FP-EPS-005-ID006

Cost Analysis for Sugarcane Transporting Improvement from Loading Station to Sugar mill

Kris Promsiri[1] and Jumpol Vorasayan[2,*]

[1] Department of Agro-Industrial Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok, Thailand;

[2] Department of Agro-Industrial Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok, Thailand.

* Correspondence: jumpol.v@ku.th; Tel.: +66-2562-5093 Ext. 5372

Received: 7 July 2018; Accepted: 20 December 2018; Published: 6 January 2020

Abstract: The transportation of sugarcane is one of major costs of sugar production. Large vehicles such as 22-wheel full trailer and semi-trailer are used for long-distance transportation because it incurs less transportation cost per ton. The objective of this research is to compare annual cost and benefit analysis model for two sugarcane transportation protocols single-loop and double-loop. In situation where the process is continuous and deterministic, the results showed that, the double-loop protocol had higher cost than single-loop protocol.

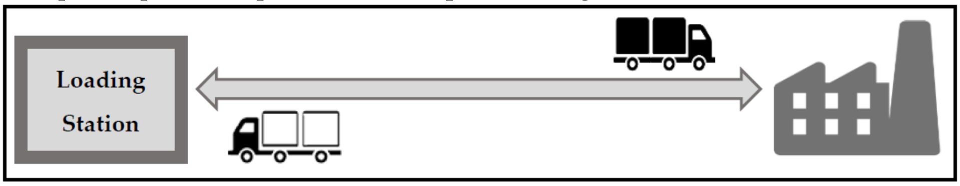
Keywords: cost analysis; transportation; sugar mill; loading station

1. Introduction

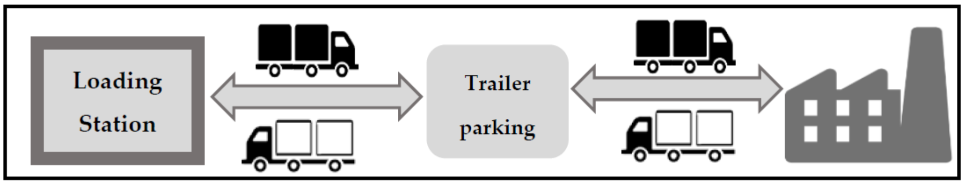
Sugarcane is a perennial agricultural crop that is mainly grown for its expressed juices, which used to produce raw sugar that is later refined into sugar. [1] In 2016, sugar accounted for over 80% of all sweeteners consumed globally, with products such as sugar, high-intensity sweetener (HIS), an artificial sweetener. Approximately 85% of all sugar produced globally come from sugarcane, which grows in equatorial regions such as Brazil and parts of Asia-Pacific. The remaining 15% comes from beetroot, which is grown in Europe, parts of the United States, Canada, and China. In 2016, combined global production came to 175 million tonnes (of raw sugar) and the most important producers were Brazil (22.9% of global production), India (12.8%), the European Union (9.7%), Thailand (5.9%) and China (5.6%). [2] The logistic and production cost plays a major role to gain competitive advantages during periods where the price of sugarcane is low. The logistics cost of the sugar industry in Thailand is apparently high compared with other major sugar export countries such as Brazil, Australia etc. Reasons include the increasing labor costs, inefficient use of machinery due to small farm size, improper system support, and lack of integration between farmer, transport companies, and sugar mill. [3] Thus, the transportation of sugarcane is the major cost of sugar production. All sugarcane in Thailand is transported by road vehicles. Large vehicles such as trailer and semi-trailer are increasingly used to reduce the transportation cost per ton. However, in order to achieve the low cost per ton, the careful operational plan is required to maximize efficiency. The purpose of this research is to developed cost and profit model as a tool to properly manage the number of vehicles for two sugarcane transportation protocols: single-loop and double-loop transportation protocols. The obtained result could assist sugar mill and transport company to understand the benefits of the redesigned system and it could be applied to improve sugarcane logistic efficiency.

