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https://doi.org/10.5109/24271

出版情報：九州大学大学院農学研究院紀要. 43 (1/2), pp.269-280, 1998-11. Kyushu University
バージョン：
権利関係：

J. Fac. Agr., Kyushu Univ., **43** (1·2), 269–280 (1998)

Study on Reducing Raw Milk Transportation Cost in Taiwanese Dairy Industry

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(Received June 18, 1998 and accepted August 7, 1998)

The production cost of milk products in Taiwan is higher than most countries like America, New Zealand, Australia, and European countries. The main reason is that the scale of dairy farming is too small to save the labor cost and other raw milk producing costs in Taiwan. Moreover, the marketing costs including shipping, handling cost (between farms and factories as well as between factories and consumers) and company's other marketing cost are major part of total costs. In this paper, we would like to determine optimum routes to minimize the transportation cost of raw milk between dairy farms and factories under the assumption of fixed supply and demand. We conclude that under the condition of least cost routes of classical transportation problem, we can save around 10 percent of transportation cost. Then we consider the difficulty which we face to when we try to realize the least cost route under current factory demand and area supply of raw milk in practice. Finally, we would like to consider some appropriate policy to make factories (dairy companies) cooperate with dairy farmers in order to reach the goal of least transportation cost.

INTRODUCTION

Dairy farms and factories (plants) in Taiwan are located in 14 different counties (Hsien) as shown in figure 1. The proportion of farms' raw milk producing quantity in North, Middle, South and East of Taiwan is 15%, 30%, 52%, and 3% respectively. However, the proportion of plants' raw milk processing quantity in North, Middle, South and East of Taiwan is 37%, 33.6%, 27.6%, and 1.6% respectively as in table 1. The east part of Taiwan is currently a region of self-support and self-sufficiency due to the inconvenience of transportation as well as the scarcity of population. However, comparing with western part, eastern part has not only a suitable weather, but also cheaper lands. There may be another possibility to utilize the foothills for dairy farms in eastern part. According to the above figures, this kind of unbalanced distribution between dairy farms and factories causes high transportation costs and makes raw milk easily spoiled. As the figure 1 indicates, the milk consumption (raw milk equivalent) concentrated on the north and middle of Taiwan. There must be another unbalanced distribution between factories and consumers (stores), so it is a possible topic for our next research.

As table 1 of present situation of delivering raw milk, there are 14 counties (Hsien) of raw milk supply as well as 33 factories (belonging to 29 companies) in Taiwan in the year of 1996. The biggest three companies which owns two or three factories each have 67 percent share of total raw milk processing quantity. They do not set up fixed raw milk processing quantity for each factory (as table 1 indicates, from factory 1 to factory 7), because they adjust the processing quantity among those two or three factories

(1)

