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# Simulation- based approaches for processes improvement of a sugar mill yard management system: A case study of the sugar industry in the central region of Thailand

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**Abstract**

Inbound logistics in the sugarcane industry focus on the efficiency of sugarcane transportation to the sugar mill under mill capacity constraints. At present, the issue of the long waiting time for vehicles at the mill yard occurs because of the high uncertainty of vehicle arrival rate and the important factor is not an unloading machine allocation strategy. This research proposes a methodology to improve mill yard management that aims to reduce the time in the system for sugarcane transport vehicles. The current management system of the mill yard system was simulated using Arena software. To treat this as a waiting time problem, the current study focuses on the average vehicle time in the system, to lead to further improvements by developing alternative configurations. Two alternative scenarios were proposed as (1) the proposed model 1: developing a registration process based on a grower type priority serving all grower types on a first come first served (FCFS) basis and (2) the proposed model 2: allocating unloading machines depending on the type of sugarcane grower. The results show that with the current system, vehicles spend 10.18 hours in the system. Proposed model 1 shows that they will spend 9.31 hours in the system while proposed model 2 predicts that they will spend 9.02 hours in the system. Thus, improvements reflected in reduced time in the system show reductions of 0.87 hours (52.2 minutes, 8.55%) and 1.16 hours (69.6 minutes, 11.39%), respectively.

**Keywords:** Agro industry, Supply chain management, Queuing theory, Scheduling and sequencing, Sugarcane inbound logistics

## 1. Introduction

Sugarcane is a food and energy plant. The sugar industry is highly important to the economy of Thailand. The country is the second largest sugar exporter in the world. In the past, sugar was produced solely for consumption in Thailand, but at present, it is increasingly being produced for export. For the 2015/2016 crop, the sugarcane cultivation area in Thailand was 1,762,054 hectares (1 hectare equals 6.25 rai) producing 9,780,923 tonne of sugar. Furthermore, Thailand's market needs to consistently increase because government policies promoting sugar production. The sugar producing system includes fifty-one sugar mills located in various regions of Thailand. There are many stakeholders in the industry, such as growers, laborers, entrepreneurs or owners, as well as production factors including machines, equipment, trucks for transportation, and sugar factories [1].

The sugarcane industry supplies chain and logistics in Thailand consist of three sections, inbound logistics, internal logistics, and outbound logistics. Inbound logistics starts with sugarcane cultivation by growers. When the sugarcane is ready for harvest (after about eight to twelve months, the growers will harvest the sugarcane by cutting it and loading it onto trucks, where it will be transported to the sugar mill for crushing. Then the trucks will be marshalled at the mill yard by the sugar mill. The final product of this section is cut sugarcane. Internal logistics consists of a production plan, production and quality control, material transfer, packing and storage, and information management. These can all be considered as internal processes of the sugar mill that are continuous in nature. The processes involved in this section are juice extraction, juice purification, evaporation, crystallization, and centrifugation. The final products of the internal logistics section are raw sugar, refined sugar, and byproducts including bagasse, molasses, and other materials. The outbound logistics begins at the sugar mill warehouse, from where sugar is distributed to the trade, customers, or industry. The operations involved in this section are comprised of marketing, production transportation and distribution, warehouse management, export management,

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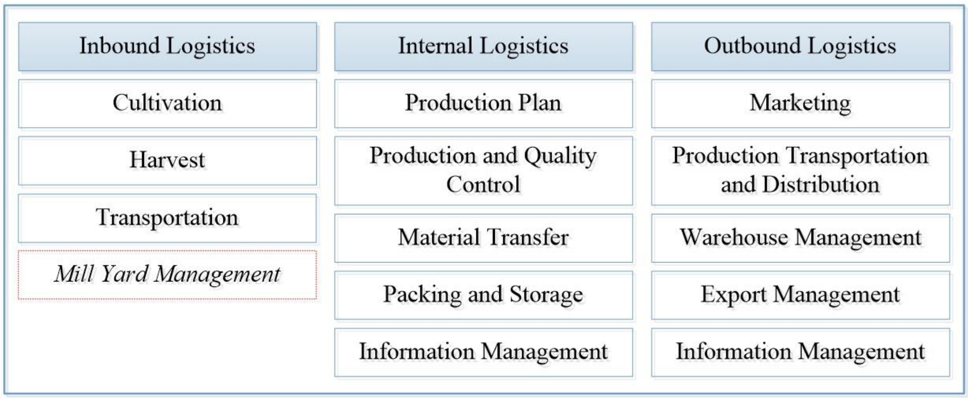



**Figure 1** Sugar industry logistics and supply chain system in Thailand [2]

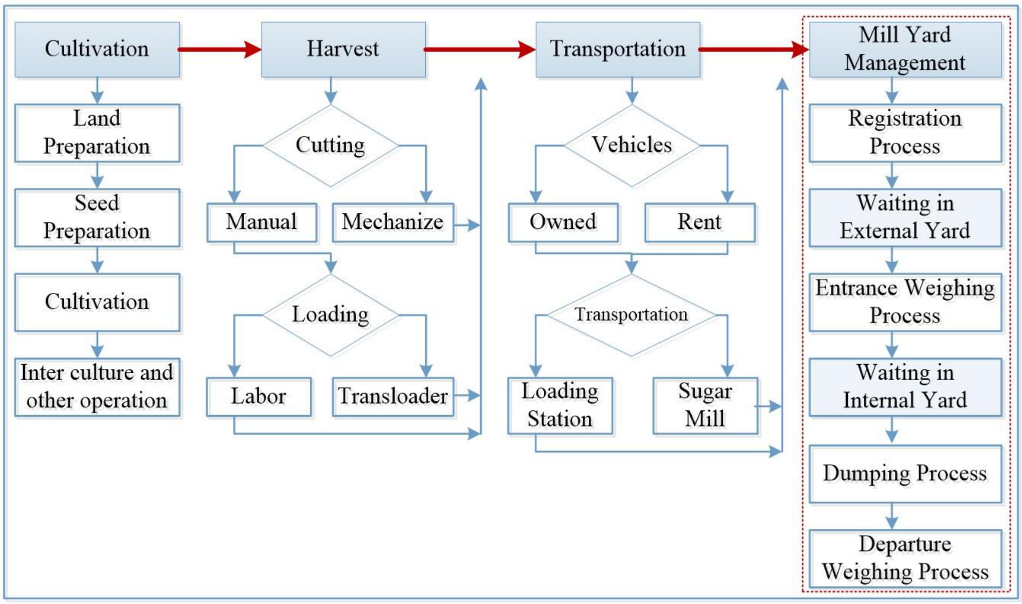



**Figure 2** Items for sugarcane inbound logistics [3]

and information management. The final products are raw and processed sugar.