2. Materials and Methods

The methodology started from collecting the data of fixed and variable cost in sugarcane transportation and other data that related to sugarcane transportation from loading station to sugar mill including transportation processes and the route in yard into sugar mill. These data were collected from the in-depth interview on sugarcane transportation stakeholders such as manager, officers, staffs and 3rd-party logistic provider in north eastern part of Thailand. [4] This research used cost and benefit analysis model for the sugarcane transportation protocol which considers two protocols: single-loop and double-loop. The first protocol the truck will pick up sugarcane from the loading stations to sugar mill in the order to unload sugarcane. Consequently, this truck go back to the loading station to repeat the loading process. On the other hand, the second protocol used two sets of semi-trailers. Semi-trailers in the first set carry trailer between the loading stations and parking area of the sugar mill. The trailer is released from the tractor in parking area. The tractors Semi-trailers in the second set carry the trailer between parking area and sugar mill in the order to unload sugarcane. The difference of single-loop and double-loop transportation protocols are depicted in Figure 1.



(**a**)



(**b**)

Figure 1. Comparison of sugarcane transportations (**a**) single - loop; (**b**) double - loop

2.1. Formulation of Mathematical Model

In this study, mathematical models about cost and profit of sugarcane transportation which considers two protocols: single-loop and double-loop transportation protocols that were adapted and modified from the mathematical model presented in the study of Jumpol Vorasayan (2014) [5], Watcharachan Sukcharoenvipharat (2012) [6] and W.khamjan, S.Khamjan, S.Pathumnakul (2013) [7]. The model is formulated under assumptions that activity time is deterministic and the transportations are performed continuously with unlimited supply of sugarcane.

2.1.1. Subscript and Set

i = a loading station index, I = set of loading stations = $\{1,2,3\}$

j = a sugar mill index, J = set of sugar mill = $\{1\}$

2.1.2 Notations

The notations for proposed cost and profit model are as follows;

- Notations for cost and revenue of sugarcane transportation
  - D = Distance between the loading stations to sugar mill (kilometer)
  - Tc = Truck cost (baht /truck)
  - H = Tractor cost (baht/tractor) H
  - T = Trailer cost (baht /trailer)
  - Y = Years of useful life whole vehicle (year)
  - S = Salvage Value (baht)
  - t = Vehicle tax (baht /year)
  - IN = Third class insurance expenses (baht /year)
  - Lf = Nonrenewable fuel rate when leave for sugar mill (liter/ kilometer)
  - Rf = Nonrenewable fuel rate when return to the 88 loading stations (liter/kilometer)
  - Fc = Fuel cost (baht /liter)

Tr = Useful nonrenewable tires and rims rate (baht /kilometer)
Mr = Useful nonrenewable motor oil and oil fitter rate (baht /kilometer)
w = Wage rate when vehicle driver in sugar mill (baht /kilometer)
Sw = Full-time vehicle driver salary (baht /month)
Re = Transport Revenue in each the loading stations (baht /tons)
ℓ = Loan rate for vehicle (percentage/year)

- Notations for duration of sugarcane transportation
  α = Period of waiting dumping time in each the loading station (minutes)
  β = Period of dumping time in each the loading stations (minutes)
  γ = Period of time assembly trailer in each the loading stations (minutes)
  δ = Period of arrive time to sugar mill in each the loading stations (minutes)
  ε = Period of leave time to sugar mill in each the loading stations (minutes)
  ζ = Period of unloading time in each the loading stations (minutes)
- Notations for managed sugarcane transportation from loading station to sugar mill
  AV = Arrive sugar mill average velocity (kilometer)
  LV = Leave sugar mill average velocity (kilometer)
  CF = Frequency of cycle (minute)
  CW = Frequency of work cycle (minute)
  CL = One cycle time (minute)
  V = Vehicle size (ton)
  G = Sugarcane weight (cycle/ton)
  DF = Driver in one cycle time (minutes)
  WT = Weight sugarcane target (ton)

The model is formulated as follows;

5) Number of queue card for truck and semi-trailers in each the loading stations: Q_i (queue)

$$Q_i = \frac{WT_i}{V \times CF} \tag{1}$$

6) Number of queue card of tractors for semi-trailers in sugar mill: Q_j (queue)

$$Q_j = \sum_{i=1}^{3} Q_i \tag{2}$$

7) Period of per cycle time for trucks and semi-trailers in each the loading stations: C_i (minutes)

$$C_i = \alpha_i + 2\beta_i + \gamma_i + \delta_i + \varepsilon_i + \zeta_i \tag{3}$$

