

A Two-stage Stochastic Programming Model for Districting and Transportation Lot-size of Sugarcane

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Abstract—The transporting sugarcane from cane fields to a mill factory is a potential cost in sugarcane logistics. The poorly operating vehicle (six-wheel truck) services and transportation lot size results in lost or excess of cane supplied. In this paper, we consider the integrated districting problem of whole cane field region and transportation lot size of each cane field. We formulate the combining two problems as two-stage stochastic model. The sugarcane yield in harvesting season is a random variable with known discrete distribution. The first stage, we determine the districts for each cane field zone. After, the harvesting sugarcane realized the second stage we make decision for transportation lot size. We formulate the transportation lot size as mixed integer programming model under a finite horizon during harvesting season of sugarcane. The optimal approach is based on the scenario-based method. The objective is to minimize the expected overall cost integrated two stages. We investigate the model based on generating data. Numerical results indicate that the model provides different optimal solution based on scenarios.

Keywords—Sugarcane; Districting problem; Lot sizing problem; Two – stage stochastic programming model

I. INTRODUCTION

Sugar is large quantity export of goods in Thailand. The large fields of sugarcane are grown in the northeast of Thailand. Most sugar factories are located at particular regions surrounding the sugarcane fields. Currently, the international sugar market is serious competition because of the low price of suger from many contries, such as Brazil, Australia and Cuba. The goal of sugar production systems is to obtain raw material from suppliers, deliver goods to customer on-time and minimize transportation and production cost of systems. Most sugarcane is raw material to supply to sugar industries in a supply chain system. The cost of transportating sugarcane is alternative to reduce the sugar price. The major cost of sugar supply chain is transporting sugarcane from cane fields to the mill facilities. Pongwanich-anan [1] showed the 21.91% of production cost according to sugarcane transportation cost. Traditional transporting sugarcane in Thailand, we delivered the harvesting sugarcane in a small lot size to mill facilities by using farm truck or six-wheeled truck. The small tons of transporting sugarcane to nearby mill by using farmer's vehicles, resulting in large transportation cost, complex production control and unbalance using trucks. One possible way to impose delivery time and lot size of sugarcane to mill is to partition whole sugarcane field region into small districts (sub-area). Each sub-area is grouped of nearby cane field zones, where each cane field zone consistes of grouping square of sugarcane fields area. Each sub-area (district) operates under a particular strategy. The transportation lot size strategy and high-technology to cutting-cane have been introduced and implemented in order to reduce transportation cost of sugercane delivery to mill facilities. These operate by logistic teams of mill facilities. Decision of transportation lot size to mill facilities can be scheduled, resulting in more efficiently of trucks (utilization), balancing utilization of trucks and less transportation cost. Delivery of sugarcane from fields to mill facility operates under sub-area (district) and transportation lot size policies.

Decisions regarding incorporated the sub-area (district) and the transportation lot size strategies could be improved by imposing the delivery on-time and sugarcane lot size, considering the capacity of truckloads. This transporting sugarcane problem is modeled as a two-stage stochastic programming under uncertainly. The decision of first stage is how to partition whole sugarcane field region into a sub-area (district). Decision variable is the district of each cane field zone. The district problem of cane fields zone refers to partition whold sugarcane field region into small sub-areas (district), given that the system has a fixed number and location of vehicles. We consider a sigle type of vehicle (six-wheeled truck). We consider an intra-district, which does not allow a truck to cross districts. Each sub-area transports sugarcane from cane fields zone to a mill facility using the particular trucks which located in the same districts. We determine the sub-area before the uncertain parameters realized, which are the havesting sugarcane of each cane field zone for each period though planing horizon accounting to known discrete distribution. Once the random of havesting sugarcane presents themselves for each cane field zone. The logistic team can make decision of the second stage variables in which corresponding to the havesting sugarcane quantity realized for each period. The decision of second stage is to determine the transportation lot size of each cane field zone from fields to mill facilities and holding units, which kept sugarcane at their's fields for each period though planning horizon. do that for you.

The contribution of this paper is to determine the district, identify the particular truck for each cane field zone and analyze the transportation lot size for each cane field zone for each period, resulting in more efficient utilization of trucks, balancing utilization of trucks. The objective is to minimize the expected total cost, which are setup cost (events: cutting cane and load-unload sugarcane to trucks), holding cost per period, transportation cost (depending on distances between location of a truck and distance from cane field to mill facility) and operation cost per ton of sugarcane. In this study we:

- Develop a two-stage stochastic programming model for incorporated sub-area (district) and transportation lot size policies, given the number of districts, fixed locations and number of trucks.
- Propose an optimal solution of two-stage decision variables to determine the minimum overall expected cost. Show, through the numerical results based on generating small data, where harvesting yield of each cane field zone per period according to known discrete distribution.