The proportion of costs for inbound, internal, and outbound logistics section are approximately 60%, 26% and 14%, respectively [2]. The highest cost is for inbound logistics because it includes a combination of operations with many stakeholders. Thus, this research focused on the inbound logistic section of the sugarcane industry. It has four major operations, (1) cultivation, (2) harvest, (3) transportation and (4) mill yard management (Queue Management) (see Figure 1). The bottlenecks for inbound logistics are found in the mill yard operations because of the limited sugar mill capacity, material handling capacity, management methods, queue management, and material handling allocation. The mill yard operation consists of the following processes, (1) registration, (2) entrance weighing, (3) dumping and (4) departure weighing (see Figure 2).

Most growers cultivate sugarcane at the same time due to environmental parameters, including physical factors (seed, soil type, weather, temperature, and irrigation), agricultural practices, production factors, and social and cultural factors. This affects harvest operations. So, growers harvest sugarcane at the same time. Moreover, when reflecting on harvest operations, the location of grower fields, differences in size and cultivation patterns, which involves the distribution of plots around the sugar mill, must be considered. For this case study, the sugar mill in this case study supports 500 growers and 2,500 fields. They classify the growers by distance for appropriate sugar mill subsidy strategies. There are two types of sugarcane growers. Type I includes growers within an internal zone near the mill, while Type II includes growers outside of this area and special case (see Figure 3). The distance to the mill, as well as traffic congestion, affects transportation and mill yard management operations. The middle of the sugarcane crushing period is considered because this period is a long period (about three or four months), and the growers harvest sugarcane simultaneously, delivering it to the mill at a rate higher than mill capacity. Therefore, there are long waiting times at the mill yard that negatively affect sugarcane weight and sweetness (Cane Commercial Sugar; CCS.) [4] and increases inbound logistics costs. Moreover, the price of sugarcane will decrease, since the loss of weight and sweetness depends on the waiting time after harvest. The weight of fresh sugarcane decreases by 7.9% and 16.5%, over five and ten days, respectively, after the sugarcane is harvested. Similarly, the weight of burnt sugarcane decreased by 9.4% and 33.8% over five and ten days, respectively, after the sugarcane was harvested. Also, the sugarcane sweetness decreases by 1.28% and 6.98% five and ten days,

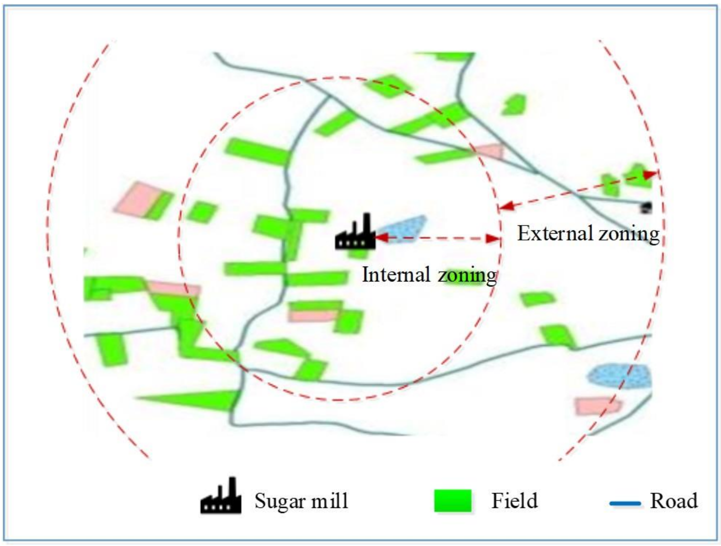



**Figure 3** Sugar supply system geographic distribution

**Table 1** The effects of long time in system at the mill yard on all stakeholders

| Grower | Sugar mill | Vehicle owner |
|---|---|---|
| - Low revenue selling from low quality sugarcane, weight and sweetness<br>- High inbound logistics costs from waiting at the mill yard | - Discontinuous raw material supply<br>- High cost per unit, low productivity, low quality of raw material | - Loss of opportunity for delivering sugarcane to the mill<br>- Low vehicle utilization |

respectively, after the sugarcane was harvested [5]. Additionally, the long waiting times at the mill yard affect all stakeholders in the supply chain as presented in Table 1.

Generally, mill yard management operation is complex and should be solved by simulation and optimization techniques since most of the inputs are uncertain and are in the form of distributions. Additionally, there are various factors resulting in long times in the system of the vehicles. These factors are that the dumping allocation at mill yard should match the throughput of material through the mill, there are many types of vehicles with various load capacities and different arrival times, and the size and capacity of the dumping machines are restricted to size and loaded capacity of vehicles. A scheduling algorithm is required to optimize unloading.

Hence, this research studied and simulated a mill yard management system for a sugar mill with many limiting constraints, and then improved the original model using simulation techniques. The simulation involved imitation of the system behavior using computer software. The current operational system was modified through data collection, analysis, and evaluation of program validity with the current system, leading to the proposed system [6]. In this way, simulation was used to analyze the current system and find an appropriate operational scenario before implementation in the real system, resulting in decreased risk, error, and uncertainty, as well as cost and time reduction [7]. The advantages of the simulation were reasonableness, provability and output comparison. [8] proposed three types of simulation classifications, (1) static and dynamic, (2) continuous and discrete, and (3) deterministic and stochastic. In a *static and dynamic* classification*,* a static event is one that occurs in a system and is constant with time. A *dynamic* event is one that changes or depends on a time. For a *continuous and discrete* events, *continuous* refers to a situation in which the system can be changed over time, while *discrete* means that the system that can only be changed at certain points in time. For probability considerations, in *deterministic and stochastic* events, *deterministic* refers events that occur under a condition and stochastic events vary with time. This affects the probability or the time variability [9-10]. The simulated model starts from an initial problem formulation that includes a definition, target setting, scope setting, and data collection. Second, the model was implemented in software. Third, the simulation was validated by comparison with a real system using data observations and verified by another program. After that, the development operations were experimentally designed with production runs, analysis of results, and documentation of the program and results reported. Finally, the best proposed model was selected for implementation [7] (see Figure 4).

