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Technical Note

Reduction in energy consumption and operating cost in a dried corn warehouse using logistics techniques

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Abstract: Corn is one of the major economic crops in Thailand. Corn postharvest operation involves various practices that consume a large amount of energy. Different energy conservation measures have been implemented but logistics consideration is not normally employed. In this work, attempt has been made to demonstrate that logistics techniques can offer a significant reduction in energy and cost. The main objective of this work is to identify and demonstrate possible approaches to improving energy efficiency and reducing operating cost for a dried corn warehouse operator. Three main problems are identified: (i) relatively high fuel consumption for internal transfer process, (ii) low quality of dried corn, and (iii) excess expenditure on outbound transportation. Solutions are proposed and implemented using logistics operations. Improvement is achieved using plant layout and shortest path techniques, resulting in a reduction of almost 50% in energy consumption for the internal transfer process. Installation of an air distributor in the grain storage unit results in a decrease in loss due to poor-quality dried corn from 17% to 10%. Excess expenditure on dried corn distribution is reduced by 6% with application of a global positioning system.

Keywords: agro-industry, logistics, plant layout design, dried corn warehouse

INTRODUCTION

Corn is one of the major upland crops in Thailand with large plantation areas throughout the whole country. Thailand has achieved considerable success in growing corn as an alternative to rice. Since the past few decades, corn cultivation has proved a remarkable success for farmers and the nation as a whole. Thailand's livestock industry consumed about 3-4 million tons of corn a year while 400,000 tons were exported. In 2009, however, the export amounted to over 840,000 tons and was worth more than 5,300 million Thai Baht (THB) [1]. Corn for domestic and foreign

consumption has become a significant contributor to the Thai economy and the demand and production continue to grow.

Typically, postharvest processes for corn involve: (i) field drying and harvesting, (ii) threshing and drying, (iii) shelling and cleaning, (iv) storage, and (v) transport [2]. In a typical warehouse, trucks, loaders, several types of dryers, storage facilities and silos can be found for drying and handling the grain. Drying is normally done before storing to ensure high quality and value. Storage is done by stacking the dried corn on a cement floor or in a silo. At this stage, deterioration of corn grain during storage due to heat liberated from the respiration process is normally controlled by passing cool air or ambient air through the bed to reduce the bed temperature. Energy is expended to power vehicles and various postharvest processing technologies are used. It is clear that a typical corn grain handling facility consumes a large amount of energy. There are a number of energy-saving techniques and many different energy conservation measures have been implemented in agro-product industries [3-6]. However, logistics techniques are not normally considered. In other industries, logistics considerations such as plant layout modification, warehouse operation, improved transportation network, and implementation of information technology have been successfully demonstrated [7-10].

Logistics activities incorporate three main areas; these are inbound, internal and outbound logistics. Inbound logistics involves activities in procurement process and supplier integration. Enhanced integration with suppliers can influence several dimensions of firm performance including cost, quality, technology, delivery, flexibility and profits [11]. Internal logistics can be viewed as operations in manufacturing, material transfer and handling, and inventory and warehouse control [12]. Internal logistics starts when raw materials enter the company until the product is ready for distribution. The activities of internal logistics affect numerous aspects of the products including cost, quality and performance. Consequently, they must be constantly monitored and evaluated from a continuous improvement perspective [13]. Outbound logistics encompasses such processes as distribution, marketing, sales and service. A system based on information technology is found to enhance such processes in many ways including accurate order delivery information used to provide appropriate capacity at expertise level regarding customer support. Moreover, the tracking of product delivery allows for increased customisation, fulfillment of customers' requirements and reduction in long-term transportation cost. This results in a higher inventory turnover with a higher market share driven by reliable and responsive availability of those products/services most desired by customers [14].

In this investigation an attempt is made to apply logistics techniques to improving energy efficiency and reducing the cost of operating a dried corn export business. The main focus is on the activities of internal and outbound logistics, where the main problems usually take place.

RESEARCH METHODOLOGY

Case Study

In this study a dried corn processing company (Nipen Kaset Paisan Co., Ltd.) is used as a case study. It is situated in Payao province, about 700 km north of Bangkok. Corn grain of 40% moisture or less is purchased from farmers, dried to below 14.5% moisture and kept in storage prior to transporting to customers. The monthly capacity is about 3,000 tons.