This paper is organized as follows. In Section 2 we present an literature review of districting problem and transporting sugarcane problem. Section 3 we develop the two-stage stochastic programming model for incorporated sub-area (district) and transportation lot size strategies. Section 4 we show the numerical results and discussion of the optimal solution approached. Finally, Section 5 we present the conclusion and discussion of future research.

II. LITERATURE REVIEW

The study related to operation of sugarcane logistics to the mill factory. First we categorized related work by characteristic problems (e.g. transporting sugarcane, districting, and stochastic transporting lot size) being described.

Most of significant work had been proposed transporting sugarcane in harvesting season. Diaz and Perez [2] considered transporting sugarcane system in order to minimize a limited resource allocations using simulation. Higgins et al. [3] improved a value chain of harvesting sugarcane and transportation system. They build several models of harvesting sugarcane and transportation system, accounted for financial transfers, and analyzed scenarios with case study. In addition, Milan et al. [4] presented the transporting sugarcane to mill factory under various constraints using a mixed integer linear programming model. They considered scheduling of road transportation, cutting tasks and vehicle routing to minimize overall cost. Grunow et al. [5] investigated the production of sugarcane. The aim was operating system at a constant production rate, in which depended on preserving supply rate. They determined the cultivation and harvesting planning. The approach developed to supply chain of sugarcane operation system by Piewthongngam et al. [6]. They introduced cultivation planning, harvest scheduling into model using a mathematical programming in order to maximize the expected overall sugar production. In addition to location problem, Khamjan et al. [7] proposed the location of the sugarcane loading station problem. They allocated cane fields to each loading stations to minimize overall cost, including the investment, the transportation and the loss production cost. However, most of previous transporting sugarcane works considered a whole cane field region into model using limited trucks to transport sugarcane from cane fields to mill factories. The limited transportation time is important for implementation of sugarcane operation model. Therefore, the decisions regarding transportation could be developed by imposing a limitation on travel time from truck locations to each cane field. We consider districting strategy to improve the transportation system of sugarcane.

Initially study described in districting problem, Hess et al. [8] address the service area of police patrol system into small sub-areas. They formulated a model using an integer programming model. Gass [9] extended the model using heuristic for police patrol system. A few studies have investigated the overall travel time while considering workload balance (i.e., Marlin [10]). Fleischmann and Paraschis [11] presented the districting problem of sales territories. The aim of study was to minimize the total scores of products according to distances between center coordinate and center locations of sales territories. Hojati [12] considered the political districting problem using splitting problem to solve the problem. Iannoni et al. [13] presented two combined configuration of the location and districting problems into model bases along emergency medical service (EMS) system on highway. Recently, Bandara [14] improved the performance of EMS system by applying the combination of dispatching and districting strategies. He formulated the integer programming model of the districting problem given known locations of ambulances and number of districts.

Traditional approaches to this stochastic lot size involved with scheduling production. This problem considered multiple products with random demand that had limited capacity of resources. Sox et al. [15] proposed the survey of research dealing with the stochastic lot scheduling problem. Beraldi et al. [16] analyzed the parallel machine lot-sizing with uncertain situation. They formulated model based on scenario-based planning. Another related work dealing with a two-stage stochastic model for transportation, Liu et al. [17] considered the transportation network protection models. They determine the allocation of resource over multiple highway bridges. Winands [18] presented a survey of the stochastic economic lot scheduling model. This survey focuses on the production problems. Most previous researches of stochastic lot size ignored the transportation lot size aspect to district problem. This idea could impose delivery time and lot size of sugarcane to mill, resulting in balancing utilization of transportation trucks.

In this paper, we address the application of districting problem for transporting sugarcane problem. We extend the districting problem proposed by Bandara [14]. The modification determines the integrated districting and lot size problems in order to minimize the expected overall cost for transporting sugarcane problem. Moreover, our work differ the previous study in that we consider the realistic system accounting to probability of sugarcane yield occurring after we made decision for districting problem.

III. DESCRIPTION OF MODEL

Given the characteristics of realistic transporting sugarcane from the cane field zones to mill facilities, we incorporate sub-area (district) and transporation lot size strategies. The model is formulated using the assumptions given below. do that for you.