Simulation techniques have been widely used by researchers for the continuous development of computer software to support decision-making in many fields, such as medicine, industry, factories, transportation, production distribution, and various business services such as banks and hospitals. Previous researchers used simulation to study the sugarcane supply chain. [11] used a simulated model for analysis of the harvesting and transportation from a sugarcane plantation to increase machine utilization. This involved a reduction in the amount of machinery needed without increased time in the system. [9] used a simulation model for capacity planning in sugarcane transport, considering the number of locomotives and shifts required, the number of bins required, and the delays in harvesting operations resulting from harvesters waiting for bin deliveries. [12] applied discrete simulation techniques to study operational processes and policies in a sugar mill reception area, aiming to increase the amount of sugarcane

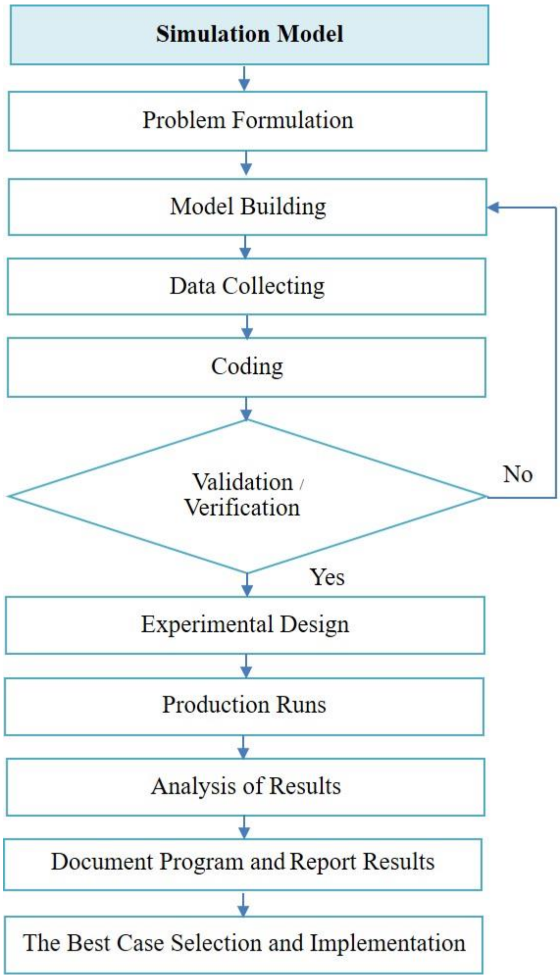



**Figure 4** Simulation Model Operation [7]

unloaded. [13] developed a simulation model as a decision support system for sugarcane supply which considered inbound logistics, harvesting, transportation, and unloading of sugarcane at the mill yard. These researchers proposed three scenarios, focusing on environmental conditions (e.g., the rainy period), the effects of policy change (different layouts of the unloading area), and the impact of new arrangements in the mill yard on time, management of sugarcane vehicles and the amount of unloaded sugarcane.

Therefore, this research proposes improvements in the mill yard management system that address complex problems constrained by many factors. It studied the current practices of mill yard management for the dumping process, and developed an alternative configuration using job scheduling and sequencing techniques to determine an appropriate algorithm to improve mill yard operations and apply a simulation technique to develop two proposed models. These are proposed model 1: development of a registration process and (2) proposed model 2: a dumping machine allocation based on the ratio of grower types for reduction of a vehicle's time in the mill yard, leading to an increase in sugarcane quality from the system (sugarcane quantity and sweetness). Moreover, the results can improve the system and be implemented in a large-scale of industry.

## 2. Material and methods

The simulation model was generated from a real system for evaluation and analysis of the current practice. In this research, the mill yard management system of the case study was simulated and the system improved as a proposed model, by applying a simulation with Arena 11.0 software. The conceptual framework consisted of three parts, input, the simulation model and output with the following details. For inputs, there were multiple types of sugarcane growers and types of vehicles. The simulation model considered the registration process, waiting in the yard area, the entrance weighing process, waiting in internal yard area, the dumping process, and departure weighing process. The key performance indices (KPI) of output are time in the system (units: hours) and average number of trucks leaving the system (unit: number of trucks) (see Figure 5).

### *2.1 The management of a mill yard system (AS-IS analysis)*

The mill yard management of this case study starts with the vehicles arriving at the mill yard in the external yard area. Each vehicle will register and get a queue card, then park in the external yard area and do the weighing process. The maximum parking at the external yard area is enough for 300 vehicles. Then, the vehicle will be called into the internal yard area for dumping sugarcane, with parking for a maximum of 60 vehicles. After the dumping process, the empty vehicles are weighed again to measure the actual amount of sugarcane per trip (unit: tonnes). At present, the mill has five sugarcane dumping machines, which support a maximum capacity of approximately 50 tonnes/machine/time. The queue discipline pattern of the