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Data Collection and Preliminary Analysis

A preliminary interview with the company owner was conducted to identify the most important problems regarding energy and operating cost, which were: a high operational cost, large amounts of poor quality product and uncontrolled transportation costs. Data on activities were then collected based on internal and external operations. In the case of the former the details of plant layout and storage system of dried corn were collected. In the case of the latter the data on transportation cost were gathered, together with the quality of product in terms of per cent humidity. The data on current practices of the company were analysed to identify the activities with the highest costs using logistics cost analysis with activity-based costing (ABC) technique. The technique is defined by the Chartered Institute of Management Accountants [15] as 'an approach to the costing and monitoring of activities which involves tracing resource consumption and costing final outputs. Resources are assigned to activities, and activities to costing objects based on consumption estimates. The latter utilise cost drivers to attach activity costs to outputs.'

Four related costs: area utilisation, personnel, machines and consumables were used in the ABC calculations. The approach to the logistics ABC calculations is summarised in Figure 1 and the cost analysis results of existing activities are presented in Table 1. Problematic areas can be identified, which leads to an alternation of the existing warehouse, which could considerably reduce the cost on internal transfer. The costs on activity number 2, 3 and 6 have been reduced accordingly. Since high expenditure was spent on activity number 5 and 7, the actual root causes of the problem are further evaluated by cause and effect analysis using fish bone diagrams. The problem analysis on dried corn storage activity and dried corn delivery are shown in Figures 2 and 3 respectively. It is clearly seen that the problem of inappropriate dried corn storage can lead to the deterioration of the product quality. Additionally, high transport cost stemmed from the driving behaviour of the employees. The solutions to these problems are proposed in the next section.

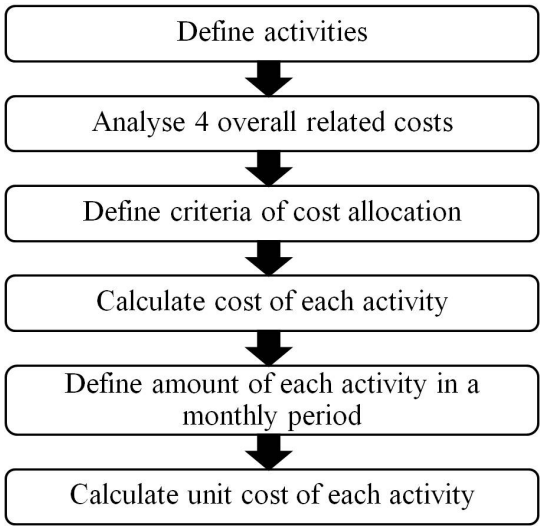

Figure 1. Approach to logistics cost calculation

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Table 1. Existing monthly costs calculated by ABC technique

Activity	Cost (THB)	Number of activities (tons)	Unit cost (THB)
1. Pre-dry corn weighing	3,074	3,000	1.025
2. Transfer of pre-dry corn to dryer	37,000	3,000	12.33
3. Transfer of firewood to dryer	121,443	230	528.0
4. Corn drying process	59,655	3,000	19.88
5. Dried corn storage	94,656	2,490	38.01
6. Transfer of dried corn from dryer to truck	37,903	2,490	15.22
7. Dried corn delivery	651,459	2,490	261.6
8. Return of poor-quality dried corn	77,080	125	616.6
Total	1,081,470		