- We group a square of sugarcane fields into each cane field zone.
- Each cane field zone $i, i = 1, 2, \dots, n$ is located surrounding the mill facility. We consider the transporting sugarcane system with a single vehicle type (six-wheeled truck) $j, j = 1, 2, \dots, J$.
- Before harvesting sugarcane season coming, we analyse the system in which whole sugarcane field region is partitioned into sub-areas (districts) $k, k = 1, 2, \dots, K$. We have been grouping cane field zones to districts.
- We know the number of districts and the number of vehicles and their locations.
- The decision of this first stage (FS) is how to determine the district for each cane field zone given a fixed number of trucks and their locations, prior to tons of harvesting sugarcane yield realized.
- We define a finite set $z = (z_{1k}, \dots, z_{ik}, \dots, z_{nk})$, where we allocated the cane field zone i at district k . Each cane field zone i is operated under particular policy at same district k .
- There is a finite set $x = (x_{1k}, \dots, x_{jk}, \dots, x_{Jk})$, where we allocated the truck j at district k . Each truck j transports tons of sugarcane from particular cane field zones in its same district k .
- There is a finite set $y = (y_{11k}, \dots, y_{ijk}, \dots, y_{njk})$, where we assign the vehicle j to transport sugarcane from the cane field zone i at district k to the mill facility. Each cane field zone i is used particular truck s , which allocated in its same district k .
- Each period $t, t = 1, 2, \dots, T$, the tons of sugarcane need to transport to satisfy capacity of the mill factory.
- After harvesting sugarcane yield realized, each period $t, t = 1, 2, \dots, T$, the harvesting sugarcane of each cane field zone i have been its random tons of harvest, set $Q = (Q_{1t}, \dots, Q_{it}, \dots, Q_{nt})$, and expressed in term of tons per time period t in which harvesting sugarcane is yield. We define a finite set of scenario $l, l = 1, 2, \dots, L$, where a likelihood of the scenario l follows an arbitrary discrete distribution, ξ_l .
- The second stage (SS), we determine recourse action or decisions of transportation lot size, $q(q_{1t}, \dots, q_{it}, \dots, q_{nt}, Q_{1t}, \dots, Q_{it}, \dots, Q_{nt})$ and holding units (keeping at cane field zones), $h(h_{1t}, \dots, h_{it}, \dots, h_{nt}, Q_{1t}, \dots, Q_{it}, \dots, Q_{nt})$ for each cane field zone i , the optimal lot size and holding units of each cane field zone and each period given the first stage decision variables x, y, z and a scenario ξ_l of the random variables Q .

We formulate a model using a two-stage stochastic programming model. We consider the method of the scenario based approach, where known the random variables of harvesting sugarcane as discrete distribution. In the first stage, the decision is made at once particular time of starting planning time. We formulate the second stage model using a mixed integer programming model as a finite horizon. The objective is to minimize overall expected cost, including transportation cost, setup cost (cutting-cane and load-unload cane to trucks), production cost and holding cost. The process flow of the incorporation of sub-area (district) and transporation lot size strategies shown in figure 1 as following.

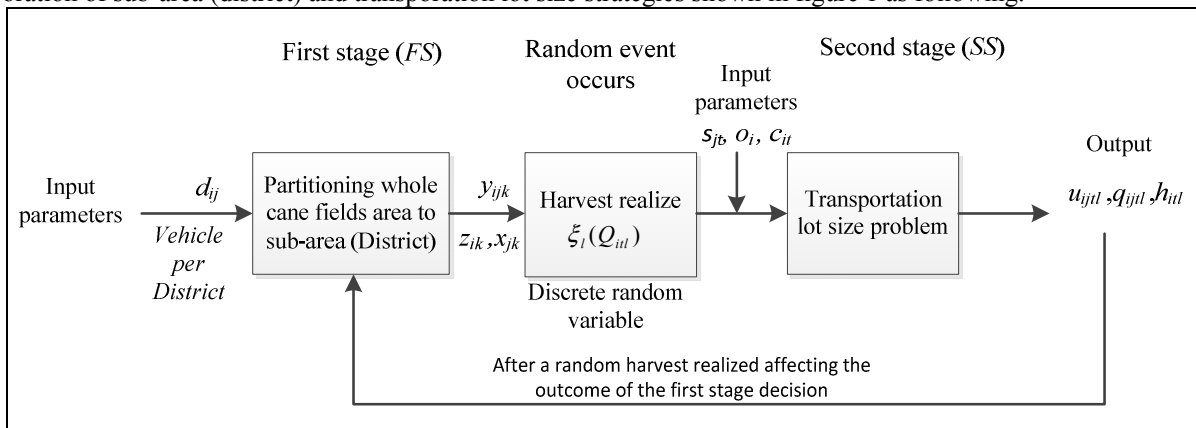


Figure 1. The process flow of the incorporating the sub-area (district) and the transporation lot size model