8) Period of per cycle time of tractors for semi-trailers in sugar mill: C_j (minutes)

$$C_j = \alpha_j + 2\beta_j + \gamma_j + \delta_j + \varepsilon_j + \zeta_j \tag{4}$$

9) Number of tractors for trucks and semi-trailers in each the loading stations: T_i (unit/tractor)

$$T_i = \frac{Q_i}{\frac{CL}{C_i}};\ T_i < U_i \ \text{ where } U_i = \frac{C_i}{\zeta_i} \tag{5}$$

Let U_i is the number of tractors that makes the loading stations take trucks and semi-trailers continuously all the time.

10) Number of tractors for semi-trailers in sugar mill: M_j (unit/tractor)

$$M_j = \frac{Q_j}{\frac{CL}{C_j}}\ ;\ M_j < X_j \text{ where } X_j = \frac{C_j}{\beta_j} \tag{6}$$

Let X_i is the number of tractor that makes the dumper unloading sugarcane with semi-trailer continuously all the time.

11) Number of trailer for semi-trailers in each the loading stations: L_i (unit/trailer)

$$L_i = T_i + E \tag{7}$$

Let E is Number of trailer that need to get the tractors not waiting the trailers in sugar mill, from simulation model assume about $1 \le E \le 5$.

12) Number of trailers for semi-trailers in sugar mill: N_j (unit/trailer)

$$N_j = M_j \tag{8}$$

13) Deprecation of truck: DTc (baht/year)

$$DTc = \frac{Tc - \frac{S}{(1+\ell)^Y}}{\frac{1 - \frac{1}{(1+\ell)^Y}}{\ell}} \tag{9}$$

14) Deprecation of tractor for semi-trailers: DH (baht/year)

$$DH = \frac{H - \frac{S}{(1+\ell)^Y}}{\frac{1 - \frac{1}{(1+\ell)^Y}}{\ell}} \tag{10}$$

15) Deprecation of trailer for semi-trailers: DT (baht/year)

$$DT = \frac{T - \frac{S}{(1+\ell)^Y}}{\frac{1 - \frac{1}{(1+\ell)^Y}}{\ell}} \tag{11}$$

16) Deprecation of added trailers for semi-trailers in sugar mill: DTa (baht/year)

$$DTa = \frac{T - \frac{S}{(1+\ell)^Y}}{\frac{1 - \frac{1}{(1+\ell)^Y}}{\ell}} \tag{12}$$

Note: The trailer in the loading stations and in sugar mill are the same price.

17) Usage fuel cost for trucks and semi-trailers in each the loading stations: FV_i (baht/month)

$$FV_i = D_i \times (Lf + Af) \times Fc \times Q_i \tag{13}$$

18) Usage fuel cost of tractors for semi-trailers in sugar mill: FV_j (baht/month)

$$FV_j = D_j \times (Lf + Af) \times Fc \times Q_j \tag{14}$$

19) Usage tires and rims cost for trucks and semi-trailers in each the loading stations: RV_i (baht/month)

$$RV_i = D_i \times 2 \times Tr \times Q_i \tag{15}$$

20) Usage tires and rims cost of tractors for semi-trailers in sugar mill: RV_j (baht/month)

$$RV_j = D_j \times 2 \times Tr \times Q_j \tag{16}$$

21) Usage motor oil and oil fitter cost for trucks and semi-trailers in each the loading stations: MV_i (baht/month)

$$MV_i = D_i \times 2 \times Mr \times Q_i \tag{17}$$

22) Usage motor oil and oil fitter cost of tractors for semi-trailers in sugar mill: MV_j (baht/month)

$$MV_j = D_j \times 2 \times Mr \times Q_j \tag{18}$$

23) Wage and salary cost for trucks and semi-trailers in each the loading stations: SV_i (baht/month)

$$SV_i = DW \times SW \times G \times Q_i \tag{19}$$

24) Wage and salary cost of tractors for semi-trailers in sugar mill: SV_j (baht/month)

$$SV_j = \frac{CL}{1440} \times \frac{CL}{DF} \times M_j \times \frac{Sw}{30} \tag{20}$$