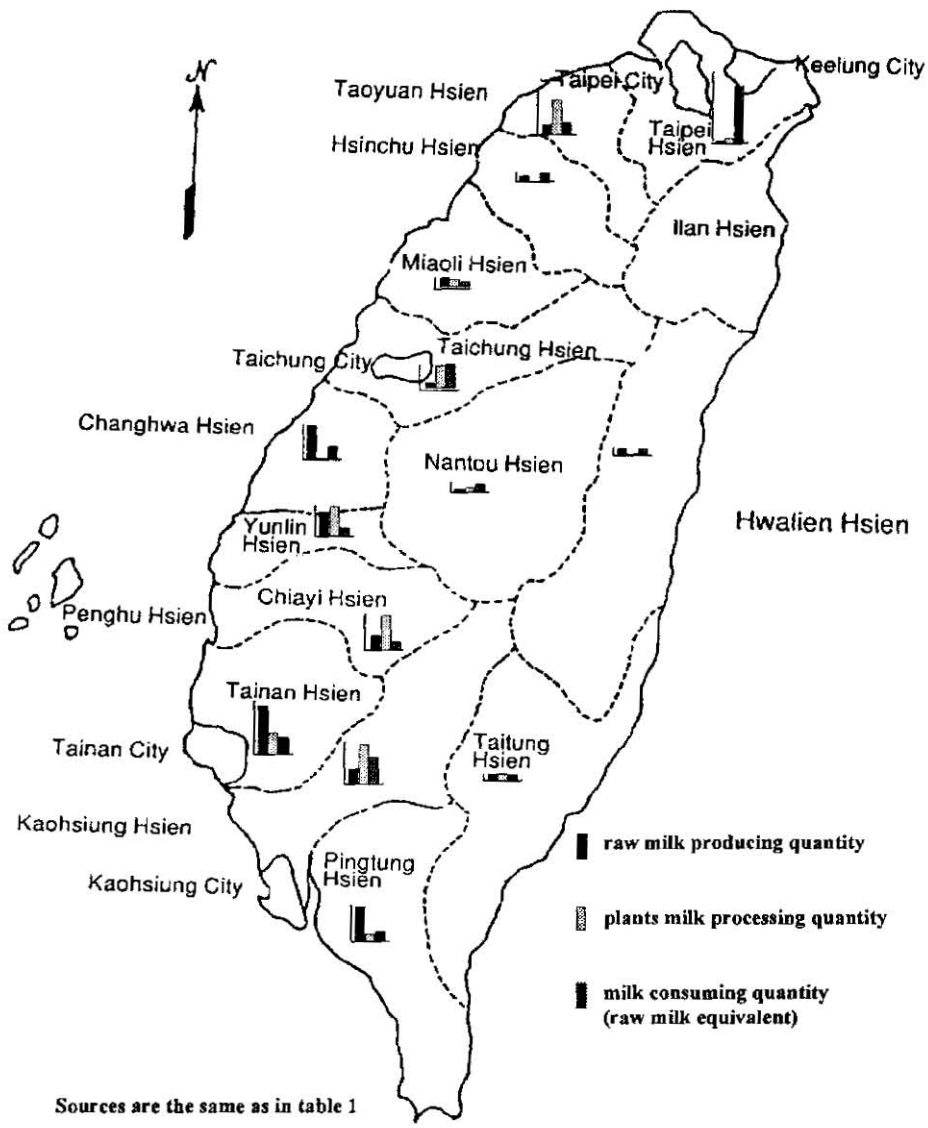


Fig. 1. Regional distributions of raw milk producing quantity, plants milk processing quantity, and milk consuming quantity (raw milk equivalent) in Taiwan in 1996

Table 1. Raw milk shipment quantity from each supply area to each factory in 1996

Unit: ton

Factory / Area(Hsien)	1[a] 1[b]	2 8	3 11	4 2	5 10	6 2	7 9	8 2	9 5	10 4	11 5	12 5	13 2	14 2	15 11	16 13	17 5
1[c] Taipei	2,580					1,602		931									
2 Taoyuan						16,442		3,147					177	347			
3 Hsinchu						6,998											
4 Miaoli				631		940				11,640		86					
5 Taichung						1,404			200		1,370		370				1,290
6 Changhwa				11,223		657			22,455			773					5,153
7 Nantou				1,184									1,497				
8 Yunlin	24,040						5,522										
9 Chiayi				7,135			9,058						2,653				
10 Tainan	8,873				26,394		29,407						5,735				
11 Kaohsiung		11,260			965		4,707								1,547		
12 Pingtung			34,909		592												
13 Taitung																3,928	
14 Hwalien					4,426												
Total	35,494	11,260	34,909	20,173	32,376	27,503	48,694	4,078	22,655	11,640	1,370	859	10,432	347	1,547	3,928	6,442
%	11.3%	3.6%	11.1%	6.4%	10.3%	8.8%	15.5%	1.3%	7.2%	3.7%	0.4%	0.3%	3.3%	0.1%	0.5%	1.3%	2.1%