A. Notation

The model is formulated using the notation below:

1) Indices

n	number of cane field zones
J	number of trucks
K	number of districts
T	number of time periods
L	number of scenarios
i	cane field zone index as $i = 1, 2, \dots, n$
j	existing truck index as $j = 1, 2, \dots, J$
k	district index as $k = 1, 2, \dots, K$
t	time period as $t = 1, 2, \dots, T$
l	scenario index as $l = 1, 2, \dots, L$
$BigM$	a large integer number
VPD	number of trucks per district
COV	capacity of each truck
COF	delivery quantity of sugarcane required per period below:

2) Parameters

d_{ij}	transportation cost of cane field zone i to mill factory by truck j
s_{jt}	setup cost per time (fixed cost) of truck j at time period t , where consist of load-unload cost and cutting cane cost
o_i	production cost per ton of sugarcane of cane field zone i
c_{it}	holding cost per ton of sugarcane of cane field zone i at time period t
Q_{itl}	quantity of harvesting sugarcane of cane field zone i in time period t , if the scenario l occurs
ξ_l	probability of the scenario l occurs
VPD	the minimum number of trucks per district
COF	required tons of transporting sugarcane to mill factory per time period
COV	capacity of a truck (tons) notation below:

3) Decision variables

z_{ik}	1 if we allocate cane field zone i to district k 0 otherwise
x_{jk}	1 if we allocate truck j to district k 0 otherwise
y_{ijk}	1 if the cane field zone i and truck j are allocated to same district k 0 otherwise
u_{ijtl}	1 if we transport sugarcane of cane field zone i by vehicle j at time t , when the scenario l occurs 0 Otherwise
q_{ijtl}	quantity of sugarcane, which transport by truck j at time t , when the scenario l occurs
h_{itl}	holding units (tons) of cane field zone i , kept at its field at the end of time period t , where the scenario l occurring
f	optimal value

B. Mathematical model

The proposed model can be used to determine the problem of how to partition the whole sugar field region to small sub-area. However, we consider on probability of sugar yield from each cane field zone after harvesting occurs. We focus on limited trucks risk to transport lot size for each cane field zone to mill factory. We consider a single type of vehicle (six-wheeled truck). The problem is stated as how many of transportation lot size for each period given district constraints and likelihood of harvesting yield realized. We formulated the model as the two-stage stochastic programming model; the first stage of district problem is to make decision before the harvesting occurs, while the second stage is to evaluate the total cost of transportation lot size due to a realized harvest. The second stage cost (recourse cost) is random variable dependent on the first stage district decision and the particular realized scenario for each cane field zone. The minimum overall expected cost is determined with respect to the random variables of harvest sugarcane yield occurring. The mathematical model is formulated as follow:

$$f = \min \sum_{i=1}^n \sum_{j=1}^J \sum_{k=1}^K d_{ij} y_{ijk} + \sum_{l=1}^L \xi_l \left(\sum_{i=1}^n \sum_{j=1}^J \sum_{t=1}^T s_{jt} u_{ijt} + \sum_{i=1}^n \sum_{j=1}^J \sum_{t=1}^T o_i q_{ijt} + \sum_{i=1}^n \sum_{t=1}^T c_{it} h_{it} \right) \quad (1)$$

Constraints

(FS)

$$\sum_{j=1}^J \sum_{k=1}^K y_{ijk} \geq 1 \quad \forall i \quad (2)$$

$$\sum_{k=1}^K x_{jk} = 1 \quad \forall j \quad (3)$$

$$\sum_{j=1}^J x_{jk} \geq VPD \quad \forall k \quad (4)$$

$$y_{ijk} \leq z_{ik} \quad \forall i, j, k \quad (5)$$

$$y_{ijk} \leq x_{jk} \quad \forall i, j, k \quad (6)$$

$$z_{ik} + x_{jk} - y_{ijk} \leq 1 \quad \forall i, j, k \quad (7)$$

$$\sum_{k=1}^K z_{ik} = 1 \quad \forall i \quad (8)$$

$$x_{jk} \in \{0, 1\}, y_{ijk} \in \{0, 1\}, z_{ik} \in \{0, 1\} \quad (9)$$

(SS)

$$h_{itl} = h_{it-1,l} + Q_{itl} - \sum_{j=1}^J q_{ijt} \quad \forall i, t, l \quad (10)$$

