built to minimise production and transportation costs (Ferreira et al. 2012), and to deal with the inventory problems in FAP supply chains (Fikry, Gheith, and Eltawil 2021; Utamima, Reiners, and Ansaripoor 2019; Wiedenmann and Geldermann 2015; Behzadi et al. 2018a, 2018b; Federgruen, Lall, and Şimşek 2019; Tan and Çömden 2012).

FAP supply chain governance may include environmental management with the aim of increasing the capabilities of local FAP supply chains (Fan et al. 2021). Nonetheless, to protect the apparent economic benefits within FAP supply chains, a governance approach through policy and economic incentives should also be considered (Chen 2019). In this instance, governance can be used to improve FAP production and distribution and absorb the uncertainty of product supply (Ahumada, Villalobos, and Mason 2012).

The current design of FAP supply chain governance discussed in the body of literature, however, has been largely focused on improving the capability and capacity of FAP supply chains for single markets that are usually under the contract farming (Federgruen, Lall, and Şimşek 2019; Tan and Çömden 2012; Wang et al. 2021; Wiedenmann and Geldermann 2015). Meanwhile, market diversification (e.g. domestic and export markets) is needed to create robust FAP supply chains that can deal with the disruptions (Behzadi et al. 2018a, 2018b). This is the research gap we attempt to address by developing the logistics governance targeting multi-market FAPs. We thus propose an innovative way to design formal FAP logistics governance models for both domestic and export markets, whose characteristics are completely distinct in terms of the products and supply requirements.

In particular, our paper addresses specific problems in the FAP logistics networks of developing countries, including Indonesia, where the FAP supply chains typically involve small-holder farmers in dispersed locations and are not well integrated (Perdana and Kusnandar 2012). To improve small-holder farmers' competitiveness especially in accessing the markets, the Indonesian government have introduced many farmers improvement programmes aiming at facilitating the contractual agreements with existing markets, for example, supermarket suppliers, exporters, and hotel-restaurant-catering industries (Abdulsamad, Stokes, and Gereffi 2015; Fischer and Qaim 2012; Moustier et al. 2010; Subervie and Vagneron 2013). However, many of the abovementioned improvement programmes unfortunately put less emphasis on improving logistics network governance. Against this background, we set out the following research question: 'How can the logistics governance model for FAP products for multiple markets involving small farmers be developed?'

There is a growing body of theoretical and empirical research on FAP logistics network governance in the extant literature. Good logistics network governance is essential for reducing logistics costs, increasing the efficiency of the FAP logistics network, and improving the small farmer's competitiveness in the supply chain. Our work contributes to this critical aspect of FAP logistics network governance theory and specifically to improving the fundamental understanding of the appropriate governance for FAP logistics networks in the context of developing countries, incorporating many small-holder farmers that serve multiple markets. Our work also joins the recent discourse in supply chain governance, especially in the International Journal of Logistics Research and Application, for instance Sharma et al. (2020).

Due to the increased complexity and uncertainty of FAP logistics networks, there is a compelling need for a more practical and easier-to-assess FAP logistics network governance model for multi-market decisions that incorporates both endogenous and exogenous parameters (Guo et al. 2017; de Keizer et al. 2017). For this reason, the FAP logistics network governance model proposed in this paper adopts a simulation modelling approach that uses discrete-event simulation (DES). The selection is based on the premise that DES is a valuable and proven method for evaluating various design alternatives, primarily if the system being analysed operates in an uncertain environment (Pujawan et al. 2015).

The remaining sections of this paper are organised as follows. Section 2 describes the factors underpinning logistics network governance. Section 3 presents the logistics network system that is the focus of this study, followed by a description of the method used in this study in Section 4. Sections 5 and 6 illustrate the simulation model development and experimentation, while Section 7 discusses the implications of the research. The paper concludes with some insights and recommendations for future work.

2. Logistics network governance for fresh agricultural products (FAPs)

In this paper, 'FAP logistics network' refers to the business ecosystem that consists of the interconnected and complementary actors within the supply chains of FAPs, such as fruits, vegetables, meats, and marine products (Choi, Dooley, and Rungtusanatham 2001). The actors work interdependently to increase their profits by adding the value of their products. The performance of such FAP logistics networks relies upon the number and duration of logistics operations and environmental conditions, which affect the quality of the perishable FAPs (de Keizer et al. 2017).

de Keizer et al. (2015) highlighted both internal and external factors affecting logistics network performance (de Keizer et al. 2015). The internal drivers relate to having a process-oriented strategy and include minimised costs, high product quality and a wide brand reputation. The external drivers relate to having market-oriented strategies and include flexibility, policy, and stakeholder awareness. Additionally, Bosona and Gebresenbet emphasised that logistics networks should determine the appropriate points at which agricultural produce is collected and processed to minimise these costs (Bosona and Gebresenbet 2011). Cost minimisation is thus subject to transport routes, distance, and total transport time.

Collaboration and integration among logistics network actors are also crucial for good agricultural logistics performance (Haggblade 2011; Manzini and Accorsi 2013). In terms of FAPs, such integration enhances production capacity, cost-efficiency, and price satisfaction for both producers and consumers, and it also improves product quality (Trienekens and Zuurbier 2008; Van Der

Vorst, Tromp, and Zee 2009; Vitanov, Tjahjono, and Marghalany 2007). Furthermore, mutual relationships between all the related actors within FAP supply chains improve logistics performance (Fredriksson and Liljestrand 2015). Logistic network governance is needed to ensure that the right level of integration and collaboration is achieved. Good governance ensures the delivery of high-quality products in the right quantities to consumers on time while effectively managing logistics costs (Bantham and Oldham 2003; Aghazadeh 2004).

Recent discourses in the extant literature have highlighted two types of FAP logistics network governance: centralised and distributed (Hong, Ammons, and Realff 2008; Ostrom 2010; Almena et al. 2019). Table 1 summarises the definitions of both governance types. The forms of governance are regarded as a configuration of networks between the actors in FAP supply chains through which ideas, resources, products, and information flow.

In the centralised type of governance, a single actor controls all activities within the supply chains (Gallemore and Munroe 2013). Centralisation is typically associated with severe asymmetric information problems and little collaboration between actors (Salema and Buvik 2018). An example of centralised governance is the use of logistics service providers (LSPs) (Cai et al. 2013; He et al. 2013; Chen and Liu 2017). They provide logistics services for the management of post-harvest handling, warehouses, distribution, and transportation to maintain product quality (Martin and Jagadish 2006). The services provided by LSPs, however, are often too complex for the needs of small businesses (He et al. 2013).

The (fully) distributed type of governance is considered poly-centric; it transfers the authority for planning, management, and decision-making from higher to lower levels (Sreeramareddy and Sathyanarayana 2019). In other words, each actor within this governance type has the authority to manage themselves, and each actor is able to enhance the effectiveness of the logistics network as a whole (Ostrom 2010). Therefore, this governance type is suited to serving multiple markets (i.e. traditional markets, supermarkets, and exporters).

Many studies have been performed to develop FAP logistics governance with the aim to increase profitability, cost and time efficiency, and environmental sustainability. These aims have been pursued through the development of various logistics models spanning from production to distribution. From the production side, there are production planning models (e.g. crops planting, harvesting, the use of machines plans) using a deterministic approach (Fikry, Gheith, and Eltawil 2021; Utamima, Reiners, and Ansaripoor 2019; Wiedenmann and Geldermann 2015), production

Table 1. Governance of fresh agricultural product logistics networks.