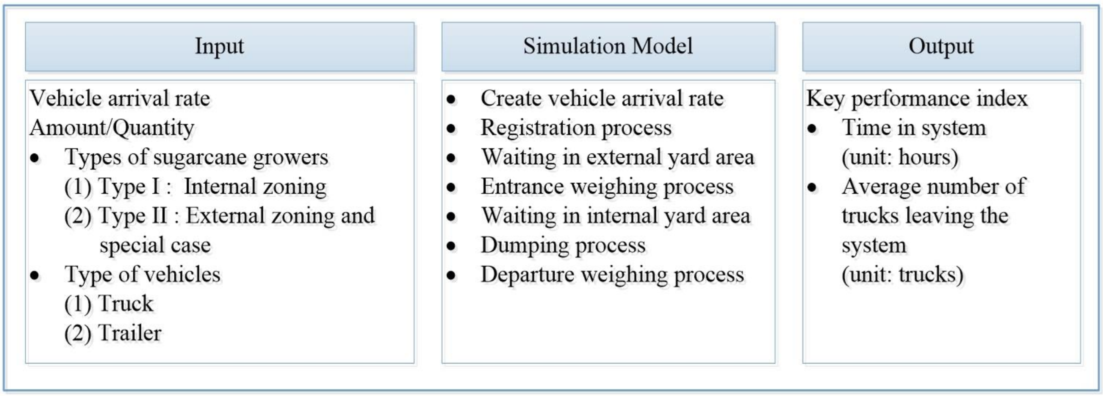



**Figure 5** Conceptual research framework

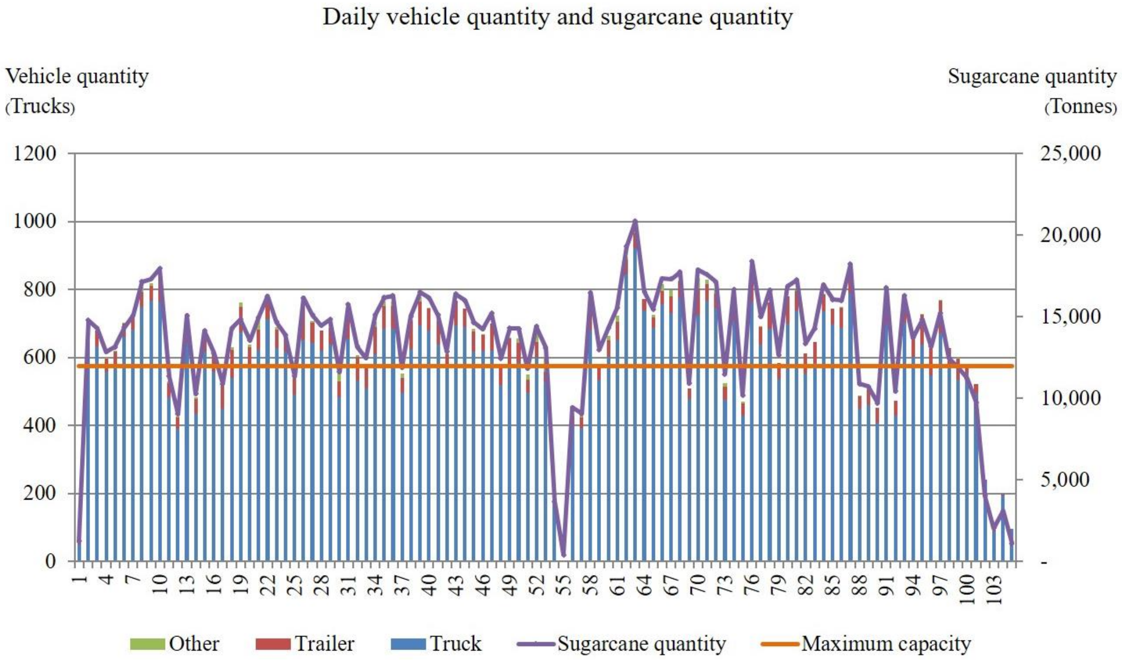



**Figure 6** Daily vehicle and sugarcane quantity in the system based on the production crop of 2014/2015 [1]

registration process, entrance weighing and departure weighing processes are a single-channel-single-phase system (SCSP system) and the dumping process is a multiple-channel-single-phase system (MCSP system). Queue discipline in most processes is first come first served (FCFS) except for the dumping process that contains first come first served (FCFS) and priority that depends on type of sugarcane grower as detailed below (see Figures 8 (A) and 9 (A)). From crop production data in 2014/2015, the maximum capacity of the sugar mill was 12,000 tonnes/day. During this time, the cumulative sugarcane quantity in the system was 1,428,544 tonnes, the average amount of sugarcane processed was, min - max (average) 404 - 20,859 (13,605) tonnes/day. The cumulative number of vehicle unloaded in the system was 67,366 trucks, the average number of vehicles in the system, min - max (average) 57 – 976 (648) trucks/day, as shown in Figure 6 and Table 2.

*2.2 Input analysis*

The scope of this study was to consider the time in the system and the average number of vehicles in the system at the mill yard. Figure 7 shows the input analysis.

*2.2.1 Resources*

Resources do activities with entities or objects. There are four resource types, registration workers, entrance weighing workers, five dumping machines (D1-D5), and departure weighing workers.

*2.2.2 Entities*

An entity is an object that the programmer is interested in and can change the status of the system. The entities in the current research are vehicles delivering sugarcane to the mill (unit: number of trucks).

*2.2.3 Attributes*

Attributes are characteristics of entities. There are two types of attributes as below.

The first is the type of sugarcane grower. There are two groups of growers. Type I (90%) are growers in the internal zone and Type II (10%) are the growers in the external zone and special case growers. Special cases involve issues such as broken down trucks, growers with large quantities of

**Table 2** Daily vehicle quantity and sugarcane quantity in the system based on the 2014/2015 crop

| Item | Quantity |
|---|---|
| - Cumulative sugarcane quantity in system (unit: tonnes/production crop) | 1,428,544 |
| - Sugarcane quantity in system min - max (average) (unit: tonnes/day) | 404 - 20,859 (13,605) |
| - Cumulative vehicle quantity in system (unit: trucks/production crop) | 67,366 |
| - Vehicle quantity in system min - max (average) (unit: trucks/day) | 57 – 976 (648) |

Note: Production data 104 days (production crop 2014/2015)
Sugar mill maximum capacity 12,000 tonnes/day

**Table 3** Distribution of time between arrival and processing time for each process

| Item | Registration process (Arrival rate) | Entrance weighing process | Dumping process | Departure weighing process |
|---|---|---|---|---|
| - Distribution of the time between arrivals | Type I: LOGN (2.71, 4.15)<br>Type II: LOGN (8.56, 14.4) | 0.999 + EXPO(1.61) | 0.999 + EXPO(5.39) | -0.001 + EXPO(2.64) |
| - p-value | 0.0664 | 0.0847 | 0.0523 | 0.0683 |

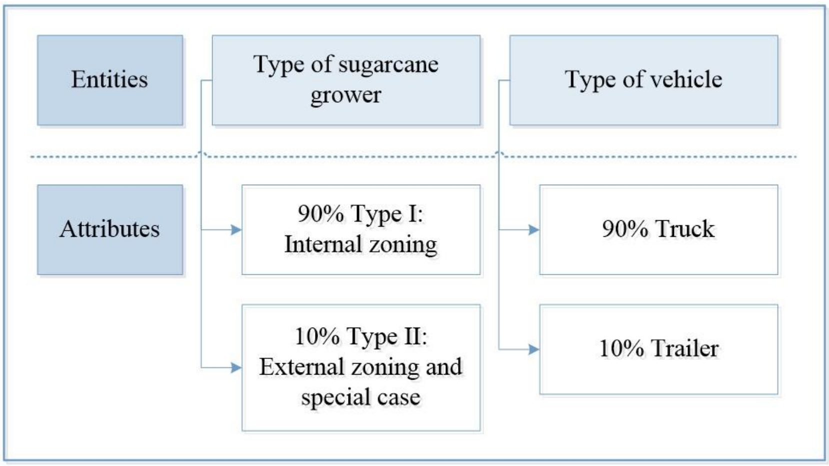



**Figure 7** Classification of entities and attributes in the mill yard system

sugarcane, burned sugarcane fields and emergency cases that have been approved by the sugar mill manager.