$$Q_{itl} \geq \sum_{j=1}^J q_{ijt} \quad \forall i, t, l \quad (11)$$

$$q_{ijt} \leq \text{Big}M(u_{ijt}) \quad \forall i, j, t, l \quad (12)$$

$$q_{ijt} \leq \text{Big}M\left(\sum_{k=1}^K y_{ijk}\right) \quad \forall i, j, t, l \quad (13)$$

$$\sum_{i=1}^n \sum_{j=1}^J q_{ijt} \geq COF \quad \forall t, l \quad (14)$$

$$\sum_{i=1}^n q_{ijt} \leq COV\left(\sum_{k=1}^K x_{jk}\right) \quad \forall j, t, l \quad (15)$$

$$q_{ijt} \geq 0 \quad \forall i, j, t, l \quad (16)$$

$$h_{itl} \geq 0 \quad \forall i, t, l \quad (17)$$

$$u_{ijt} \in \{0, 1\}, q_{ijt} \in \{\text{int}\}, h_{itl} \in \{\text{int}\} \quad (18)$$

The minimum expected overall cost of the sub-areas (districts) and transportation lot size model under uncertainty is formulated as two-stage stochastic programming model. The objective function is total cost of transportation cost, setup cost, production cost and holding cost as shown in equation (1). The equation consists of transportation cost, which is the product of the decision variable y_{ijk} and distance d_{ij} (distance cost between truck station j and cane field zone i adding distance cost between cane field zone i to sugar mill), adding the products of the probability of the scenario ξ_l and the total cost of the second stage decision. The second stage costs are setup cost, production cost and holding cost. The setup cost is the product of setup cost per time s_{jt} and the decision variable u_{ijt} . There is production cost, which is the product of production cost per ton of sugarcane and the decision variable transportation lot size q_{ijt} . The holding cost is product of holding cost per unit c_{it} (kept in cane field zones) and the decision variable h_{itl} .

The constraints of the first stage, constraint (2) ensures that each cane field zone i be allocated at least one of district k and be transported by at least one of truck j . Constraint (3) requires that each truck j be assigned to only one district k . Constraint (4) specifies the minimum number of trucks allowed at any district. Constraint (5) ensures that if we allocate cane field zone i to district k , we can assign the truck j to transport harvested sugarcane from cane field zone i to mill, when the truck j is assigned to district k . Similarly, constraint (6) ensures that if we assign the truck j to transport harvested sugarcane from cane field zone i , we can allocate cane field zone i and the truck j to the same district k . Constraint (7) guarantees that if the cane field zone i and the truck j are allocated to the same district k , the truck j requires to transport harvested sugarcane of cane field zone i to sugar mill. Condition (8) ensure that we allocate the cane field zone i to only one district k . Constraint (9) requires that the decision variables x_{jk} , y_{ijk} and z_{ik} are integer of 0 or 1.

The constraints of the second stage, constraint (10) calculates the holding units at the end of time period t dependent on the harvested sugarcane realized on each scenario l . Condition (11) ensures that total transportation lot size of cane field zone i is limited by harvested sugarcane of cane field zone i after yield realized on each scenario l . Constraint (12) requires that if the transportation lot size from cane field zone i is greater than zero, there is setup cost of cutting cane and load-unload sugarcane at cane field zone i occurs. Similarly, constraint (13) ensures that if the transportation lot size from sugarcane i in time period t is greater than zero, we assign truck j to transport sugarcane from cane field zone i , where i and j being in the same district k . Condition (14) requires the minimum total tons of transporting sugarcane to mill factory. Condition (15) specifies the minimum of tons of transporting sugarcane per truck. Constraint (15) and (16) requires that the decision of transportation lot size and the holding units of the cane field zone i is non-negative integer. Constraint (9) requires that the decision variable u_{ijt} is integer of 0 or 1 and, the decision variables q_{ijt} and h_{it} are integer.

IV. NUMERICAL RESULTS

A. Generating Data

In this section, we show the results of our model based on random generating data. We partition the whole sugarcane field region into 8 small field areas called cane field zone. We consider a number of trucks of 4, where are fixed their locations. The map of the whole sugarcane field area shows in Figure 2. The generating data consists of transportation cost, where is the distance cost of pair each cane field zone and each truck station, the setup cost per time for each truck for each time period, production cost per unit of each cane field zone shown in Table 1.