25) Usage tractors for trucks cost in each the loading stations: Ω_i (baht/month)

$$\Omega_i = T_i \times \left(\frac{DTc + t + IN}{CW} \right) \tag{21}$$

26) Usage tractors for semi-trailers cost in each the loading stations: Ψ_i (baht/month)

$$\Psi_i = T_i \times \left(\frac{DH + t + IN}{CW} \right) \tag{22}$$

27) Usage trailers for semi-trailers cost in each the loading stations: Φ_i (baht/month)

$$\Phi_i = L_i \times \left(\frac{DH}{CW} \right) \tag{23}$$

28) Usage tractors for semi-trailers cost in sugar mill: HS_j (baht/month)

$$HS_j = M_j \times \left(\frac{DH + t}{CW} \right) \tag{24}$$

29) Usage trailers for semi-trailers cost in sugar mill: TS_j (baht/month)

$$TS_j = \left(N_j \times \frac{DT}{CW} \right) + \left(A \times \frac{DTa}{CW} \right) \tag{25}$$

Let A is number of added trailers of sugar mill, in this case we determine to 2 per unit

30) Cost per ton for trucks in each the loading stations: CT_i (baht/ton)

$$CT_i = \frac{\left(\dfrac{\Omega_i + FV_i + RV_i + MV_i + SV_i}{Q_i}\right)}{G} \tag{26}$$

31) Cost per ton for semi-trailers in each the loading stations: CS_i (baht/ton)

$$CS_i = \frac{\left(\dfrac{\Psi_i + FV_i + RV_i + MV_i + SV_i}{Q_i}\right)}{G} \tag{27}$$

32) Cost per ton of tractors for semi-trailers in sugar mill: CS_j (baht/ton)

$$CS_j = \frac{\left(\dfrac{HS_j + TS_j + FV_j + RV_j + MV_j + SV_j}{Q_j}\right)}{G} \tag{28}$$

33) Total cost of trucks in each the loading stations: TC_i (baht)

$$TC_i = CT_i \times WT_i \tag{29}$$

34) Total cost of semi-trailer in each the loading stations: TCs_i (baht/year)

$$TCs_i = CS_i \times WT_i \tag{30}$$

35) Total cost of tractors for semi-trailers in sugar mill: TC_j (baht)

$$TC_j = CS_j \times WT_j \tag{31}$$

36) Total revenue for trucks and semi-trailers in each the loading stations: TR_i (baht)

$$TR_i = \mathrm{Re} \times WT_i \tag{32}$$

37) Profit per ton for truck in each the loading stations: PS_i (baht/ton)

$$PT_i = \mathrm{Re} - CT_i \tag{33}$$

38) Profit per ton for semi-trailers in each the loading stations: PS_i (baht/ton)

$$PS_i = \mathrm{Re} - CS_i \tag{34}$$

39) Total profit for trucks in each the loading stations: ZT_i (baht)

$$ZT_i = PT_i \times WT_i \tag{35}$$

40) Total profit for semi-trailers in each the loading stations: ZS_i (baht)

$$ZS_i = PS_i \times WT_i \tag{36}$$

With data collected from the participant on sugarcane transportation in the production year 2017/2018, the estimate values of the model parameter as shown in Table 1 used in this case study.

Table 1 Model parameters of the case study sugar mill in the production year 2017/2018.

Parameter	Values	Parameter	Values
Tc	3.75×10^6 baht[1]	CW	160
H	3.05×10^6 baht	Lf	0.6
T	700,000 baht	Af	0.4
Y	15 year	Fc	27 baht
S	500,000 baht	Tr	1.50
t	10,000 baht	Mr	0.50
IN	20,000 baht	w	0.1
CF	100	Sw	15,000 baht /month
ℓ	5%[2] and 7%[3]		

[1] Thai Baht: 1 Baht ≈ 0.0304956 USD.

[2] For calculated to deprecation added trailer in sugar mill.

[3] For calculated to deprecation truck, tractor and trailer in each the loading stations.