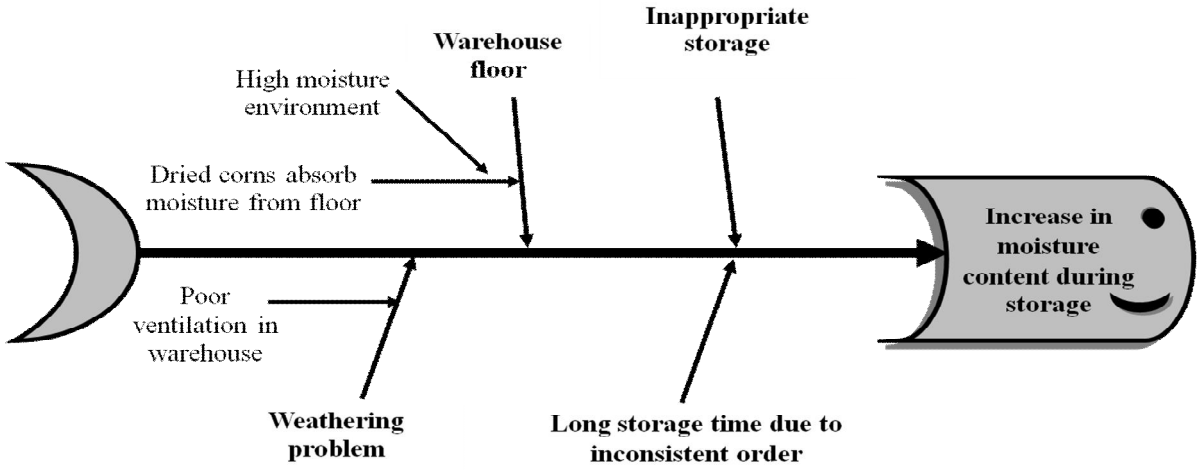

Figure 2. Cause and effect analysis for corn storage problem

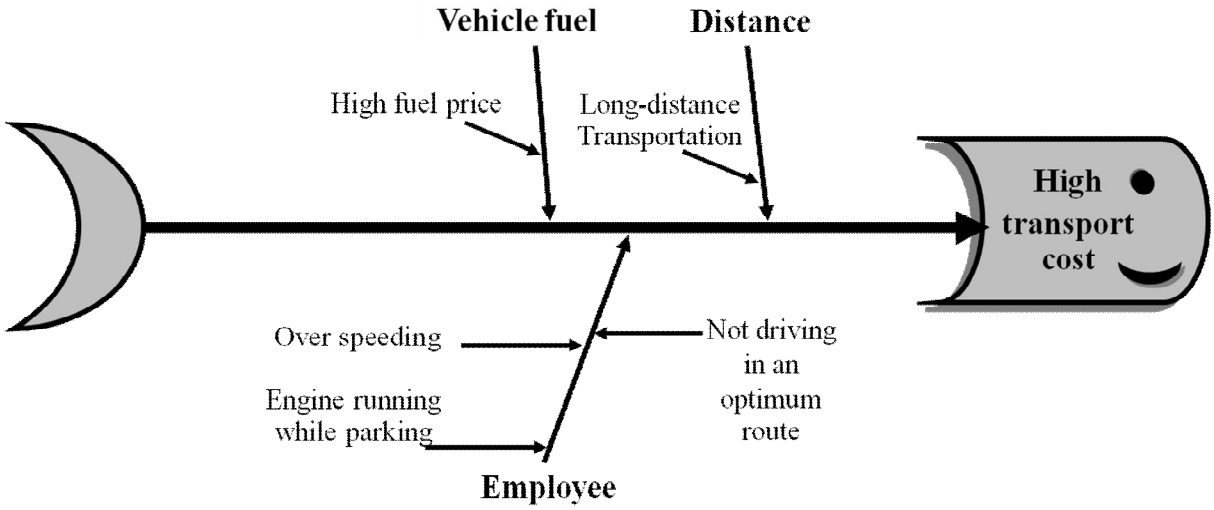

Figure 3. Cause and effect analysis for corn delivery problem

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Improvement Approaches

Appropriate solutions were proposed and implemented to the company's existing practice. Economic feasibility of the proposed techniques was also evaluated using break-even analysis. These improvement approaches are:

Alteration of existing plant layout

Existing plant layout led to high energy consumption and long operation time. Modification should be made to the current layout. Unnecessary movements should be eliminated from the current transfer processes. A plant layout alteration should be adopted to reduce the overall transfer distance of internal logistics for higher efficiency in terms of energy consumption and time taken.