TABLE I. THE DATA OF TRANSPORTATION COST

Cane field zone (i)	Truck				Production cost per unit
	$j=1$	$j=2$	$j=3$	$j=4$	
1	18	2	35	16	3
2	17	2	33	14	4
3	16	2	34	15	2
4	15	5	32	13	4
5	14	2	31	11	5
6	13	4	29	10	3
7	15	2	32	14	3
8	14	2	31	12	2

TABLE II. THE QUANTITY OF HARVESTING SUGAR (TONS) OF EACH CANE FIELD ZONE FOR EACH TIME PERIOD

Cane field zone (i)	Time period								
	$t = 1$			$t = 2$			$t = 3$		
	Scenario $l = 1$	Scenario $l = 2$	Scenario $l = 3$	Scenario $l = 1$	Scenario $l = 2$	Scenario $l = 3$	Scenario $l = 1$	Scenario $l = 2$	Scenario $l = 3$
1	630	700	770	495	550	605	450	500	550
2	576	640	704	405	450	495	450	500	550
3	675	750	825	360	400	440	423	470	517
4	495	550	605	342	380	418	450	500	550
5	693	770	847	423	470	517	468	520	572
6	585	650	715	360	400	440	432	480	528
7	666	740	814	342	380	418	405	450	495
8	585	650	715	351	390	429	495	550	605

We generate the quantity of harvesting sugar (tons) of each cane field zone for each time period presented in Table 2. The Table 2 show the harvesting yield of sugar cane after made decision of districting problem. The data in Table 2 present the tons of sugar cane based on scenarios and time period. The setup cost, and holding cost of each cane field zone Table 3 and Table 4, respectively.

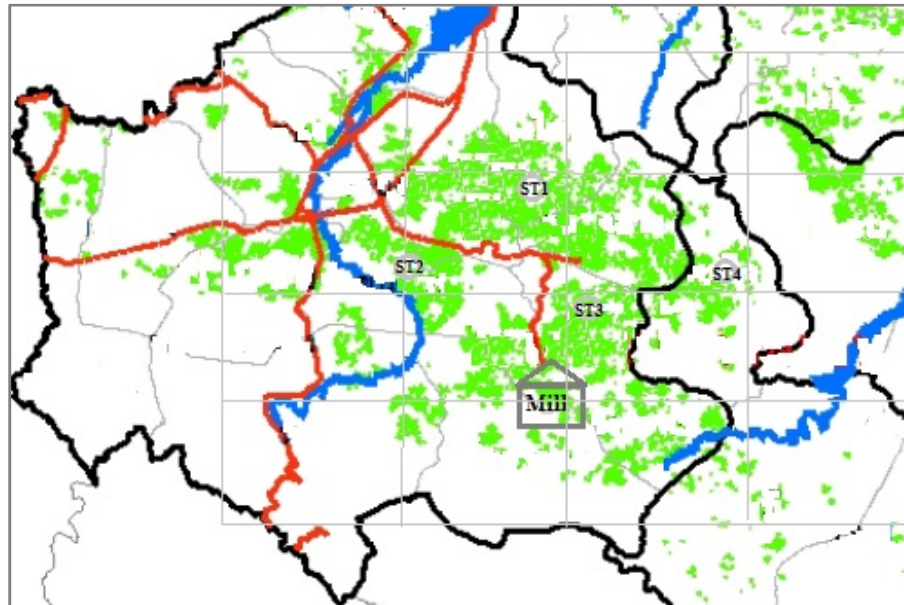


Figure 2. Small case study

TABLE III. THE DATA OF THE SETUP COST PER TIME

Truck (<i>j</i>)	Time period		
	<i>t=1</i>	<i>t=2</i>	<i>t=3</i>
1	4000	10000	13000
2	15000	20000	24000
3	4000	11000	12000
4	6000	11000	14000

TABLE IV. THE DATA OF HOLDING COST PER UNITS

Cane field zone (<i>i</i>)	Time period		
	<i>t=1</i>	<i>t=2</i>	<i>t=3</i>
1	2	3	4
2	2	3	4
3	1	4	5
4	1	4	5
5	2	4	5
6	2	3	4
7	1	4	5
8	2	3	4

The capacity required of sugar mill per time period is equal to 3,000 tons. The capacity of each truck is equal to 1,500 tons. We generate a probability of occurring scenario for each time period presented in Table 5.

TABLE V. THE PROBABILITY OF SCENARIO OCCURRING

ID	# of Scenario	Probability of Scenarios		
		$l=1$	$l=2$	$l=3$
A	3	0.333	0.333	0.333
B	2	0.65	0.35	-

We investigate the optimal solution of incorporating sub-area (district) and transportation lot size policies based on generating data above. The results shown in Section 4.2.