	Centralised	Distributed	Source
Definition	Decision-making by a single actor from production to marketing	Decision-making by many centres of production and marketing	Almena et al. (2019); Ostrom (2010), Hong, Ammons, and Realff (2008)
Advantages	• Net profit maximisation • Better forecasting • Consistent production • Lower material costs • Minimised handling and distribution costs	• Profit distribution • Equal and better information distribution • Flexibility • Closer to consumers • Lower labour costs	Almena et al. (2019); Ostrom (2010)
Disadvantages	• Inflexibility • Bottleneck problem[a] • Slower decision-making • Asymmetric information • No allocative efficiency	• High capital investment • Conflicts between actors • Multiple forms of order	Hong, Ammons, and Realff (2008); Almena et al. (2019)

[a]The bottleneck problem occurs when logistics stations do not efficiently handle the balance of product in-flow and out-flow gates, resulting in a long queue at the out-flow of each station. This problem leads to stalls in production and supply overstock.

planning models incorporating demand uncertainty (Behzadi et al. 2018a, 2018b), and production uncertainty (Federgruen, Lall, and Şimşek 2019; Tan and Çömden 2012). From the distribution aspect (encompassing route optimisation and vehicle routing problem models), there are distribution planning models focusing on the economic aspects (Liu, Wang, and Xing 2019; Teng 2021) and the environmental aspects, especially in minimising carbon emissions (Ji et al. 2021).

In addition to the individual production and distribution models, there are also models integrating both the production and distribution sides using deterministic approaches (Ahumada and Villalobos 2011; Rocco and Morabito 2016) and models incorporating the production uncertainty (Ahumada, Villalobos, and Mason 2012). These logistic governance models were designed from the perspective of a single actor, either a large grower/company who has many farm locations or a company/processing unit that is supplied by many farmers. This paper contributes to fill this gap by proposing the logistics network governance involving small-holder farmers from multiple locations serving multiple markets.

3. Description of the FAP logistics network

To better illustrate logistics network governance, the logistics network utilised in the production of French beans in the Indonesian province of West Java, one of the FAP production centres in Indonesia. West Java's French beans production contributes 26.84% of the national output (Statistics Indonesia 2022). Most FAP (including French Beans) farmers in West Java are small-holders with less than 0.20 Ha of farming areas, located in scattered locations. This signifies the importance of a logistics network governance.

The French Beans logistics network in this case is a complex system of farming activities performed in production centres, LSP processing units and markets, which operate in a sequential process (Figure 1). Each part consists of several stations. Farmers are the main actors in the production centres, and they are categorised into two groups based on the location of their farms, in Lembang and Pangalengan (see Figure 2).

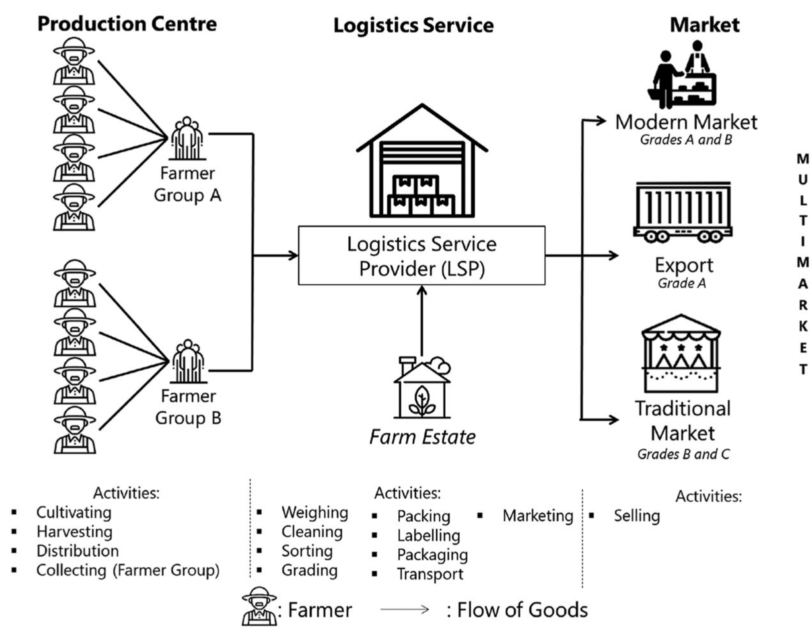


Figure 1. The logistics network for the French bean.

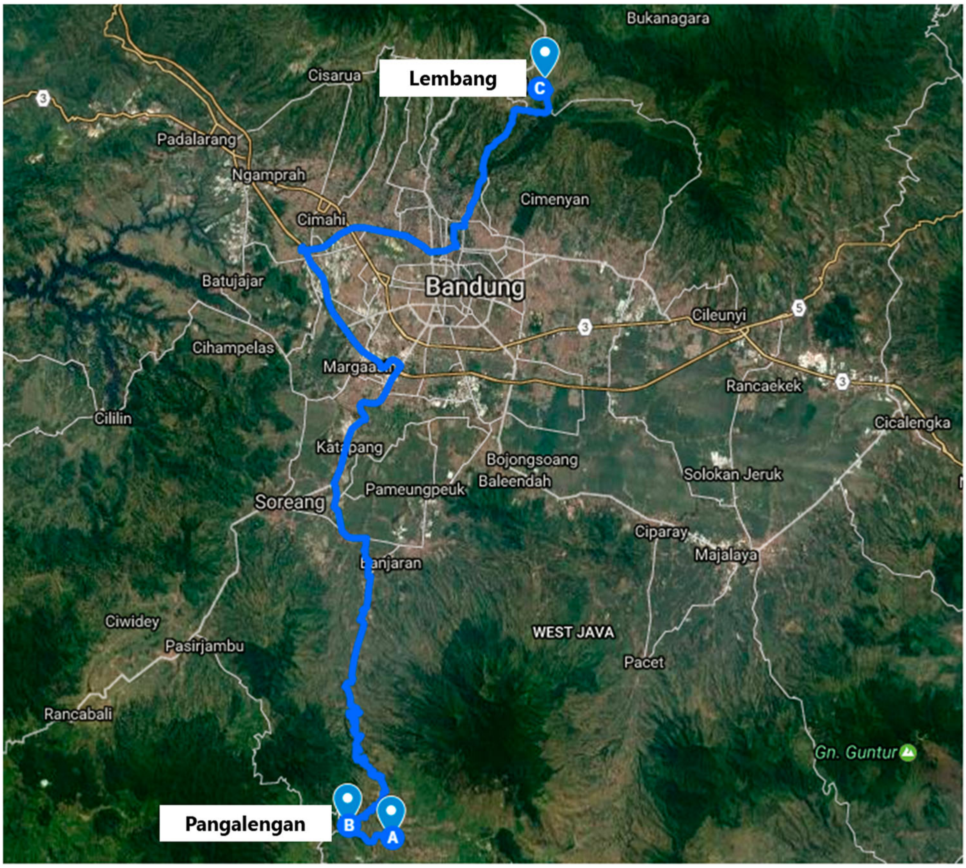


Figure 2. Locations of the farms and LSP.

The second part of the system is the logistics centres operated by the LSP in Pangalengan. The LSP is responsible for the following post-harvest activities: weighing (arrival), cleaning, sorting, and grading, packing, labelling, packaging, transporting, and marketing. In the current logistics network, Grade A French bean handled by the LSP are reserved for export markets and beans of lower grade are considered off-grades. In addition, there are small packing houses in each sub-district supplying French beans to the LSP. These packing houses support the LSP in the handling of post-harvest activities. One of the six farm fields – managed by the LSP – contributes about 50% of the total production amount supplied to the LSP.