Factory / Area(Hsien)	18 6	19 11	20 12	21 8	22 14	23 5	24 14	25 6	26 1	27 3	28 11	29 5	30 6	31 7	32 4	33 11	Total	%
1[c] Taipei									631								5,204	1.7%
2 Taoyuan																	20,112	6.4%
3 Hsinchu										432							7,430	2.4%
4 Miaoli	523													1,486	291		15,596	5.0%
5 Taichung									2,973			187					7,794	2.5%
6 Changhwa	1,665			2,058				376	1,097				38	2,952			48,448	15.4%
7 Nantou				457		200								544			3,883	1.2%
8 Yunlin				2,777													32,339	10.3%
9 Chiayi				1,045					1,645		215						21,752	6.9%
10 Tainan																1,701	72,111	23.0%
11 Kaohsiung			237								3,758						22,473	7.2%
12 Pingtung		2,187	9,646								173						47,507	15.1%
13 Taitung																	3,928	1.3%
14 Hwalien					503	0	587	0									5,516	1.8%
Total	2,188	2,187	9,883	6,338	503	200	587	376	6,346	432	4,145	187	38	4,983	291	1,701	314,094	100%
%	0.7%	0.7%	3.1%	2.0%	0.2%	0.1%	0.2%	0.1%	2.0%	0.1%	1.3%	0.1%	0.0%	1.6%	0.1%	0.5%	100%	

Source: Taiwan Provincial Department of Agriculture and Forestry

[a] The number from 1 to 33 represents the factories, here we do not include the name of factories (company) because of privacy.

[b] The number in this raw indicates the area which factory is located in, and same as the number represented in the column of Area.

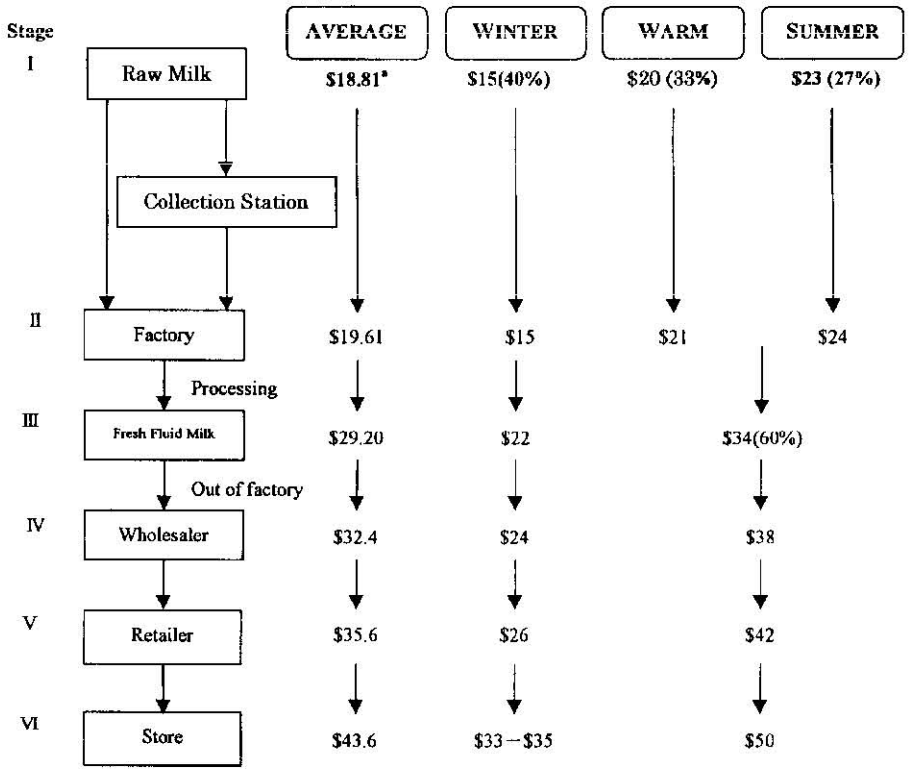
[c] The number of area from 1 to 4 indicates the north of Taiwan.
The number of area from 5 to 9 indicates the middle of Taiwan.
The number of area from 10 to 12 indicates the south of Taiwan.
The number of area from 13 to 14 indicates the east of Taiwan.