The vehicles are of two types, trucks (90%) with capacities of 20-25 tonnes, (2) trailers (10%) with capacities 40-48 tonnes (average 45 tonnes).

*2.3 Data acquisition and distribution fitting*

The study period was a sugarcane crushing season in the production crop year 2014/2015 (approximately 73 days, 24 hours/day except for machine breakdowns). Arrival time was measured as well as the time required for each process. This information was put into a database. Statistical techniques were used to select or clean data to ensure that these data can be used as the inputs data to the problem solution. Next, the database was used to test the distribution of times between arrival and processing time with the input analyzer function of Arena and using a Chi-square test for validation at a confidence interval 95% (p-value > 0.05). These distributions and parameters can be used as a representative of the real system inputs shown in Table 3.

*2.4 The simulation model*

The simulation model consisted of two parts. The first was the original model of the mill yard system, which is known from the current practice. The second part presents alternative configurations using the two proposed models. These are proposed model 1: registration and dumping process development to improve the queue discipline of these processes in a FCFS manner (independent of grower type) and proposed model 2: allocation of dumping machines dependent on the type of sugarcane grower (See Figures 8, 9, and 10). The average time within the system and average number of vehicles were used to validate and verify the model, since these were the key performance indices used in practice with the notation below:

$i$ Model index; $i$=1 (current practice), $i$=2 (proposed model 1), $i$=3 (proposed model 2)
$TIS_i$ Time within model system $i$ (hours)
$NO_i$ Average number of trucks leaving the system (trucks)

**Table 4** Validation model between real system and simulation model (original model)

| Key performance index | Observed (Average) | Original Model (Average) | p-value |
|---|---|---|---|
| - $TIS_i$ | 10.92 | 10.18 | 0.0547 |
| - $NO_i$ | 34,093 | 35,188 | |

**Table 5** Verification model between simulation model and calculation using Microsoft Excel

| Key performance index | Original Model (Average) | Program (Average) | p-value |
|---|---|---|---|
| - $TIS_i$ | 10.18 | 10.39 | 0.0613 |
| - $NO_i$ | 35,188 | 35,176 | |

*2.4.1 Original model of the mill yard (Current situation model)*

Conditions of the dumping process are as below.

*Type of vehicle:* (1) 6 or 10-wheel trucks can dump sugarcane in all dumping machines (D1-D5), (2) trailers can dump only into machines 1 and 2 (D1-D2) with the head of the trailer dumped at machine 1 (D1) and the tail of the trailer dumped at machine 2 (D2) because of space limitations and raw material flow.

*The conceptual framework of dumping machine allocation* was considered by the type of cane grower: Type I, the internal zoning area the queue was arranged as FCFS. For Type II, the external zoning area and special cases will have priority (1 hour waiting time) due to sugar mill strategy. If there are all types of sugarcane growers, a sample dumping allocation could be:
(1) Allocation set 1: Type I (5 dumps);
(2) Allocation set 2: Type I (4 dumps) & Type II (1 dump);
(3) Allocation set 5: Type I (5 dumps) and repeat until the end of the process.Dump is the amount of unloading that can be assigned to 1 vehicle.

*2.4.2 Alternative configurations*

Two alternative scenarios were forwarded, proposed model 1: developing a registration process and (2) proposed model 2: allocating the dumping machines as below.

*Proposed Model 1: a registration process development (FCFS based)*
This model, developed from the original model in the queue discipline pattern of the registration process and the dumping process, was a FCFS system for all types of sugarcane growers. (Type II, outer zone areas and special cases are queued similarly to Type I, the internal zoning area at the registration process. Similarly, Type II, the external zoning area and special cases will not have priority) (see Figures 8 (B) and 9 (B)).

*Proposed model 2: dumping machine allocation (depending on the type of sugarcane grower)*

This model was developed from proposed model 1: the registration process development (FCFS based). Moreover, the queue discipline pattern of the dumping process was an FCFS system for all types of sugarcane growers. Dumping machine allocation depends on the size of the sugarcane grower's plantation (see Figure 8 (C) and Figure 9 (C)).

*2.5 Validation and verification*

*2.5.1 Validation*

The original model was validated against the real system by comparing results averaged over time within the system and the average number of vehicles by using a t-test for statistic validation. The parameter settings of the experiment were measured with five replications. The results showed that average vehicle times in the system for the current system and the simulation models were 10.92 and 10.18 hours respectively. Moreover, the average numbers of trucks leaving the current system and the simulation model were 34,093 and 35,188 trucks respectively. Therefore, considering the p-value is greater than 0.05 (confidence interval value 95) as shown in Table 4, this model can be used as a representative of the real system.