Installation of grain aeration system

Previously, dried grains were piled on a cement floor, exposed directly to ambient condition. Some fractions of the grains were prone to moisture absorption and recondensation, leading to damage. This was due mainly to poor storage condition. Improvement of the current storage should be implemented to preserve the quality of dried corn. This could be done by installing a proper aeration system to control the relative humidity and temperature of the dried grain bed. The aeration system consists of an air pump and a network of air distribution pipes laid on the base of the storage floor. There are holes along the length of these distribution pipes to supply air under the piles of dried grains. In this way the moisture content and temperature of the grains could be regulated.

Application of GPS in transportation

Fuel consumption of trucks plying the route from and to the company warehouses amounted to a high operating cost. The major problems involved overspeeding, driving out of the optimum route and keeping the engine running while parking. Installation of a global positioning system (GPS) in trucks would enable the company to track the product movement as well as the driving behaviour of drivers. This technique could increase reliability of product delivery and decrease vehicle fuel consumption during transportation.

RESULTS AND DISCUSSION

Change in Plant Layout Design

The plant layout in the case study with three internal transfer activities which appeared to have excess movements was modified. These activities were:

- Transfer of pre-dry corn to the dryer
- Transfer of firewood to the dryer
- Transfer of dried corn from the dryer to trucks for distributionx c

A wheel loader was used for these internal transfer processes. Improvements made were: (i) moving the location of pre-dry corn closer to the dryer, (ii) moving firewood station closer to the dryer, and (iii) shortening the path between the dryer and the distribution area. Results are schematically illustrated in Figures 4-6 respectively. Unnecessary movements were eliminated and the overall layout were changed, leading to a significant reduction (greater than 170 m) in the transfer distance. Table 2 summarises the percentage reduction in distance after the plant layout improvement on the three internal transfer activities. Table 3 shows savings in fuel consumption after the layout improvement. The cost assessment for overall logistic activities within the company is presented in Table 4. Only the vehicle fuel cost was considered. Three internal activities are highlighted. The overall fuel cost was found to be reduced from about 135,000 THB to around