In Lembang, beans are currently produced at three different farms. The produce from these farms is transported to the packing house and then distributed to LSP for quality control and other logistics processing. Although the distance between these regions is only around 67 km, the main roads linking the two production areas are often congested, causing delays and product damage.

3.1. Logistics staff

The logistics staff consists of the farmers, the farm workers and the LSP and packing house workers who, together, are responsible for the on-farm, harvest, and post-harvest activities. There are 17 and 14 workers in the production centres at Lembang and Pangalengan, respectively. They are hired to plant, fertilise, weed, and harvest the French beans.

Meanwhile, the post-harvesting activities of the LSP are handled by 18 workers. They work together in one station and move as a group to the next station after completing the required activities (i.e. weighing (arrival), cleaning, sorting, and grading, quality control, packing, labelling, weighing and packing). However, only 1, 10 and 4 people are hired to manage the weighing (arrival), quality control and weighing and packing, respectively. The rest of the workers are idle at these stations.

3.2. Process stages and product flow

French beans are ready to harvest about 50 days after planting. The farmers harvest the beans every day for a month. If they miss one day of harvesting, the beans are of lower grade and are not suitable for export. The typical yield for French beans is about 7–10 tonnes per hectare. In each region, farmers combine their yields, and these groups then sell the products to the LSP, either in bulk or using the selected harvesting method. The farmer groups and the LSP establish a selling partnership with specific product requirements determined by the LSP. The farmers receive 6,000 Indonesian rupiah (IDR) per kg when the product is sold in bulk and 9,000 IDR when the selected harvesting method is used. All activities in each production centre in Pangalengan and Lembang are completed in one day and the products are delivered to the LSP on the same day.

The second stage involves the post-harvesting activities performed by the LSP in Pangalengan. These include weighing, cleaning, sorting, and grading, packing, labelling, packaging, and marketing. These activities are required to fulfil the demands of the export markets for French beans. Table 2 describes the quality requirements for French beans for export markets, distributed three times a week (every Mondays, Wednesdays, and Fridays).

Upon delivery to the arrival station of the LSP, the French beans are weighed, and the amounts delivered by the farmer groups are recorded. The Pangalengan farmer groups sell the products in bulk, while the Lembang farmer groups deliver selected beans to the LSP.

The next stage is the cleaning process. This is the first checkpoint for product quality, although it only involves separating the products that were damaged during transport from the farmer groups to the LSP. The good-quality beans are sorted and graded at the sorting and grading station. Export markets require French beans that are straight in shape and uniform in length (Table 2). The beans that are not of the required grade are moved to rejection baskets. Each farm field has a different number of rejected products. The rejection rate is about 5% for beans from Lembang and about 2% for beans from Pangalengan. The higher rate is attributed to more damage being done to beans during transport from Lembang.

Next, the products are weighed, packaged, and labelled according to the exporter's requirements. The weight of each package is 170 g, with an estimated loss of 30 g due to shrinkage during distribution and when the products are displayed. The LSP workers must recheck to ensure that all products are of the highest quality grade (Grade A) at every station. Then, the packaged products are packed in 2.0 kg per box. The LSP then exports the Grade A products to Singaporean markets via an exporter located in Bandung. Currently, the rejected products (around 15%) are directly sold to

Table 2. French Bean specifications and demand requirements.

Market Requirement		Size
Bean specification	Weight (g per piece)	7–8
	Length (cm per piece)	12–15
	Quality grade	A
Commodity entrance per day (kg)		630
Export demand	Number of packages or wrap (pack per day)	3,060
	Weight per package (g)	170
	Packing or box (g)	2,000
	Number of packages (wrap) per box	11–12

several traditional markets around Bandung if the products still fall into Grades B or C. Otherwise, they are treated as waste. The detailed information pertinent to the data used in this paper is provided in 'Data availability statement' section.

4. Research method

Considering the aim of this research, which was to identify the most appropriate logistic network governance model for FAPs under disruptive conditions, simulation modelling was chosen as the research method. The use of simulation modelling is a worthwhile approach for solving supply chain and logistics problems, especially if uncertainties and randomness are inherent in the system (Benedettini and Tjahjono 2009), when the characteristics of the logistics and transportation system are difficult to model with analytical approaches (Riddalls, Bennett, and Tipi 2000; Wang and Law 2007) and when there is a need to assess different design alternatives of the logistic systems (Rosyida, Santosa, and Pujawan 2019). Thus, a 'what-if' analysis is required (Terzi and Cavalieri 2004). The use of simulation modelling is also relevant to the context of this research because simulation modelling can model the logistic system's complex inter-relation and describes how the actual system might behave (Rossetti 2015).

As our focus was on operational decision-making and reducing the learning curve of the actors in the logistics network, we chose the DES technique to build the simulation model (Tako and Robinson 2009). DES can capture heterogeneity in population characteristics, continuous processes, time-varying event rates and prior events after subsequent event rates (Karnon and Afzali 2014). DES is thus considered appropriate to solve problems in complex FAP systems, especially involving small-holder farmers with agricultural lands spread across several locations and with differing agricultural complexities.

DES modelling is thus a process of codifying the behaviour of sequential and well-defined events in discrete time (Kiran 2019). DES is widely used in decision support tools for logistics and supply chain management (Seay and You 2016) as it provides a low-cost way of collecting information for decision-making (Foster-Fishman et al. 2001). It is particularly suitable for use in the (re)design of logistics systems in which there are food production uncertainties in terms of quality, quantity, and prices. For instance, long queues in one of the LSP's stations will cause delays for subsequent stations and increase production costs. The DES algorithm makes it easier to analyse each logistics station so that non-expert users can make informed decisions for handling such problems (Caro and Möller 2016).

A model is a representation of reality, so it is crucial to understand the real system when developing a simulation model to ensure model accuracy and credibility. We therefore adhered to the guidance provided by Banks (1998) when conducting the simulation study (Banks 1998). The guidance consists of four steps: (1) model building, (2) model verification and validation, (3) experimentation and (4) analysis of results.

For our model, data inputs included production, harvesting, post-harvest, logistics and transportation activities. The data outputs, which are essentially the key performance indicators of the model, included the utilisation of stations and the efficiency of the system. Some data inputs were represented using the built-in statistical functions of ProModel®, a commercial off-the-shelf DES tool that we used to develop the simulation model. Verification was performed to ensure that the logic of the simulation model was correct and properly executed. Validation was performed to ascertain that the model represented reality (Kleijnen 1995; Banks 1998) (discussed in more detail in **Section 5**). The third step was to run some experiments. We followed the practical approach proposed by Tjahjono and Fernández (2008) to ensure that the what-if scenarios properly evaluated the different practices in the logistics governance network (Tjahjono and Fernández 2008). The last step was the analysis of the results, where we compared the results of the three scenarios, hence assessing the alternative strategies.

5. Model development

5.1. Identifying simulation problems

Our preliminary observations in the production centres and the LSP locations revealed several obstacles within the existing FAP logistics network. These shortcomings decreased product quality and caused inconsistent supply delivery to the exporter. The consequences of these issues were found to be more serious during the COVID-19 pandemic, when people's access to sustainable, healthy food is crucial.