*2.5.2 Verification*

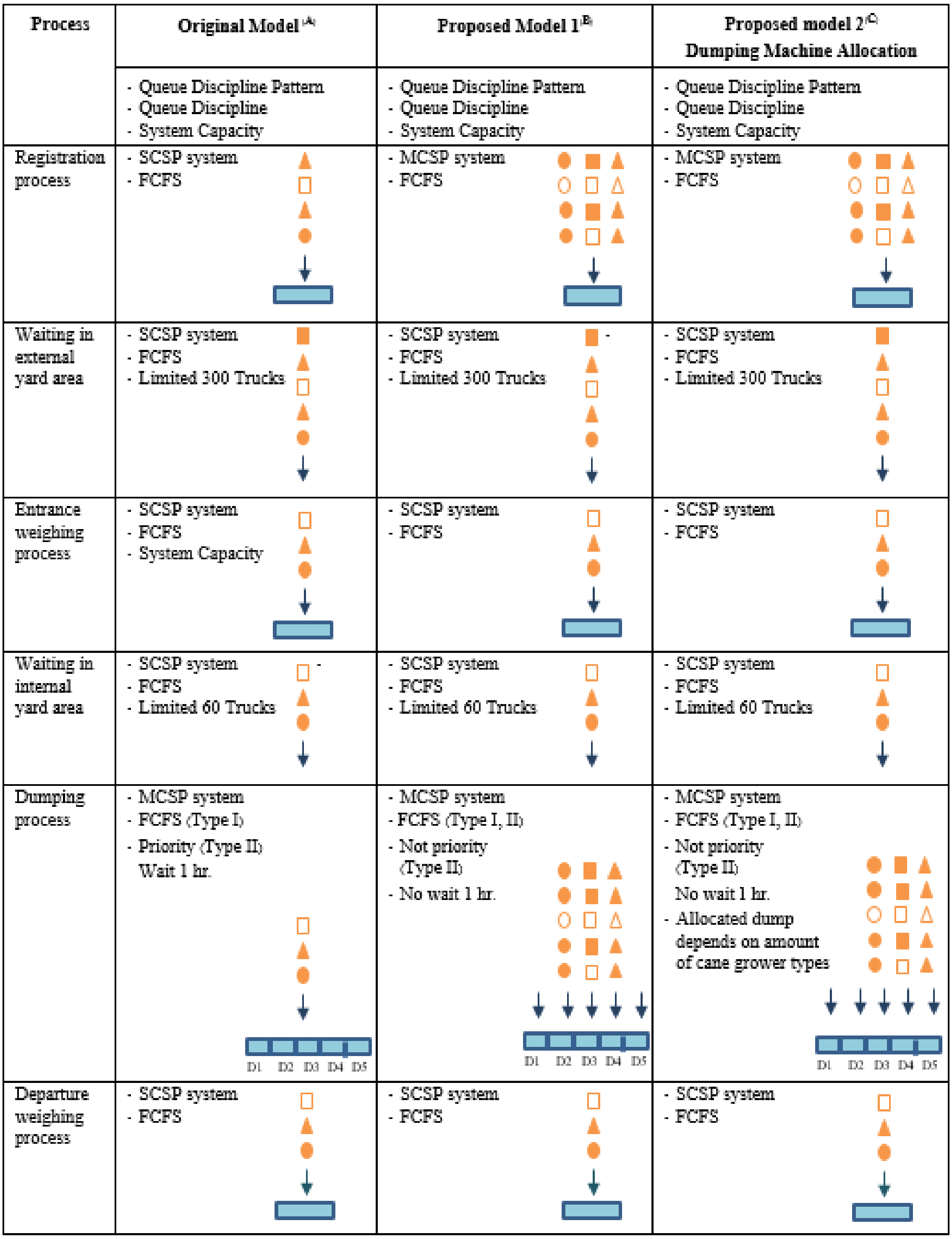
The original model was verified by hand-calculated simulation with another program for simulation model confirmation. In this case we used Microsoft Excel in a step-by-step manner to verify the original model and for logical rechecking. The results showed that average vehicle times in the system for the simulation model and program were 10.18 and 10.39 hours, respectively. Moreover, the average number of trucks leaving the system in the simulation model and program were 35,188 and 35,176 trucks respectively. Thus, the model was applicable because the p-value was greater than 0.05 (confidence interval value 95%) as shown in Table 5.

## 3. Results

Experimental parameters were obtained from preliminary tests. The parameter settings of the simulation models were set at 5 replicates as determined from the half width at a confidence interval 95%. The warm-up period was seven days, replication length was 73 days, 24 hours/day, and time was measured in hours, since these parameters are used in the database of the real system. The results represent the average of a vehicle's time in the system and the average number of trucks leaving the system. These values were compare to observations in the mill yard under study. The original model and alternative configurations (proposed model 1 and proposed model 2) are shown in Table 6.

*3.1 Original model of the mill yard system (Current situation)*

The observations of the current system showed that the average vehicle's time in the system was 10.92 hours and the average number of trucks leaving the system was 34,093 trucks/crop year. The original model showed the average vehicle's time in the system was 10.18 hours and the average number of trucks leaving the system was 35,188. Therefore, this model can be used as a representative of the real system, because the p-value is 0.0547, which is greater than 0.05 (confidence interval of 95%) as shown in Table 6.




Note: Type of cane grower: Type I: the internal zoning ( ● ), Type II: external zoning and special case ( ■ , ▲ )
Type of vehicle: Truck ( ● ■ ▲ ), Trailer ( ○ □ △ ) Station each process ( ▭ )

**Figure 8** The management of a mill yard system comparing the actual system and alternative configurations (proposed model 1 and proposed model 2)

**Table 6** Summary of performance measure between original model and alternative configuration models

| Key performance index | Observed | Original model | Alternative configuration models | |
|---|---|---|---|---|
| | | | Proposed model 1 | Proposed model 2 |
| | (A) | (B) | (C) | (D) |
| - $TIS_i$ | 10.92 | 10.18 | 9.31 | 9.02 |
| - $NO_i$ | 34,093 | 35,188 | 35,257 | 35,303 |
| - *p-value* | 0.0547 (Comparison A&B) | | 0.0472 (Comparison C&D)) | |