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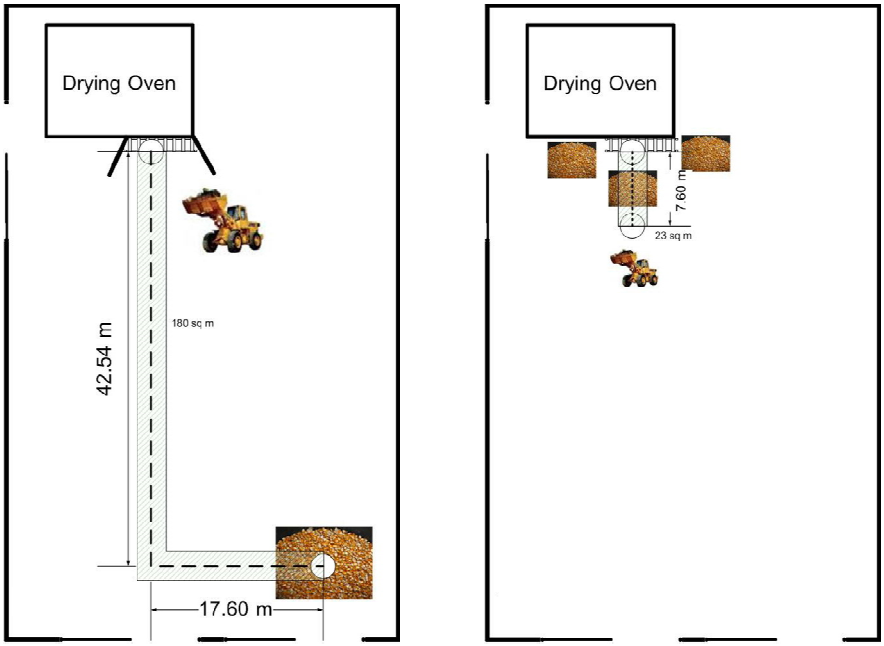
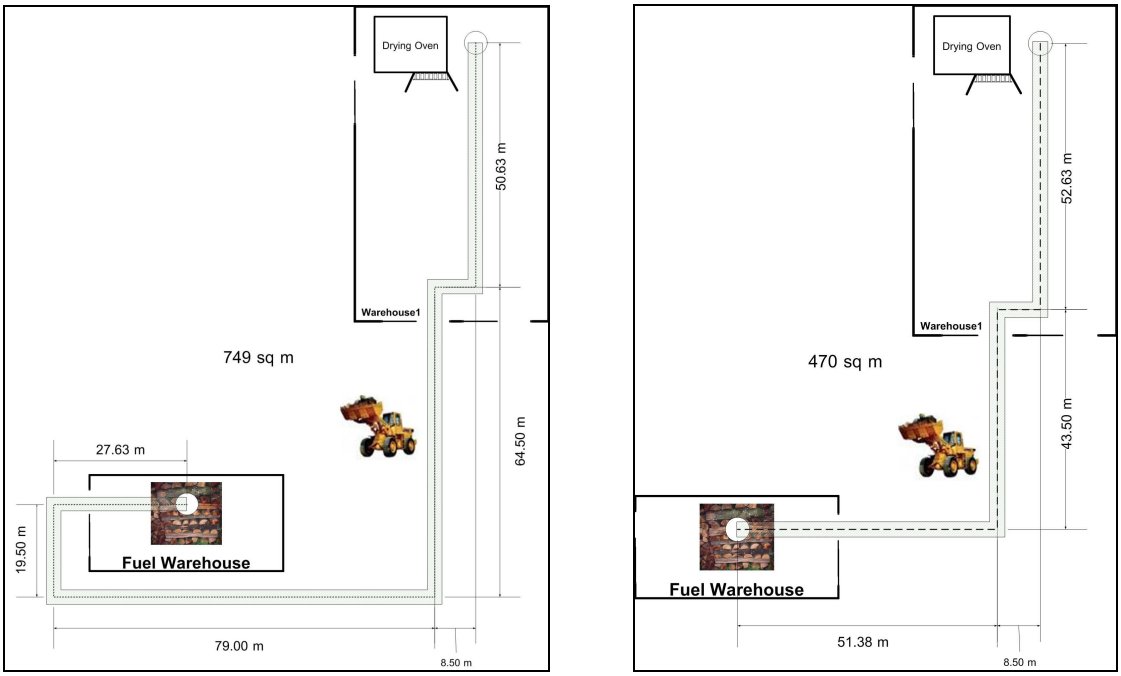
72,000 THB per month. This is almost a 50% saving on the internal transfer cost. It is clear that the change in plant layout can significantly lower energy usage.



(before) (after)

Figure 4. Layout modification of the transferring of corn to the dryer



(before) (after)

Figure 5. Layout modification of the transferring of firewood to the dryer

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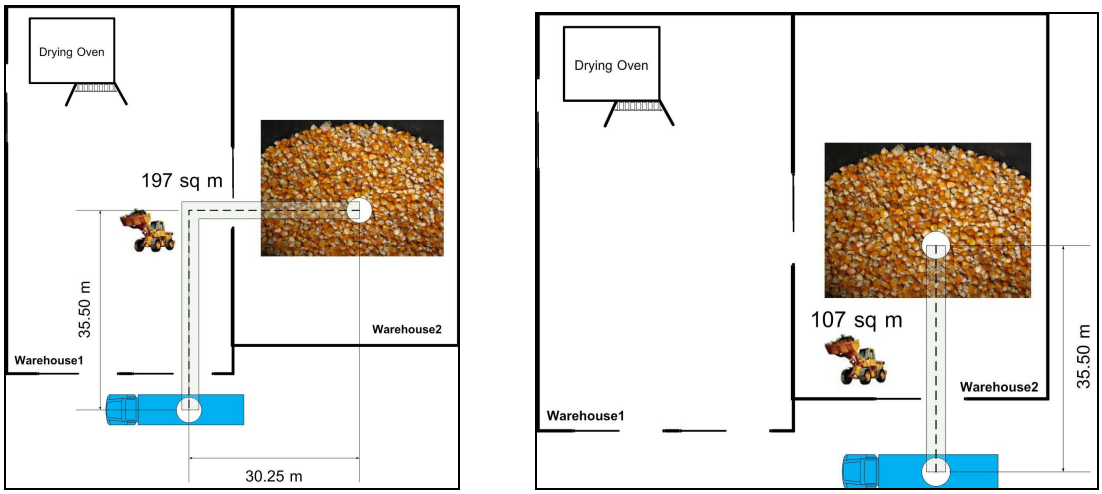