depending on the season and the local demand. Therefore, we estimated the quantity for factories from number 1 to 7 in table 1 throughout the survey including phone call and data collected of Taiwan raw milk shipment quantity from supply counties to demand companies. We made phones calls to those biggest three companies of dairy division to inquire their raw milk distribution situation for their factories. For the company owning factory 1, 2, and 3 (as shown on table 1), its factory 1 located in Taipei processes raw milk shipped from the county of Taipei, Yunlin, and Tainan; factory 2 located in Yunlin processes raw milk shipped from the county of Kaohsiung; factory 3 located in Kaohsiung processes raw milk shipped from the county of Pingtung. For the company owning factory 4 and 5 (as shown on table 1), its factory 4 processes raw milk shipped from the county of Chiayi and Chiayi's north counties; its factory 5 processes raw milk shipped from Chiayi's south counties. For the company owning factory 6 and 7 (as shown on table 1), its factory 6 processes raw milk shipped from the county of Changhwa and Changhwa north counties; its factory 7 processes raw milk shipped from Changhwa's south counties. However, those three companies do not absolutely follow this regular rule of transportation routes. As above mentioned, they may adjust the processing quantity among those two or three factories depending on the season and the local demand.

Taiwanese dairy industry

Before the study of transportation problem in Taiwanese dairy industry, a brief introduction of that industry is useful. Although consumption of milk products are getting widespread in Taiwan, the retail prices of milk products are still high and 80 percent of raw milk equivalent needs to be imported. Those imported dairy products are mainly composed of manufactured dairy products. While the raw milk production in Taiwan are mostly processed 65% for fresh drinking milk, 15% for flavored milk, 8% for long lift milk and 1% for fermented milk based on 1995 data. In figure 2, it shows that the price constitutes of fresh drinking milk in each producing and marketing stage. The distribution proportion rate of raw milk for the season of winter, warm, and summer are 40%, 27%, and 33%, respectively. Thus, we calculate the raw milk price of $18.81/kg. for the average factory purchase price of 1990 according to the rate. However, most factories need to pay subsidies of transportation fee to the dairy farmers and take the risk of loss or spoiled, so we add $0.8/kg. for those costs which lead the total cost to $19.61/kg.. From the stage 2 to stage 3, we estimated that the average processing cost is $9.59/kg. based on the survey of factories, which we may consider it is so high to cover 33% of selling price out of factory (9.59/29.2=33%). Moreover, we can tell that the marketing cost is quite high from the stage 3 to stage 6 which almost reaches 73 percent of a factory's material cost.

Based on the above analyses, it shows one feature of fresh drinking milk price constitution that each stage's cost seems very high. Especially, the purchase price of raw milk for factories is over 60% of factories' total cost. That is because Taiwanese government sets up the high guarantee purchase price for raw milk. Furthermore, the purchase price of raw milk through the negotiation of dairy farmers and factories becomes two dollars higher than before from June of 1997 due to global price increase of fertilizers and labor cost increase in Taiwan. The current imported dairy products of Taiwan are mainly composed of manufactured milk products, however, it will be asked to



Unit: NT$/kg.
Source: Taiwan Council of Agriculture, November 1991, based on 1990 data of milk factories
Winter: Dec., Jan., Feb., Mar. Warm: Apr., May, Oct., Nov. Summer: Jun., Jul., Aug., Sept.
(%): proportion of milk quantity in that season to all of the year
* The purchase price becomes 2 dollars higher from June of 1997.

Fig. 2. Average price of fresh drinking milk in each producing and marketing stage in 1990

open more market share for fluid milk including flavored milk, long lift milk and fermented milk when Taiwan becomes a member of WTO (World Trade Organization). (Lio, H. M. 1997) If the price of Taiwan milk products still continues to maintain in such high level, it may face the problem of competition with imported products in the near future due to an open market. Therefore, under the trend of liberalization and internationalization, Taiwanese dairy industry will be asked to reduce tariffs and trade

subsidies, limit production quota, lower price support as well readjust dairy structure. Some dairy farmers may suffer from discontinuance of farm operation because of severe competitions.