3. Results

3.1. Sugarcane Transportation Cost With Two Protocol

In our analysis, we determine the loan rate for the vehicle. In fact, sugar mill takes on a loan agreement to the transport company in the order to the purchased vehicle. In this section, we have shown the result of the sugarcane transportation cost and profit in the loading stations are as shown in Table 2 to Table 4. In this case study, we required to carry weight sugarcane around 35 tons that calculated the cost and profit in two protocols are specific compared to the loading stations number 1, 2 and 3 respectively which these are located around northeastern part of Thailand. We selected these stations because the transport company with sugar mill used these stations to curry sugarcane. In single - loop protocol has total cost about 26,570,718.8 baht/year, which the loading station number 3 has got cost more than other stations about 11,985,109.0 baht/year. And total revenue about 31,728,045.0 baht/year, which the loading station number 3 has got revenue more than other stations about 14,310,000.0 baht/year, so a total profit in this protocol is 5,157,326.3 baht/year which the loading station number 3 has got profit more than other stations about 2,324,891.0 baht/year. Next, in double - loop protocol, we combined the results of tractors in the parking of area sugar mill also, so it has total cost about 27,582,420.9 baht/year, which the loading station number 3 has got cost more than other stations about 11,629,216.0 baht/year. And total revenue about 31,728,045.0 baht/year, which the loading station number 3 has got revenue more than other stations about 14,310,000.0 baht/year, so a total profit in this protocol is 4,145,624.1 baht/year which the loading station number 3 has got profit more than other stations about 2,680,784.1 baht/year.

Table 2. Transportation cost and profit for trucks of single - loop protocol in each the loading stations.

i	Q_i	C_{1i}	T_{1i}	Ω_i	FV_{1i}	RV_{1i}	MV_{1i}	SV_{1i}	CT_{1i}	TC	TR	PT_i	Z_{1i}
1	5.1	857.3	2.4	6,432.9	21,024.2	2,336.0	778.6	4,356.9	194.8	3,492,883.3	4,356,990.0	48.0	864,106.7
2	14.0	956.3	7.5	19,725.1	68,058.3	7,562.0	2,520.6	13,061.0	225.0	11,092,726.4	13,061,055.0	40.0	1,968,328.6
3	15.4	945.3	8.1	21,362.8	73,316.5	8,146.2	2,715.4	14,310.0	221.9	11,985,109.0	14,310,000.0	43.0	2,324,891.0

Table 3. Transportation cost and profit of tractors for semi-trailers of double - loop protocol in sugar mill.

j	Q_j	C_j	M_j	N_j	HS_j	TS_j	FV_j	RV_j	MV_j	SV_j	CS_j	TC	R	PS_j	Z_j
1	34.6	213.6	4.1	4.1	8,350.1	2,817.7	935.1	103.9	34.6	5,138.9	14.3	1,738,040.3	-	-	-

Table 4. Transportation cost and profit for semi-trailers of double - loop protocol in each the loading stations.

i	Q_i	C_{2i}	T_{2i}	L_i	Ψ_i	ϕ_i	FV_{2i}	RV_{2i}	MV_{2i}	SV_{2i}	CS_i	TC	TR	PS_i	Z_{2i}
1	5.1	657.3	1.9	3.9	4,033.6	1,859.3	21,024.2	2,336.0	778.6	4,356.9	191.8	3,438,885.0	4,356,990	51.2	918,104.9
2	14.0	756.3	5.9	7.9	12,757.7	3,802.9	68,058.3	7,562.0	2,520.6	13,061.0	228.6	10,776,279.6	13,061,055	46.3	2,284,775.3
3	15.4	745.3	6.4	8.4	13,774.4	4,0269.4	73,316.5	8,146.2	2,715.4	14,310.0	215.3	11,629,215.9	14,310,000.0	49.6	2,680,784.1