(before) (after)

Figure 6. Layout modification of the transferring of dried corn to truck for distribution

Table 2. Distance reduction resulting from plant layout improvement

Activity	Distance before improvement (m)	Distance after improvement (m)	% Reduction
1. Transfer of pre-dry corn to dryer	60.1	7.6	87.0
2. Transfer of firewood to dryer	249.7	156.0	38.0
3. Transfer of dried corn from dryer to trucks	65.8	35.5	46.0

Table 3. Vehicle fuel consumption (monthly) before and after plant layout improvement

Activity	Fuel consumption (before)		Fuel consumption (after)	
	% Cost allocation	Cost (THB)	% Cost allocation	Cost (THB)
1. Pre-dry corn weighing	-	-	-	-
2. Transfer of pre-dry corn to dryer	5.05	21,665	0.75	2,740
3. Transfer of firewood to dryer	20.96	89,917	15.37	56,166
4. Corn drying process	-	-	-	-
5. Dried corn storage	-	-	-	-
6. Transfer of dried corn from dryer to truck	5.52	23,680	3.50	12,790
7. Dried corn delivery	61.23	262,678	71.88	262,672
8. Return of poor-quality dried corn	7.24	31,060	8.50	31,062
Total	100.00	429,000	100.00	365,430

Table 4. The comparison of costs before and after plant layout modification

Activity	Number of activities	Cost in THB (before)		Cost in THB (after)	
		Process cost	Unit cost	Process cost	Unit cost
2. Transfer of corn to dryer	3,000 tons	37,000	12.07	18,075	6.030
3. Transfer of firewood to dryer	230 tons	121,443	528.0	87,692	381.3
6. Transfer of dried corn to truck	2,490 tons	37,903	15.22	27,013	10.85
Total		196,346		132,780	

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Installation of Grain Aeration System and GPS

When the grain aeration system was installed, it was found to operate well, with temperature and humidity being controlled at required values. With the aeration system, the corn grains were dried to 14.5% moisture content rather than the previous 13.8%. With a better storage system, over-drying of the product was no longer necessary. The installation also reduced firewood consumption by about 10% during the drying process (from 230 tons to 210 tons a month). Furthermore, the waste derived from poor quality product after storage was cut down by over 40% (from 510 tons to 300 tons).

Equipping trucks with the GPS increased monitoring and control of driving pattern as well as reliability of transportation. In this way the vehicle fuel was reduced; for a typical round-trip route of about 600 km, almost 20 litres or 6% of diesel fuel were saved.

Economic Analysis

An economic analysis using break-even point was employed and the results are shown in Table 5. Plant layout improvement was found to deliver the best return on energy cost; the transfer cost was reduced by almost 50%. The payback period of this investment was only 3 months, which was very attractive for the investor. Installation of the aeration system appeared to involve the highest initial investment cost. The substandard product was reduced by 40% per month, leading to an increased revenue by almost 50,000 THB per month. Moreover, the firewood utilised during the drying process was reduced by nearly 10%. Saving in energy was an additional benefit. However, the company had to invest around 1,100,000 THB with a payback period of almost two years. High initial investment could deter the owner from adopting this method. Installing of the GPS provided the shortest break-even time for investment with only 17 days to recover, although the cost saving was only 6% compared with operations without GPS.