On the other side, the cost of raw milk production compared with other countries seems too high (table 2). The environment of raw milk production in Taiwan is very close to Japan's. Table 3 tells us that the cost of fertilizes and wages holds obviously an important proportion. To reduce those costs is not an easy work, so the better way to solve the problem should be increasing the productivity in both countries. Some reasons causing low productivity, especially for Taiwan, are the weather, dairy farm operations and technologies and etc.. It seems difficult to improve those factors not only because of the cost but also the uncontrollable natural conditions such as weather, location, and geographical features.

Table 2. Comparison of dairy related data among selected countries

		Number of dairy farms	Number of cows	Cows per farm	Total milk production	Milk per cow	Production cost per 100 kg.
Country	Year	Number	1000 head	Number	1000 ton	kg.	US$
Taiwan	1995	968	66	69	318	4,788	47.52 (100)
Japan	1994	48,000	1,247	26	8,388	6,726	64.95 (80~)
German	1993	275,000	5,293	17	34,097	6,314	38.94 (200)
America	1994	148,690	9,525	64	80,322	8,433	28.08 (172)
England	1989	47,000	2,933	62	16,822	5,854	23.62 (207)
New Zealand	1994	14,649	2,831	193	12,057	4,259	15.01 (181)

Source: Taiwan Council of Agriculture; The MAFF of Japan, Statistics of Livestock Products
EC Dairy Facts & Figures; Statistics New Zealand, LIC; USDA Agricultural Statistics

Table 3. Composition of raw milk production cost in Taiwan and Japan

Unit: US$/per 100 kg. raw milk, %

	Fertilizers	Wages	Replacement livestock	Interest	Machine & facility depreciation	Others	Total
Taiwan (1995)	25.83	6.34	5.72	2.59	2.44	4.6	47.52
%	54.36	13.34	12.04	5.45	5.13	9.68	100
Japan (1995)	29.06	14.09	12.53	1.65	1.95	5.67	64.95
%	44.74	21.69	19.29	2.54	3.00	8.73	100

Source: Lui, Shoa Yin 1996 Booking analysis of dairy farm management in Taiwan. Taiwan Council of Agriculture
Taiwan Livestock Research Institute
The Ministry of Agriculture, Forestry and Fisheries of Japan, Statistics and Information Department

In this paper, we will not discuss how to increase production or reduce the producing or marketing cost by changing any factors mentioned above. We would rather study how to lower the transportation cost of raw milk under current condition of its demand and supply. Thus, we only consider the stage of shipping raw milk from dairy farms to factories while ignoring processing stage and the procedure of shipping milk products from factories to retail stores, and test if current raw milk shipping system is under least transportation cost.

THEORETICAL MODEL AND APPLICATION

Specification of theoretical model–classical transportation problem

We specify the problem of determining the least cost solution for both of raw milk shipping quantity and shipping routes as classical transportation problem as follows.

$$\text{Minimize } z=\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}\,x_{ij}$$

Subject to the following conditions:

$$\sum_{j=1}^{n} x_{ij} = a_i, \quad i=1,2,\cdots,14$$

$$\sum_{i=1}^{m} x_{ij} = b_j, \quad j=1,2,\cdots,33$$

$$x_{ij} \geqq 0, \quad i=1,2,\cdots,m; \quad j=1,2,\cdots,n \qquad \text{m=14} \quad \text{n=33}$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \quad \text{(total supply quantity =total demand quantity)}$$

where

c_{ij} : unit transportation cost from supply area i to factory j (table 4)
x_{ij} : shipment quantity from supply area i to factory j
a_i : supply quantity of area i shown in table 1 (total of raw i)
b_j : demand quantity of factory j shown in table 1 (total of column j)