The existing logistics network produces only one type of premium product (i.e. for export markets), and there are no other market segmentations. Product of a lower-quality grade is simply sold to traditional markets. When there are disruptive conditions (e.g. the COVID-19 pandemic), farmers cannot rely on a single market, such as the export market – differentiation is necessary. Therefore, this study considered a multi-market scenario, for example, with local supermarkets and traditional markets in addition to export markets.

Another current issue is that there are no sorting and grading stations at the farm level. Consequently, farmers sell beans only in bulk at low prices. In terms of the LSP processing stations, long delays ensue at almost all the harvest, post-harvest, and distribution station gates. Bottleneck problems occur at the stations. As a result, post-harvest station activities take a long time to complete, which reduces product quality. Ultimately, optimal profits are barely realised in the current French bean logistics system for both farmers and the LSP. FAP logistics governance requires redesigning the product flow from the production centres to the LSP so that such engineered governance could reduce inefficiencies within the logistics system and maintain product quality for the end consumers.

5.2. Defining the logistics network system and model configuration

We defined the logistics network system based on the flow of the product from the farmers in the production centres to the packing houses and the LSP to serve multiple markets (i.e. traditional markets, supermarkets, and export markets). This system involves collaboration among all involved actors within the French bean supply chain and allowed us to focus on the post-harvest station activities of the LSP. In other words, all the LSP activities were variables in our simulation model.

The activities performed by the LSP are sequential; the next activity can be conducted only after the previous activity is completed. For example, sorting and grading station work cannot begin before cleaning station work is finished. The LSP workers do not start working at the arrival station until the Pangalengan or Lembang farmer groups arrive at this station.

In our modelling, we specified that the product is sold not only to the exporter but also to modern retailers (supermarkets) and traditional markets. This segmentation relied on the quality grade of the product. The activities at the LSP stations produce Grade A beans, which are delivered to an exporter. At the exit gates of the sorting and grading stations and at the controlling for quality station, rejected beans are set aside for re-sorting and re-grading, which yields Grade B product for modern markets and Grade C product for traditional markets.

5.3. Determining model assumptions

Guerriero and Miltenburg (2003) suggested that the quality of a simulation model is influenced by how high utility of each station is achieved in the simulation – with maximum utilisation being 100% – and how workload is distributed across stations. This implies that the bottleneck problem can be solved (Guerriero and Miltenburg 2003).

The following four assumptions were made to select the optimal scenario:

1. The LSP and packing house workers were assumed to have the same capability; hence, these workers would all complete one cycle of the production process in the same amount of time.
2. The post-harvest process is sequential. For the product handled by the LSP and packing houses, when it reaches the end of a station, it is ready to be processed at the next station.
3. Farmers in all the production centres harvest the French beans at the same time. Of all the product supplied to the LSP, 21%, 29% and 50% is from the farm fields of Lembang, Pangalengan and the LSP, respectively.
4. The data used for measuring the proportion of rejected product are the same for each simulation scenario and based on the existing logistics network. We set the rate at 6% for bulk yields and 3% for selected harvests.

5.4. Data collection

Primary data were collected from the farmers at the Pangalengan and Lembang production centres and the LSP in Pangalengan using field observations and in-depth interviews. Two packing houses located in the two sub-districts were also included. In addition, we investigated where the products are sold and the roles each actor has in the logistics chain by interviewing 38 farmers and LSP employers. These primary data captured information on the characteristics and schemes of the French bean supply chain, which include:

- actors involved in the supply chain,
- tasks of each actor,
- time spent on each FAP logistics process,
- costs for each FAP logistics process, and
- labour utilisation for each process.

Those data were used to build the simulation model. To obtain a baseline (status quo) for our simulation model, we quantitatively measured the time taken and costs incurred at each LSP station during a one-cycle production process. The scenarios developed in this study include several variables: the process of minimising the product damage during distribution from farms to LSP, labour utilisation, and duration hence the cost of each operation. The model analysis aimed at improving the handling process in a day's worth of production, which would ultimately comply with the market demands requiring continuity of supply.

During a one-cycle process, the product flows from the production centres to the end of the LSP stations (i.e. weighing, sorting, and grading, packaging, controlling for quality, labelling, packing and distributing). Time was measured in minutes and monetary costs were quantified in IDR at every station. This measurement was repeated consecutively 15 times for each station and the values were averaged for our simulation baseline data inputs.

Table 3. Operating time for each activity performed by the logistics service provider.

	Operating Time (mins)					
	Weighing on arrival	Cleaning	Sorting-Grading	Packaging	Labelling	Weighing-Packing
Observations	15	15	15	15	15	15
Normal Parameters						
• Mean	5.513	0.314	1.681	2.365	0.206	0.944
• Std. deviation	0.146	0.022	0.030	0.095	0.019	0.042
Most Extreme Differences						
• Absolute	0.203	0.172	0.157	0.184	0.202	0.196
• Positive	0.203	0.172	0.157	0.154	0.202	0.196
• Negative	−0.130	−0.100	−0.106	−0.184	−0.171	−0.170
Kolmogorov–Smirnov Z	0.787**	0.667**	0.609**	0.712**	0.784**	0.759**
Asymp. Sig. (2-tailed)	0.566	0.765	0.852	0.691	0.571	0.612

Note: ** Significance level at .05.

Based on our observations, we considered the following six technical rules for the simulation model:

1. All products must be fully processed within 6.5 h (status quo).
2. French beans are measured per unit (kg).
3. Order-commodity execution follows the rules of first-in-first-out.
4. A break time of 10 min per two hours is set for the entire one-cycle production process.
5. Each post-harvest activity location has a different usage time limit, which is set according to recent activities at the working stations.
6. Based on the Kolmogorov–Smirnov test, the operating time for each activity is normally distributed at 5% significance. The time spent on each activity is shown in Table 3.

Table 3 shows the data from the observation of operating time at each station, performed 15 times. Using the Kolmogorov–Smirnov test, it was found that the data at every station has the Asymp. Sig. (2-tailed) value that is > 0.05, meaning they are normally distributed.

Based on that result, the data input distribution in ProModel use the normal distribution as seen in Table 4. For instance, *n* (5.5, 0.14) on 'arrival' means the data is normally distributed with average processing time of 5.5 and standard deviation of 0.14. These data are used in the simulation model for Scenarios 1, 2 and 3.

5.5. Model verification and validation

Verification was performed by testing whether the model could run without any errors. This is a continuous process being performed as the model is developed (Banks 1998). The verification process included the model walkthrough and logical tests carried out collaboratively by the simulation modeller and the FAP logistics experts. The simulation results in a relatively short run time were then compared with manual calculations to ascertain that the model behaves as intended (Banks 1998; Manuj, Mentzer, and Bowers 2009).

Validation involves both qualitative and quantitative analyses. The qualitative validation was performed by conducting interviews with the management of LSP and heads of farmer groups as key informants to confirm the model structure (Shaw et al. 2017). Based on the interview results the informants confirmed that the model does represent the real system. In addition, the informants also confirmed that about 630 kg of French Beans can be completed in about 6–7 h.

The quantitative validation involves performing t-test using Microsoft Excel by comparing the actual output data and the simulation results (status quo) (Forde and Maina 2017). The actual data output is obtained from the LSP and the Farmer Group Packing house. Meanwhile, the status quo output is obtained from the model output with 20 repetitions. The actual data obtained is then compared with the simulation results. This is to obtain more objective observation results and reduce data measurement error.

Table 4. Time taken for each activity.