Table 5. Break-even analysis of improvement approaches

Approch 1 : Plant layout improvement	
1. Plant layout improvement cost	191,240 THB
Total cost for improvement	191,240
Cost reduction (fuel consumption based)	
Internal transfer cost (before improvement)	135,262 THB/month
Internal transfer cost (after improvement)	71,696 THB/month
Cost saving (per month)	63,566
Break-even point	3 months
Approach 2: Aeration system installation	
1. Aeration system installation cost	851,676 THB
2. Yearly maintenance cost	129,600 THB
3. Electricity cost per year	144,000 THB
Total cost	1,125,276
Improvement detail	
Value of damage (before improvement)	119,340 THB/month
Value of damage (after improvement)	70,200 THB/month
Cost saving (per month)	49,140
Break-even point	23 months

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Table 5. (continued)

Approach 3: GPS installation	
1. GPS equipment cost	14,500 THB
2. Yearly system maintenance cost	4,200 THB
Total cost for GPS	18,700
Improvement detail	
Fuel consumption (before GPS installation)	316.84 litres/round
Fuel consumption (after GPS installation)	297.72 litres/round
Fuel saving	19.12 litres/round
Fuel cost	28.6 THB/ litre
Saving per round	546.83 THB
Break-even point	34 rounds = 17 days (2 rounds/day)

CONCLUSIONS

It was clear that logistics considerations can offer options in the improvement on energy efficiency and cost reduction in dried corn production, hence significant savings for dried corn warehouse operators. Similar analysis may benefit other agro-product manufacturers who wish to adopt similar improvement approaches.

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REFERENCES

1. Office of Agricultural Economics, Ministry of Agriculture, Thailand, "Import-export of major agricultural crops", **2010**, www.oae.go.th (Accessed: Jan. 2010).
2. Food and Agriculture Organization (FAO), "Maize in human nutrition", **1993**, www.fao.org/docrep/ T0395E/T0395E00.htm (Accessed: Jan. 2010).
3. N. Dussadee and T. Kiatsiriroat, "Performance analysis and economic evaluation of thermosyphon paddy bulk storage", *Appl. Thermal Eng.*, **2004**, *24*, 401-414.
4. N. Tippayawong, C. Tantakitti and S. Thavornun, "Energy efficiency improvements in longan drying practice", *Energy*, **2008**, *33*, 1137-1143.
5. N. Tippayawong, C. Tantakitti, S. Thavornun and V. Peerawanitkul, "Energy conservation in drying of peeled longan by forced convection and hot air recirculation", *Biosyst. Eng.*, **2009**, *104*, 199-204.
6. V. Smil, P. Nachman and T. V. Long, "Technological changes and the energy cost of US grain corn", *Energy Agric.*, **1983**, *2*, 177-192.
7. L. C. Lin and G. P. Sharp, "Quantitative and qualitative indices for the plant layout evaluation problem", *Eur. J. Oper. Res.*, **1999**, *116*, 100-117.
8. M. T. Torres, M. C. Barros, P. M. Bello, J. J. Casares and J. M. Rodriguez-Blas, "Energy and material flow analysis: Application to the storage stage of clay in the roof-tile manufacture", *Energy*, **2008**, *33*, 963-973.

Maejo Int. J. Sci. Technol. **2013**, *7*(02), 258-267

9. S. Jia, H. Peng, S. Liu and X. Zhang, "Review of transportation and energy consumption related research", *J. Transport. Sys. Eng. Inform. Technol.*, **2009**, *9*, 6-16.
10. S. McCabe, M. Roorda and H. Kwan, "Comparing GPS and non-GPS survey methods for collecting urban goods and service movements", Proceedings of 8th International Conference on Survey Methods in Transport, **2008**, Annecy, France.
11. B. Dehning, V. J. Richardson and R. W. Zmud, "The financial performance effects of IT-based supply chain management systems in manufacturing firms", *J. Oper. Manage.*, **2007**, *25*, 806-824.
12. B. S. Blanchard, "Logistics Engineering and Management", Pearson Prentice Hall, Upper Saddle River (N.J.), **2004**.
13. A. Gunasekaran, C. Patel and R. E. McGaughey, "A framework for supply chain performance measurement", *Int. J. Product. Econ.*, **2004**, *87*, 333-347.
14. S. K. Vickery, J. Jayaram, C. Droge and R. Calantone, "The effects of an integrative supply chain strategy on customer service and financial performance: An analysis of direct versus indirect relationships", *J. Oper. Manage.*, **2003**, *21*, 523-539.
15. Chartered Institute of Management Accountants, UK, **2013**, www.cimaglobal.com/ (Accessed: May 2013).