B. Results and Discussion

The approach considers the random space of the scenarios as discrete distribution. The discrete distribution of occurring scenarios with a finite number L of possible harvesting yield accords to the probability ξ_l shown in Table 5. The model could be formulated as mixed integer programming equivalent problem. We programed in IBM ILOG CPLEX Optimization Studio 12.5. According to generated data in Section 4.1 we consider the number of time period of 3. We define the number of districts of 2. The minimum of number of truck per district is equal to 1. We run the model until providing the optimal solutions. The running time of size of problem 3 scenarios to find the optimal policy for each scenario was 36 hours 2 minutes and 21 seconds, while size of problem 2 scenarios spent running time only 2 hours 54 minutes and 2 seconds.

TABLE VI. THE COMPARISON OF THE DISTRICTING AND STOCHASTIC MODEL AND THE NON-DISTRICTING AND DETERMINISTIC MODEL

ID	# of scenarios	Probability scenario occurring	Districting & Stochastic harvesting yield	Non-Districting & harvesting yield based on the 1 th scenario	Deviation
			E(Total cost)	E(Total cost)	
A	3	(0.33, 0.33, 0.33)	232,869.33	242,530.00	9,660.67
B	2	(0.65, 0.35)	118,411.38	226,255.00	107,843.62

TABLE VII. SOLUTIONS OF HOW TO ALLOCATE CANE FIELD ZONE AND TRUCKS TO DISTRICTS

ID	# of scenarios	Probability scenario occurring	Cane field zone	District	Truck
A	3	(0.33, 0.33, 0.33)	1	2	3,4
			2	1	1,2
			3	1	1,2
			4	2	3,4
			5	2	3,4
			6	1	1,2
			7	2	3,4
			8	1	1,2
B	2	(0.65, 0.35)	1	1	2,3
			2	2	1,4
			3	2	1,4
			4	1	2,3
			5	1	2,3
			6	2	1,4
			7	2	1,4
			8	2	1,4

Note in Table 6 that, we show the comparison of the district and stochastic model and the non-district and deterministic model based on the optimal of the expected overall cost. The results indicate that the of the district and stochastic model

provides lower expected total cost than the non-district and deterministic model. The reasons are that the non-district and deterministic model considers a single harvesting yield situation in which might be made decisions different from realistic situation after harvesting yield realized. Moreover, non-district and deterministic model might be provided more unbalancing truck utilization because the optimal solution might choose nearby trucks first and ignores faraway trucks. This made much loads for nearby trucks and less loads for faraway trucks. The implementing policy, we partition the whole sugarcane region into 2 districts following the optimal solution in Table 7. The decision of lot size planning is made after harvesting yield realized depending on the scenarios. The results in Table 8 show the optimal solution of a lot size problem. The results show that the expected overall cost and solutions depend on the number of scenarios and the probability of scenario occurring. In addition, when we consider the size of problem 3 scenarios, the resulting optimal policies are different the size of problem 2 scenarios in allocating cane field zone and trucks to districts.

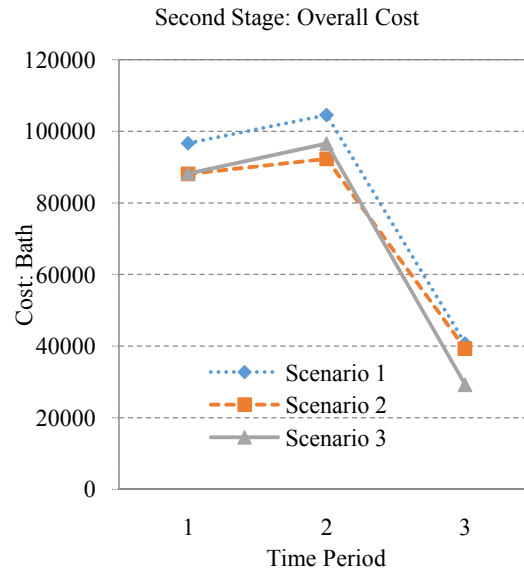


Figure 3. The second stage cost based on scenarios

Behavior of overall cost in the second stage as affected by harvesting yield realized, scenarios are shown in Figure 3. Notice that optimal overall cost in the second stage for different scenarios where provided different optimal lot sizes. In Figure 3, the overall cost in the second stage in period 2 would result in greater cost than others. Moreover, the results indicate that if scenario 3 realized would provide the lower cost in period 1 and 3 and scenario 2 would provide the lower cost in period 2. Then, these results would be benefits for operating in period of the cultivation season.