Activity	Time
Arrival (minutes/batch)	*n* (5.5, 0.14)*
Cleaning (minutes/Kg)	*n* (0.31, 0.02)*
Sorting & Grading (minutes/Kg)	*n* (1.68, 0.03)*
Packaging (minutes/Kg)	*n* (2.36, 0.09)*
Labelling (minutes/Kg)	*n* (0.21, 0.02)*
Weighing & Packing (minutes/Kg)	*n* (0.94, 0.04)*

*Normal distribution (mean, std. deviation).

Table 5. Data analysis of validation by comparing the actual output and the status quo using t-test.

	Output Box per 2 Kg		Output Reject	
	Actual	Status Quo	Actual	Status Quo
Observation	20	20	20	20
Mean	263.52	283.60	67.03	61.95
df	19		19	
P(T<=t) two-tail	2.50629E-07		0.000333606	

Table 5 shows the results of the t-test calculation of the actual data output and the status quo. Two variables were used: box output and reject output. Based on the output of the t- test, with the value of P(T< = t) two-tail for all variables being < .05, it can be concluded that the data used is valid.

6. Experimentation

6.1. 'What-if' scenarios

Our simulation model was developed to identify the most effective and efficient type of governance for FAP logistics networks from three different types, namely centralised, semi-distributed and distributed governance. We specified three what-if scenarios that represent these three types. These scenarios focused on the product flow from the farmers to the LSP storage station. The optimal scenario was measured by the percentage of utilisation of each station, which was distributed evenly or in the range of 20–80% (Foster-Fishman et al. 2001). We assumed that if utilisation was lower than 20%, the logistics station was somehow idle, and if utilisation was greater than 80%, the station was blocked or overloaded. We also considered the shortest lead time of all post-harvest activities to be a prominent scenario resulting from efficient workforce utilisation.

6.1.1. Scenario 1: centralised governance for an FAP logistics network

This scenario represents centralised governance. The LSP has a vital role in controlling all activities of the French bean logistics network. Figure 3 depicts this scenario. This scenario is based on the

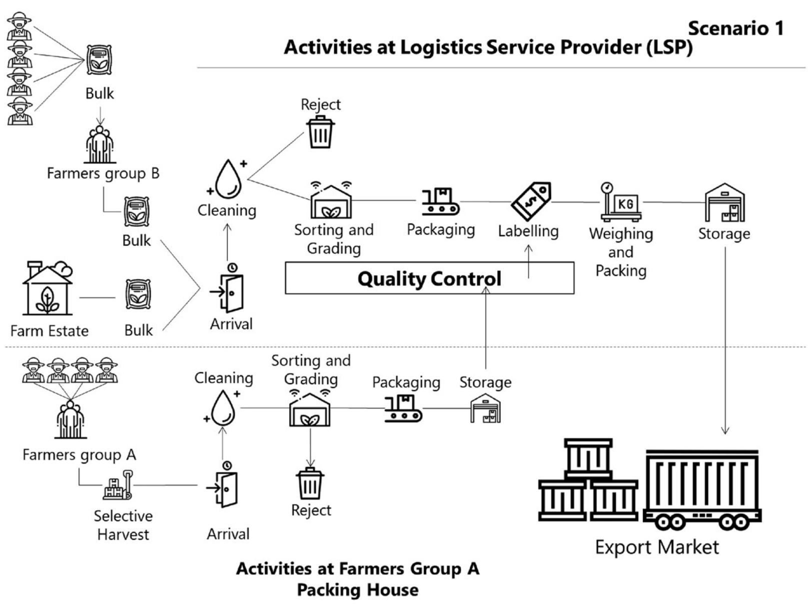


Figure 3. Scenario 1: centralised governance.

existing French bean logistics network in West Java. In this scenario, we introduced seven main actors: the LSP as a main actor, the Group A and B farmers, a farm estate located in Pangalengan, the packing houses of farmer Groups A and B and the exporter. Although the packing house in Lembang also handles post-harvest activities, the LSP still leads the whole production process.

This scenario only targets a single market – the export market. The LSP has a selling partnership with the exporter, who requires a high-quality product. This means that the LSP must ensure that all production processes within its logistics network work properly and that product quality is maintained. Therefore, it establishes and embeds quality control in all of its stations and for the product from farmer Groups A and B and the packing house of Group A.

In this scenario, products processed by the LSP are from farmer Groups A and B. Group B farmers sell their product directly to the LSP in bulk only, and Group A farmers sell their product using the selective harvest method. Before selling to the LSP, Group A farmers conduct some post-harvest activities, such as cleaning, sorting, and grading and packaging, at the Group A farmers' packing house. These packaged products are transported to the LSP for labelling and packing, with strict quality control performed by the LSP. Optimising the activities in the packing house is expected to increase the production capacity of high-quality products and to reduce the percentage of product rejected by the exporter due to low quality.

6.1.2. Scenario 2: semi-distributed governance for an FAP logistics network

This scenario combines centralised and distributed governance (i.e. semi-distributed governance). The tasks of the post-harvest activities are partially distributed. Figure 4 illustrates this scenario. The LSP in this scenario has the same number of stations as in Scenario 1. However, where the quality control is fully handled by the LSP in Scenario 1, it is partly managed by the Group B packing house in Scenario 2. This scenario optimises the roles of the Group A and B farmers and the Group B packing house in maintaining post-harvest stations.

We added a packing house in Pangalengan to increase the production capacity of the French beans for export markets. The inclusion of this additional packing house may also reduce the French bean stock shortage observed in the Group A process. This house has five post-harvest stations (weighing at the arrival station, cleaning, sorting, and grading, packaging and storing)

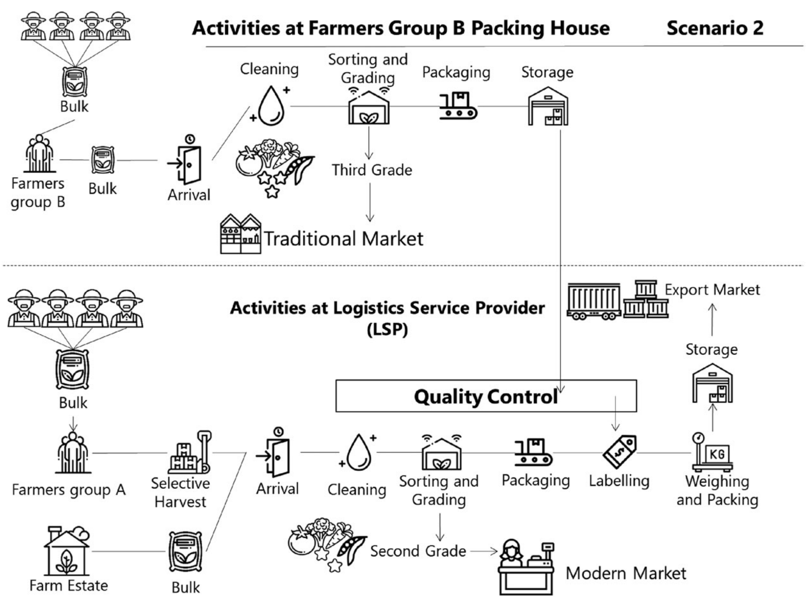


Figure 4. Scenario 2: semi-distributed governance.

and produces product of two quality grades: Grades A and C. Unlike Scenario 1, Scenario 2 results in the sale of products of three quality grades. Grade C products (i.e. those of the lowest grade) that are rejected in Group B's packing house are sold to traditional markets. The LSP yields Grade A and B products, which are delivered to modern and export markets, respectively. The packaged products from Group B's packing house are re-checked by the LSP to ensure that they are of the highest quality.