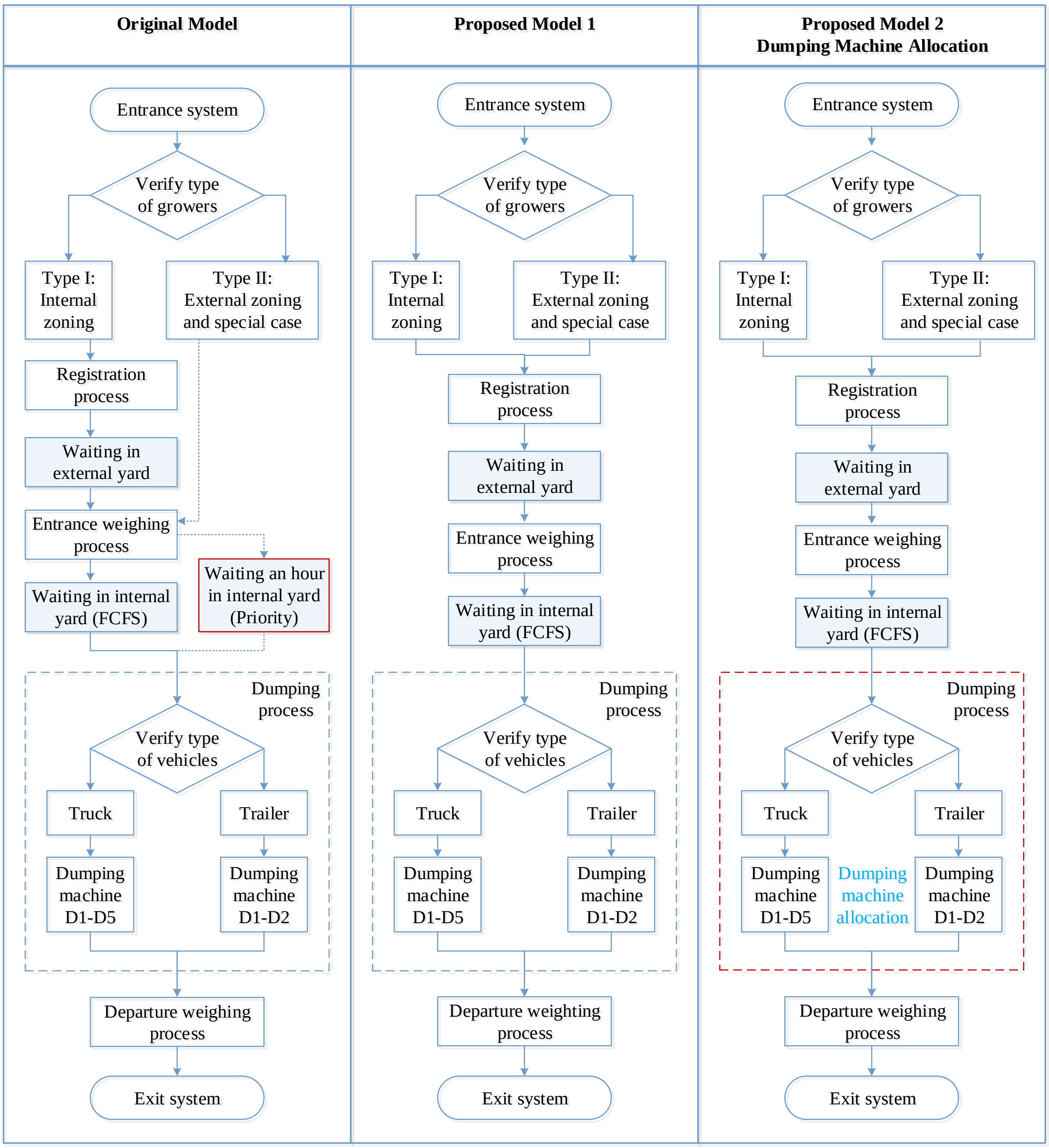



**Figure 9** Simulation model flowchart of original model and alternative configuration model at the mill yard (proposed model 1 and proposed model 2)

*3.2 Alternative configurations*

*3.2.1 Proposed Model 1: the registration process development (FCFS based)*

In this section the proposed model, the registration process was developed based on a FCFS queue discipline pattern. The results of proposed model 1 showed the average vehicle's time in the system was 9.31 hours and the average numbers of trucks leaving the system was 35,257.

*3. 2. 2 Proposed model 2: dumping machine allocation (depending on the type of sugarcane growers)*

This model was developed from proposed model 1: the registration process development (FCFS based). The results of proposed model 2 show the average vehicle's time in the system was 9.02 hours and the average numbers of trucks leaving the system was 35,303.

The p-values of proposed model 1: registration process development (FCFS based) and proposed model 2: dumping machine allocation (depending on the type of sugarcane growers) is 0.0472 which is less than 0.05. Thus, the alternative configuration models (the proposed model 1 and the proposed model 2) were significantly different (confidence interval of 95%).

Results from the simulation models were analyzed. The advantages and disadvantages of the original model and the alternative configurations with details are shown in Table 7. Additionally, the analysis of the models can be applied to strategies or policies of the sugar mill, leading to implementation and further development of the mill yard management system.