TABLE VIII. SOLUTIONS OF TOTAL EXPECTED OVERALL COST AND HARVESTING LOT SIZE BASED ON 3 SCENARIOS WITH PROBABILITY SCENARIO OCCURRING (0.33, 0.33, 0.33)

ID	E(Total cost)	Cane field zone	Scenario $l=1$			Scenario $l=2$			Scenario $l=3$		
			period $t=1$	period $t=2$	period $t=3$	period $t=1$	period $t=2$	period $t=3$	period $t=1$	period $t=2$	period $t=3$
A	232,869.33	1	630	495	450	700	550	500	0	605	550
		2	0	405	0	0	450	0	0	0	0
		3	675	360	423	750	400	470	825	440	517
		4	0	342	450	0	380	500	0	418	455
		5	693	423	345	770	470	500	686	517	0
		6	0	360	432	0	0	480	0	440	378
		7	666	342	405	740	380	0	814	418	495
		8	585	351	495	650	390	550	675	429	605

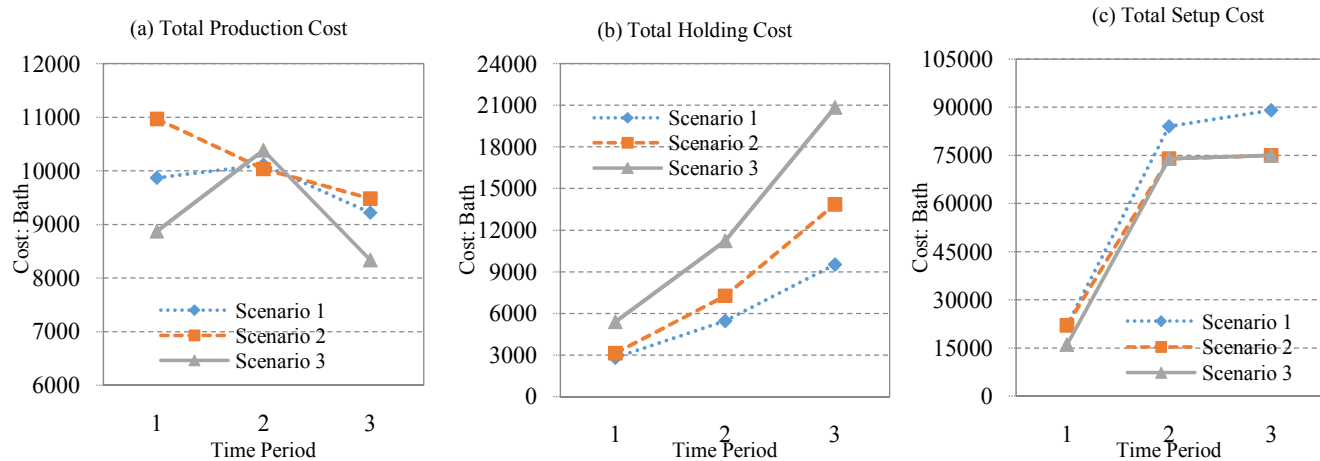


Figure 4. The second stage cost consists of production cost, holding cost and setup cost based on scenarios

In Figure 4 show the separated costs for the second stage cost: production cost, holding cost and setup cost. The results in Figure 4 (b) indicate that the scenario 3 provides higher holding cost rather than the others. This implied that we would keep sugarcane long periods at cane fields. Figure 4 (a) and Figure 4 (b) show that the production cost and setup cost of the scenario 3 provide in lower cost than the others.

V. CONCLUSION

In this paper, we developed the mathematical model to solve the integrated districting and transportation lot size problem for logistic system of sugarcane. The model formulated using the two-stage stochastic programming based on scenarios approach. The model addressed for the capacity enhancement of truck and mill factory, where we fixed the number of trucks and their locations, and number of districts. In the first stage, we determined how to partition whole cane field region into districts. We accounted the probability of scenarios occurring, in which provided different harvesting yield for each cane field zone. Then, we made decisions in the second stage for determining a lot size for each time period for each cane field zone. We investigated the mathematical model for small size problem. We presented the overall cost in the second stage based on scenarios. Numerical results on this instances showed than the different scenarios provide the different optimal solutions. The optimal solutions depend on the scenarios and the probability of scenarios occurring. We compared the district and stochastic model with non-district and deterministic model. The results showed that the district and stochastic model provided better solutions. Moreover, the district and stochastic solution trended to balancing truck utilizations. In the future, we will consider the balancing truck utilizations into model. Moreover, the heuristic algorithm will be present to approach large problem in real world.

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