6.1.3. Scenario 3: distributed governance for an FAP logistics network

Scenario 3 represents the distributed type of governance (Figure 5) and is derived from Fisher et al. (1997). They highlighted that innovative products with high demand volatility and short life cycles should be transformed through a market-responsive supply chain. Because of its flexibility, this chain should have additional production capacities and information on product demands should be (almost) perfectly disseminated to all actors inside the chain. In this scenario, post-harvest activities are no longer concentrated at the LSP. Instead, these activities are also managed by the Group A and B packing houses and farmer groups. This scenario is expected to reduce bottleneck problems at post-harvesting stations and specify products based on their quality for three different market targets.

In Scenario 3, three different markets are served by three actors (i.e. the LSP and the Group A and B packing houses), and each market receives product of a specific quality grade. The LSP serves exporters, the Group A packing house serves modern markets and the Group B packing house serves traditional markets. Quality control is vital in this scenario and is handled by each actor. The distribution of responsibility for quality control is expected to be equal among the actors involved in post-harvest activities. Hence, strong cooperation between these involved actors is crucial for enhancing the performance of the French bean logistics network.

Farmers in Groups A and B sort their products at their farms before transporting them to their packing houses. This sorting activity allows for the determination of product quality from the very beginning of FAP management. After reaching the packing houses, the beans undergo processing at four stations: cleaning, sorting, and grading, packaging and storing. These stations are responsible

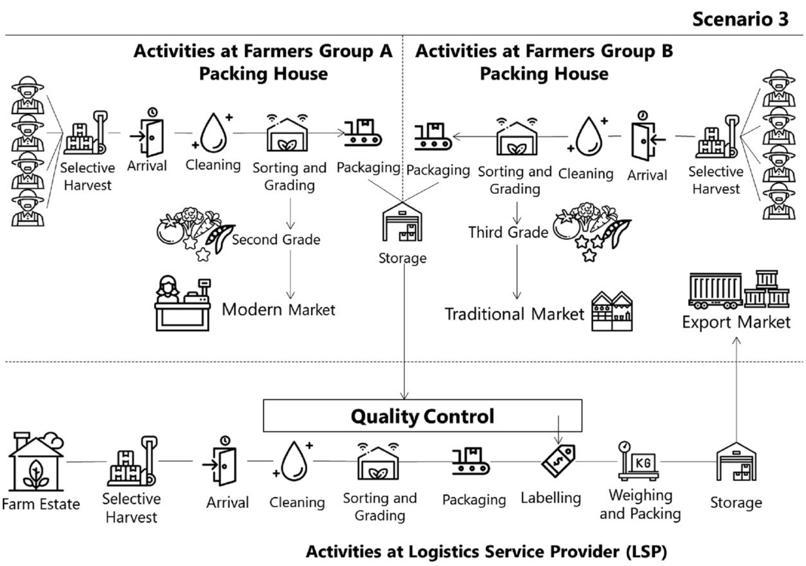


Figure 5. Scenario 3: distributed governance.

for reducing double handling and product damage. They can also increase stock turnover. The activities of all stations are designed to ensure product protection and recoverability (reusing and recycling). Each packing house produces two quality grades. Group A packing house produces Grade A and B beans, which are delivered to the LSP and modern markets, respectively. Group B packing house produces Grade A and C beans, which are transported to the LSP and traditional markets, respectively. The LSP thus handles Grade A beans from Groups A and B, as well as from its own production centres, which it then prepares for and sells to the exporter.

6.2. Simulation results

The ideal scenario would have the lowest utility percentage, with the least number of stations having a utility percentage higher than 80% (indicating no bottleneck problems) or lower than 20% (indicating idle stations). It would also have the lowest time and costs incurred for completing a one-cycle production process. To identify such an ideal scenario, we ran several models. First, we tested nine different numbers of workers in each scenario, with 520 kg of total weight processed by the LSP. This model was run to obtain the optimal number of LSP workers.

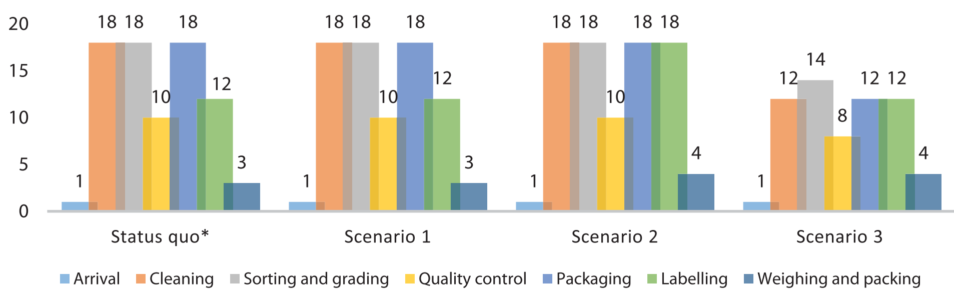
6.2.1. Number of workers, logistics cost, and operating time

Figure 6 shows the simulation results for each scenario in terms of number of workers involved in the logistics activities for one cycle of French bean production. In Scenario 3, the one-cycle production process is completed across all stations by 14 workers; this is fewer than in the other scenarios, which require 18 workers.

Despite the additional stations, the logistics cost in each scenario is lower than that of the status quo (Figure 7), which is approximately 5,789 IDR per kg. The logistics costs of Scenarios 1, 2 and 3 are 5,259 IDR per kg, 5,368 IDR per kg and 4,428 IDR per kg, respectively. This indicates that the distributed governance in Scenario 3 does reduce logistics costs by 1,300 IDR per kg.

We stopped running the simulations when they reached a steady state. The capacity of the one-cycle production process is 630 kg to produce an output of 520 kg. All stations were assumed to complete their activities (100%). Thus, their finished products were ready for the next station at its gate.

Figure 8 also shows that Scenario 3 takes about one hour less than the status quo to complete all post-harvest activities. Scenario 3 is also the most efficient compared to Scenarios 1 and 2, which require 6 and 6.5 h, respectively, to complete one cycle of production (see Figure 8). This finding implies that Scenario 3 might be preferable because it has the lowest logistics costs and the shortest operating time.



** Status quo refers to the baseline scenario based on the existing logistics network. To generate the baseline scenario, we acquired 15 measurements per station.*

Figure 6. Simulation results: number of workers.

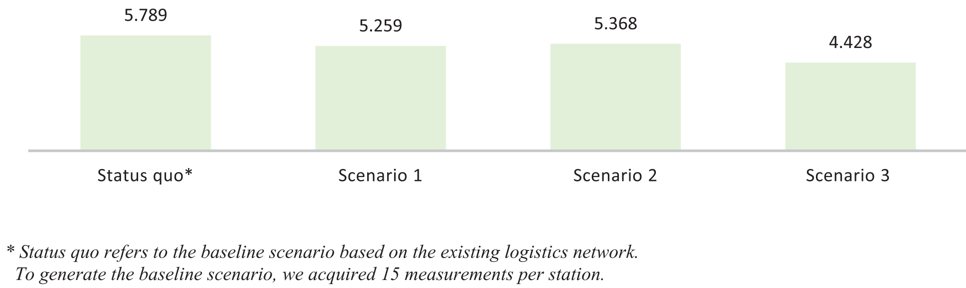


Figure 7. Simulation results: logistics cost.