The table 4 indicates the unit raw milk transportation cost between supply areas and factories by milk tank lorries. Actually, it is very difficult to collect the data of transportation fee between all of the factories and dairy farms. As a result, we did the survey for some companies or factories to calculate the average unit raw milk transportation cost. The amount of the subsidies of raw milk transportation cost which factories pay to dairy farmers is based on the distance. The unit raw milk transportation cost is NT$0.4/kg. for distance under 50 kilometer (km.), $0.65/kg. for distance from 51 km. to 100 km., $0.9/kg. for the distance from 101 km. to 150 km., $1/kg. for distance from 151 km. to 200 km., $1.2/kg. for distance from 201 km. to 250 km., and $1.4/kg. for distance over 250 km..

Optimal solution of the transportation problem and its implication

We solved the classical transportation problem specified above by linear programming

Table 4. Unit of raw milk transportation cost in 1996

Unit: NT$/ton

Area(Hsien) \ Factory	1[a]	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Taipei	400	1200	1400	400	1400	400	1200	400	1000	900	1000	1000	400	400	1400	1400	1000
2 Taoyuan	400	1000	1400	400	1200	400	1200	400	900	650	900	900	400	400	1400	1400	900
3 Hsinchu	650	900	1200	650	1200	650	1000	650	650	400	650	650	650	650	1200	1400	650
4 Miaoli	900	900	1200	650	1000	650	900	650	650	400	650	650	650	650	1200	1400	650
5 Taichung	1000	650	1000	900	900	900	650	900	400	650	400	400	900	900	1000	1400	400
6 Changhwa	1000	400	1000	900	900	900	650	900	400	650	400	400	900	900	1000	1400	400
7 Nantou	1000	400	1000	1000	900	1000	650	1000	650	900	650	650	1000	1000	1000	1400	650
8 Yunlin	1200	400	900	1000	650	1000	400	1000	650	900	650	650	1000	1000	900	1400	650
9 Chiayi	1200	400	650	1200	650	1200	400	1200	650	900	650	650	1200	1200	650	1400	650
10 Tainan	1400	650	400	1200	400	1200	650	1200	900	1000	900	900	1200	1200	400	1400	900
11 Kaohsiung	1400	900	400	1400	400	1400	650	1400	1000	1200	1000	1000	1400	1400	400	1200	1000
12 Pingtung	1400	900	400	1400	400	1400	650	1400	1000	1200	1000	1000	1400	1400	400	1200	1000
13 Taitung	1400	1400	1200	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1200	0	1400
14 Hwalien	1400	1400	1400	1400	1400	1400	1400	1400	1200	1400	1200	1200	1400	1400	1400	1200	1200

Area(Hsien) \ Factory	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1 Taipei	1000	1400	1400	1200	1400	1000	1400	1000	400	650	1400	1000	1000	1000	900	1400
2 Taoyuan	900	1400	1400	1000	1400	900	1400	900	400	650	1400	900	900	1000	650	1400
3 Hsinchu	650	1200	1200	900	1400	650	1400	650	650	400	1200	650	650	900	400	1200
4 Miaoli	650	1200	1200	900	1400	650	1400	650	900	400	1200	650	650	900	400	1200
5 Taichung	400	1000	1000	650	1200	400	1200	400	1000	650	1000	400	400	650	650	1000
6 Changhwa	400	1000	1000	400	1400	400	1400	400	1000	650	1000	400	400	650	650	1000
7 Nantou	650	1000	1200	400	1400	650	1400	650	1000	900	1000	650	650	400	900	1000
8 Yunlin	400	900	900	400	1400	650	1400	400	1200	900	900	650	400	400	900	900
9 Chiayi	650	650	650	400	1400	650	1400	650	1200	1000	650	650	650	650	900	650
10 Tainan	900	400	400	650	1400	900	1400	900	1400	1200	400	900	900	900	1000	400
11 Kaohsiung	1000	400	400	900	1200	1000	1200	1000	1400	1200	400	1000	1000	1000	1200	400
12 Pingtung	1000	400	400	900	1200	1000	1200	1000	1400	1200	400	1000	1000	1200	1200	400
13 Taitung	1400	1200	1200	1400	1200	1400	1200	1400	1400	1400	1200	1400	1400	1400	1400	1200
14 Hwalien	1400	1400	1400	1400	0	1200	0	1400	1400	1400	1400	1200	1400	1400	1400	1400

Source: 1998 Taiwan Walking Internet, for data of road distances

The data of unit transportation cost is through factories survey.