3.2. Number of Vehicle in Sugarcane Transportation

In this case study, the sugar mill used queue system that determine sugarcane volume line up into mill nearly with capacity of press sugarcane. This queue separate to one period consist of 5 quarter which it is 6 hour in each quarter. Addition the season of sugarcane harvest could transport into sugar mill about 100 cycle. And the farmers will received queue card that can dumping sugarcane under determine sugarcane volume and vehicle size. For example, a farmer has sugarcane about 30,000 ton and a truck size 15 ton. Thus, a farmer will gets queue card about 2 cards. It is meaning they will send sugarcane to 2 time in cycle. The queue system need to sugarcane transport, so we developed queue system formula is $Q_i = \dfrac{WT_i}{V \times CF}$. For example, the loading station number 20 has a weight target *(WT_2)* about 54,000 ton, a truck size *(V)* 35 ton and frequency of cycle *(CF)* about 100, so that number of queue card in the loading station number 2 is 5.1 queue. Next, when we have queue card already result to we can get calculated number of vehicle on two protocols are as shown in Table 2 to Table 4. In single - loop protocol, the loading stations number 1 to 3 used number of tractors *(T_{1i})* of truck about 3, 8 and 9 per a tractor respectively. A part of double- loop, used number of tractors of semi-trailer *(T_{2i})* about 2, 6 and 7 per unit respectively. And it has number of trailers of semi-trailer *(L_i)* about 4, 8 and 9 per unit respectively. In addition double - protocol need to tractors and trailers for transported into sugar mill also that the tractors and trailers are as equally. Thus, there are number of tractors and trailers for semi-trailer *(M_j)* and *(N_j)* are about 5 per unit which the tractors of semi-tractor in sugar mill, are sharing with all the loading stations.

4. Discussion

The result showed that the cost and benefit compared two sugarcane transportation protocols, single-loop, and double-loop sugarcane transportations. For the same amount of delivered sugarcane, the double-loop has supplementary fixed costs other than the single-loop. We can reduce the fixed cost of double-loop by using tractors, which low capacity and efficiency because the transportation distance is within reach between the parking area and sugar mill. In part of single-loop, if this protocol incurred uncertainty scenarios concerning the time variance or machine is out of order, it will put the break on transportation. But the double - loop, will put the break on the first loop only, between the loading stations and parking area of the sugar mill then, the second loop it works perfectly now. In addition, the system of the double loop will be efficiency and worthwhileness if the number of tractors and trailers that are appropriate with sugarcane transportation.

5. Conclusions

To summarize, we have shown with the mathematical model for cost and benefit of two sugarcane transportation protocols, single-loop and double-loop higher cost in double-loop is accounted for the higher fixed cost of the vehicle and the waiting time incurred by double handling of two sets of tractors. For the same amount of delivered sugarcane, the double-loop has supplementary fixed costs other than the single-loop. In addition, the number of tractors needs to balance in each periods which reduced the waiting time of transportations. This provides, in long-term investment, the sugar mill owner and 3rd-party logistic will be able to use the double-loop transportation for a worthwhile investment. In the future, this model might be compared the efficiency of two protocols when other factors such as uncertainty scenarios by using situation analysis.

Acknowledgments: The work was supported by The Thailand Research Fund under grant RDG60T0167. The researchers would like to sincerely thank the sugar mill and transport company who provide information.

References

1. Salassi, M.E., Breaux, J.B., Naquin, C.J. Modeling within-season sugarcane growth for optimal harvest system selection. Agric. Syst. 73, 2002; pp. 261-278.

2. Krungsri Research. Industry outlook 2018-2020: Sugar Industry. Available online: https://www.krungsri.com/bank/getmedia/64a1559a-2938-4f48-b5afc601e52f660c/IO_Sugar_2018_EN.aspx (Accessed on 26th August 2018).
3. Jumpol Vorasayan. A simulation to compare single-loop and double-loop transportation protocols for sugarcane industry. Industrial Technology and Management (ICITM), 2018 7th International Conference on IEEE. 2017; pp. 309-313.
4. Ongkunaruk, P. and Ongkunaruk, W. Coconut sap pick up problem with time windows: a case study. International Food Research Journal. 22.5: 2088. 2015.
5. Vorasayan, J., and S. Pathumnakul. Optimal logistics system for sugarcane mechanical harvesting in Thailand. Journal of Applied Science and Agriculture. 2014; pp. 28-35.
6. Watcharachan Sukcharoenvipharat. A study on potential of tractor-towed for transportation sugarcane Muster Thesis, Kasetsart University, Bangkok, Thailand, 2012.
7. W.khamjan, S.Khamjan, S.Pathumnakul. Determination of the locations and capacities of sugarcane loading stations in Thailand. Computers & Industrial Engineering 66.4. 2013; pp.663-674.