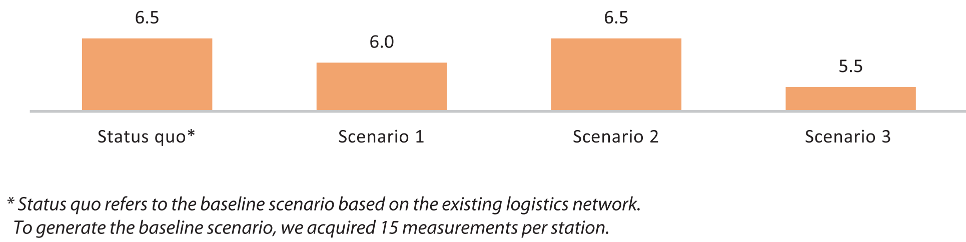


Figure 8. Simulation results: operating times.

6.2.2. Logistics utilisation

Utilisation was measured to investigate bottleneck and idle station problems within the logistics network. Understanding utilisation helps policymakers improve the efficiency of logistics chains. In this section of the study, we aimed to explore the effects of governance type on logistics utility within the stations. Figure 9 shows the utilisation of each station resulting from the simulation of the status quo and of Scenarios 1, 2 and 3.

It was found that utilisation is unevenly distributed among stations. Some stations are congested (utility >80%) or idle (utility <20%). The cleaning and weighing-packing stations in the status quo undergo congestion. All the simulated scenarios were found to generate lower percentages compared to the status quo, implying that workloads are more likely to be evenly distributed among stations, although some stations in Scenarios 1 and 3 become lightweight. Figure 8 also shows

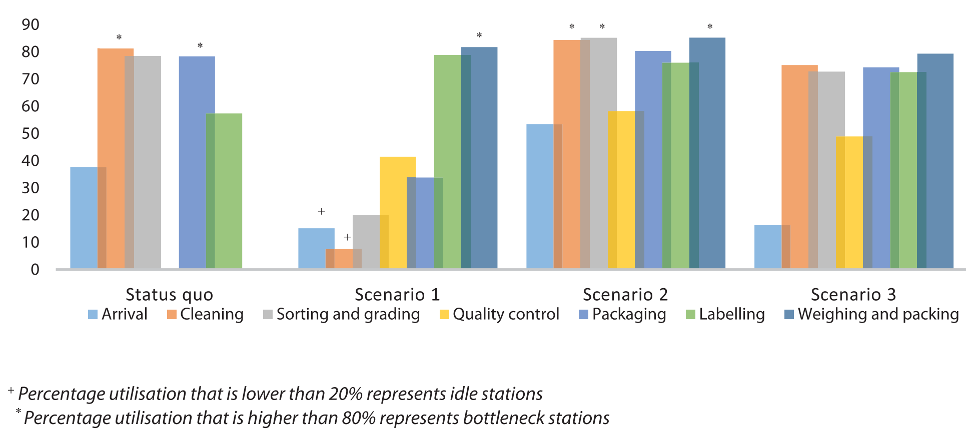


Figure 9. Simulation results: logistics utilisation.

that long queues occur at the exit gates of some stations in Scenarios 1 and 2. Scenario 2 creates more overloaded stations than Scenarios 1 and 3, with four out of six stations experiencing this problem: cleaning, sorting, and grading, packaging, and weighing and packing. This problem is also predicted to appear at the weighing and packing station in Scenario 1. In Scenario 3, the bottleneck issue does not exist, and workloads are likely to be distributed evenly within the stations, although the arrival station is idle.

Based on these results, it can be concluded that Scenario 3, with the distributed governance type, is superior for FAP logistics networks. In the case study of French beans presented here, responsibility within the supply chain should be distributed among smaller processing stations so that each station can maintain product quality for three different markets. This finding is in line with the study of Ostrom (2010), which found that distributed governance is the optimal organisational form for solving common-pool resource problems. According to Albers et al. (2003), this type of governance leads to joint responsibility. Lower-level community groups have a voice and can contribute to the system. According to Ostrom (2010), this governance form is better than the centralised form, in terms of increased productivity:

> […] On the farmer governed systems, farmers communicate with one another at annual meetings and informally on a regular basis, develop their own agreements, establish the positions of monitors, and sanction those who do not conform to their own rules. Consequently, farmer managed systems are likely to grow more rice, distribute water more equitably, and keep their systems in better repair than government systems […]. (Ostrom 2010, 657)

Scenario 3 was designed to optimise the performance of the LSP; all processing station activities are designed to reduce product damage and diminish bottlenecks (Rolle 2006). Farmers in Groups A and B in this system enhance the scale of production, in terms of the quantity of product sold, and minimise product rejection from buyers. Adopting such a governance style enables every actor in the FAP logistics network to perform their functions and make rational decisions due to access to more comprehensive and reliable information in repeated situations (Ostrom 2010). They also have no bureaucratic barriers inhibiting their decision-making for themselves. Bossert, Bowser, and Amenyah (2007) suggested that local knowledge is critical for effective performance of the logistics network. Therefore, crucial local problems, for example, in sorting and grading stations, could be overcome as soon as possible.

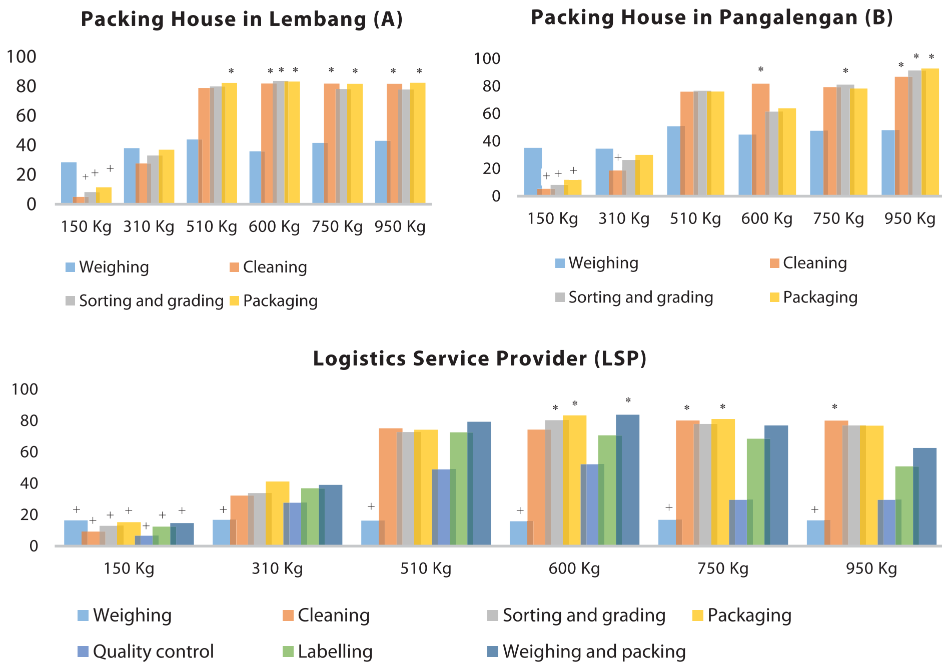
Rapid responses to handling problems are a must for FAP logistics; perishable products must be processed in timely manner to minimise product damage in the supply chains that span farming, handling, transportation, and trade practices. Scenario 3 offers a faster and more efficient way to maintain product quality for end users. A shorter operating time could potentially reduce the risk of product damage.