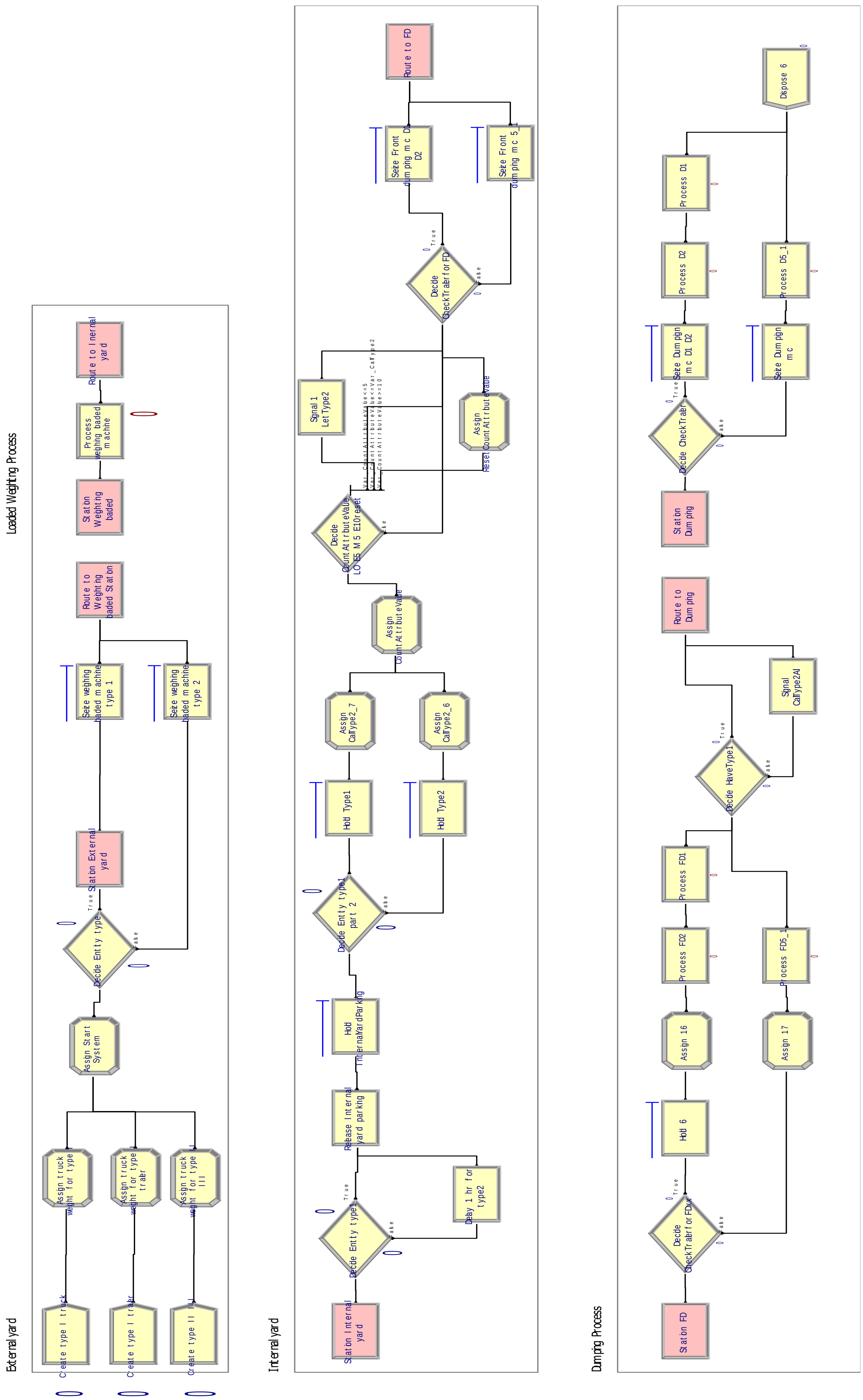



**Figure 10** Original model and alternative configuration model at the mill yard by Arena 11.0 software

**Table 7** Advantage and disadvantage of the original model and alternative configurations

| Analysis | Original model | Alternative configuration models | |
|---|---|---|---|
| | | **Proposed model 1** | **Proposed model 2** |
| Advantage | - Sugar mill strategy for continuous raw material flow (Priority)[(2)] | - Sugarcane grower equality (FCFS)[(1)]<br>- Growers of all types know the queuing status before dumping.<br>- The registration process data base was recorded for all grower types.<br>- Average vehicle time in system decreased (Constant dumping machine allocation ratio) | - Sugarcane grower equality (FCFS)[(1)]<br>- Growers of all types know the queuing status before dumping.<br>- The registration process data base was recorded for all grower types.<br>- Average vehicle time in system decreased (Dynamic dumping machine allocation ratio) |
| Disadvantage | - Sugarcane grower inequality (Priority)[(2)]<br>- Grower Type II: the external zoning and special case don't know the queuing status before dumping.<br>- The registration process data base was recorded only for grower Type I: the internal zoning.<br>- Average of vehicle time in system (Constant dumping machine allocation ratio ) | - Sugar mill strategy for continuous raw material flow (FCFS)[(1)] | - Sugar mill strategy for continuous raw material flow (FCFS)[(1)] |

Note: [(1)] First come first served all grower types
(grower type I: the internal zoning and grower type II: external zoning and special case)
[(2)] Priority only grower type II: external zoning and special case

## 4. Discussion and conclusions

This research focused on the last operation of the inbound logistics section in the sugarcane industry supply chain and logistics, i.e., the mill yard management operation. The analysis was done by considering the registration process, the entrance weighing process, the dumping process, and the departure weighing process under the limitations of the current mill yard management system. These constraints deal with the types of cane growers, types of vehicles, and the policy for dumping machine allocation, which were all of limiting factors depending on the particular sugar mill management system. This sugar mill case study was in the central region of Thailand and supported 500 grower members and 2,500 fields. Simulation techniques were applied for process improvement of the sugar mill yard management system using Arena software 11.0. The aim was to decrease the time in the system for sugarcane vehicles. Two alternative scenarios were proposed: *proposed model 1: registration process development* and *proposed model 2: dumping machine allocation*. The results show that the average vehicle's times in the system for proposed model 1 and proposed model 2 were shorter than the original model by 0.87 hours (52.2 minutes, 8.55%) and 1.16 hours (69.6 minutes, 11.39%), respectively. The average truck numbers leaving the system of the proposed models was greater than the original model by 69 trucks (0.20%) and 115 trucks (0.33%), respectively, as shown in Table 6. Since grower Type I, in the internal zone, was not waiting for Type II growers, the external zone and special cases at the registration and dumping processes, the time in the system decreased and the average truck numbers increased, leading to higher sugarcane quality and higher grower revenue. The simulation models were run for five replications. The warm-up period was seven days, replication length was 73 days, 24 hours/day, and the base time unit was an hour. Moreover, reducing the vehicle's time in the system at the mill yard can give benefits and advantages to all stakeholders in the supply chain. The growers can obtain higher revenue from better quality sugarcane, higher weight and high CCS, while the sugar mill receives higher quality of sugar in terms of weight and CCS. Lastly, the vehicle's owner realizes higher vehicle utilization. [13] considered most operations of inbound logistics from harvest, transportation, until unloading sugarcane at the mill yard They focused on environmental conditions, the effect of the policy, and the impact of the new arrangements in the mill yard on time in the system for sugarcane vehicles and amount of unloaded sugarcane. The best new arrangement in the mill yard was change of layout in the unloading area, which could reduce time in system by 33% but increased the amount of unloaded sugarcane by 0.02%. [11] improved the system using simulated models to increase machine utilization, which involved a reduction in the amount of machinery without increased time in the system. [12] applied discrete simulation techniques to study sugar mill reception area processes and policies for its operation, which aimed to increase the amount of sugarcane unloaded. The percentage improvement of the [13] results was more than in the current study, but this research changed only the process management, and did not consider the cost of implementation, so it did not affect sugar mill policy and technical parameters. However, a significant investment was required to complete the analysis. Additionally, this research should consider other physical factors such as environmental, policy, social and cultural factors, project feasibility, economics and financial evaluations to complete the analysis. Finally, all researchers showed simulation models that are appropriate and could be implemented in their sugar mill case study. All their alternative configurations affected processing time, time in the system, amount of sugarcane unloaded, or the key performance indices (KPI) that were of interest and had a large impact on the system. However, as the mill yard management process was the last process of the inbound logistics, future research should also consider the harvesting and transportation, as well as including machine breakdown for realistic systems. Other sugar mills may not be able to apply this simulation directly, but the principles of model improvement can be applied in the mill yard management system. This case study as a prototype to improve the system of the facility under study that can be implemented and extend the result to large-scale industry. As an academic contribution, the simulation technique was applied to solve a problem in a real case study for decision making, to reduce risk and uncertainty factors of conducting real-world experiments. Using simulation allows what-if analysis and the use of scheduling theory. Moreover, the approach adopted by this study can be further developed and applied to similar industries to improve the performance of complex production systems.

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