We re-ran the simulation of Scenario 3 using six different weights. We selected this scenario based on previous results, which was the most efficient governance type for FAP logistics networks. For these simulations, all parameters were set as constant, including the number of workers and the operating time for each station, as described in Figures 4 and 5. It is reasonable to conclude that simulation approaches are appropriate for investigating the stations whose utilisation is in the range of 20–80%. Therefore, we recommend improving logistics governance by setting the number of workers that could be hired at each station.

Figure 10 shows the utilisation percentages based on the simulation results of six weight ranges.

7. Discussion

This study aimed to investigate the efficiency of different logistics network governance types for FAPs. The model built in this study focused on the post-harvest process within an FAP logistics network involving small-holder farms. The results show that distributed governance is needed in the FAP logistics networks of small-holder farms. By adopting this type of governance, small-holder



+ *Percentage utilisation that is lower than 20% represents idle stations*
* *Percentage utilisation that is higher than 80% represents bottleneck stations*

Figure 10. Simulation results: utilisation based on intake weight.

farms will be able to supply their FAPs to multiple markets and ultimately earn higher incomes. Our findings have shown that distributed governance is the best strategy of those tested for minimising logistics costs and increasing time effectiveness in an FAP logistics network.

The distributed governance strategy for FAPs shortens processing time and reduces logistics costs by distributing responsibility to all involved actors. In this case study, distributed governance would involve farmer Groups A and B and the LSP autonomously managing post-harvest handling activities based on their target markets. Each actor would manage its own resources. Optimising workstation activities could also lead to effective delivery of high-quality product, efficient spending, and effective systems. Implementing a distributed type of governance in an FAP logistics network should result in actors at all levels having the authority to improve capabilities and knowledge. Accordingly, consumers can then receive high-quality products in a timely manner.

For supply chains that target multiple markets, marketing problems, such as uncertainty in quantity and quality, FAP risks and marketing competition, must be managed via a portfolio marketing strategy (Fafchamps 1992; Hamlin, Henry, and Cuthbert 2012). Implementing such a strategy is plausible with the decentralisation of governance. Distributed governance emphasises improvements in station capability, information exchange and business cycles. The characteristics of distributed governance are aligned with the conditions of FAP logistics involving small-holder farmers located in scattered locations. The most important thing is the increase in farmers' capabilities through well-distributed responsibilities and the exchange of information (Hassan et al. 2021). In this case study, implementing this governance type for all the activities performed by Group A and B farmers would impact the distribution of responsibility for improving product quality and minimising product losses during handling. It would also enhance bargaining power in the markets based on product quality.

If a centralised governance concept is adopted, with the LSP as the central control, the LSP will face challenges in order management and inventory planning. This is because the system would be very complex, with multi-market targets and numerous producers in the logistics network. According to Wanke and Zinn (2004), Patterson, Grimm, and Corsi (2003) and Chen and Liu (2017), delivery time and cost-effectiveness are the most crucial factors for an LSP within a centralised governance system (Wanke and Zinn 2004; Patterson, Grimm, and Corsi 2003; Chen and Liu 2017). In the context of the French bean logistics network, it should be relatively easy to implement distributed governance. Nordmark et al. (2012) emphasised that implementing distributed governance in logistics networks allows production capacity improvements and transportation effectiveness (specifically for time, cost-effectiveness, driving distance and total time of transport routes). Additionally, Scenario 3 requires fewer resources (workers, time, and costs) than the status quo for cleaning, sorting and grading, packing and labelling activities.

Optimising the roles of each involved actor in the FAP supply chain could enhance efficiency and reveal effective ways of utilising production capacity (Bosona and Gebresenbet 2011). Nonetheless, distributed governance requires strong cooperation between spatially close partners who perform different operations to enhance production capacity and minimise logistics costs. These types of partnerships are essential for continuing the shift to pre-packed and processed foods to extend the shelf life of food products and reduce waste in the distribution process and at the point of consumption (i.e. the home or food services provider) (Verghese et al. 2013). In the case study, this type of close partnership is represented by the partnership between the Group A packing house and the LSP packing house. Managing this close partnership could enhance the capacity of the production area, minimise loss of surplus and maximise product collection (Goffin, Lemke, and Szwejczewski 2006). Wallenburg and Raue (2011, 387) stated that '[…] unequally distributed power within cooperation is a natural source of conflict as less powerful partners are likely to feel discriminated […]'.

8. Conclusions

In this study, it was found that distributed governance can effectively reduce delays and minimise logistics costs in a logistics network that supplies multiple markets. Implementing distributed governance for FAP logistics networks could enhance efficiency and effectiveness by reducing delays and logistics costs by giving autonomy to each actor to manage their resources. Optimising workstations would result in efficient delivery of quality product and the required supply with efficient costing and an effective system. To optimally manage the interrelationships among the FAP logistics network actors and thus optimise the entire system, distributed governance should be coupled with endogenous governance. Distributed governance should be implemented in an FAP logistics network in such a way that it delivers better consumer value and provides an authority that manages and coordinates the roles of the various actors in the logistics network.

8.1. Implications for theory

Good logistics network governance is critical for reducing logistics costs and increasing the efficiency of an FAP logistics network. Our work contributes to these aspects by recommending the most suitable FAP logistics network governance type in the context of developing countries. Our findings also contribute to logistics network governance theory, especially the understanding of the different governance types for FAP logistics networks that consist of many small-holder farmers and serve multiple markets. Our work therefore expands on previous work related to governance, for instance, the theoretical framework of Ostrom (2010) and the work of Almena et al. (2019).

Due to the ever-increasing complexity and uncertainty of FAP logistics networks, there is a compelling need for a more pragmatic approach to assessing FAP logistics network governance for multiple-market decisions based on real-world cases that incorporate both endogenous and exogenous parameters. The proposed FAP logistics network governance model was subjected to DES that simulated potential growth strategies, and the impact of existing FAP logistics processes was observed (Pujawan et al. 2015; Gittins, McElwee, and Tipi 2020). In alignment with the work of Almena et al. (2019), we also employed a simulation model to design and assess the feasibility of different scenarios under conditions of uncertainty.

8.2. Implications for practice

The practical contributions of this research are particularly relevant in the context of FAP logistics networks in the developing world that involve many small-holder farmers. Small-holder farmers have particularly experienced difficult times during the COVID-19 pandemic. The distributed governance model proposed in this research has been proven to be effective in mitigating uncertainties in the supply of FAP caused by the pandemic.

The findings provide valuable insights for policymakers and practitioners into how to improve the management of FAP supply chains that involve small-holder farms. Policymakers can apply versions of the proposed FAP logistics network governance model to develop production centres that are integrated with the market. The model can be used as a reference for the construction of packing house facilities that are fully integrated with a logistics governance system developed by, for instance, a ministry of agriculture. For FAP supply chain actors, the model can be used to design and implement market portfolio strategies guided by logistics governance.

8.3. Limitations and future work

This study is intentionally focused on the specific characteristics of the FAP commodity, so there is a risk that the model may not be suitable for investigating the dynamic responses of the governance types to the processing of different product weights. This study also emphasises on logistics governance by involving the small-holder farmers in the context of post-harvest handling process that aims to meet the needs of the markets. Future work could investigate the FAP inventory routing problems, the coordination mechanism and the business system amongst actors involved in the logistic networks, and the FAP losses, perhaps through the materials flow analysis. Finally, the study may also be extended to investigate the sustainability of the FAP logistics network and to apply the life cycle analysis to move closer to decarbonising the logistics network.

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Disclosure statement

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Data availability statement

The data that support the findings of this study are openly available in Figshare at https://doi.org/10.6084/m9.figshare.19228236.v1.

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