[a] The number from 1 to 33 represents the factories, here we do not include the name of factory (company) because of privacy.

When the factory is in the same place of supply area (factory owns its own dairy farms) we consider that the unit raw milk transportation cost is "0".

method, and the results are shown in table 5 with the related data, indicating the optimum routes and quantity. The all transportation routes have a lot of change comparing in both of table 1 and table 5. The number of transportation routes in table 1 is 69 and it shifts to 45 in table 5 excluding one route which quantity is zero, which means it simplifies the transporting method for the whole milk industry under the optimal solution of least transportation cost.

It should be noted here that optimal solution of classical transportation problem is usually not unique. We can usually find many sets of optimal solutions. For example, all of the following sets of solutions are optimal.

$x_{11}=3284+\alpha$	$x_{1,26}=1920-\alpha$	
$x_{21}=20112-\alpha$	$x_{2,26}=\alpha$	$0\leq \alpha \leq 1920$
$x_{51}=595-\beta$	$x_{59}=\beta$	
$x_{61}=190+\beta$	$x_{69}=22655-\beta$	$0\leq \beta \leq 595$
$x_{82}=\gamma$	$x_{87}=18416-\gamma$	
$x_{10,2}=11260-\gamma$	$x_{10,7}=8526+\gamma$	$0\leq \gamma \leq 11260$

the values of other 450 ($=33\times14-12$) x_{ij} are as same as that in table 5

We can change the value of parameters α, β, γ and adjust the quantity of each route without changing total transportation cost. Thus, we can find infinite number of optimal solutions. If the value of β increases, the transportation cost of area 5 will reduce and it will increase in area 6. In addition, if the value of γ increases, the transportation cost of factory 2 will reduce and it'll increase in factory 7. Thus, it is obvious that the transportation costs for each factory are usually different depending on the optimal solution used.

RESULTS AND DISCUSSION

The delivery routes and quantities of raw milk is determined by individual company and dairy farmers with the contracts, with support and supervision from the government, Taiwan Provincial Department of Agriculture and Forestry. First of all, the government determines the standard raw milk price based on the production cost of raw milk. In addition, the factory pays the amount to dairy farmers based on the standard price and adjusts it according to the raw milk quality. (Lio, Y. C. 1996)

Based on the data in table 1 and table 4, we can calculate the total current transportation costs, equal to 198,812,230 NT dollars (about 7,231,902 US dollars). Furthermore, the total transportation costs decrease to 178,786,550 NT dollars after applying the optimum routes. It means that the total raw milk industry can save about 10 percent of transportation costs if the raw milk delivering system is according to optimum routs.

The problem here is how to create an improved system to reach the goal of least transportation cost. According to table 5, some factories show an increase of transportation costs, but the others show a decrease. Nevertheless, the whole milk industry can save about 10 percent of transportation cost by utilizing the optimum routes in table 5. There is one possible method to allocate those 10 percent save to each

Table 5. Optimal solution of the transportation problem and related data

Unit of quantity: ton

Factory / Area(Hsien)	1* 1**	2 8	3 11	4 2	5 10	6 2	7 9	8 2	9 5	10 4	11 5	12 5	13 2	14 2	15 11	16 13	17 5
1 Taipei	3,284																
2 Taoyuan	20,112																
3 Hsinchu	7,430																
4 Miaoli										4,441			1,0432				
5 Taichung	595									7,199							
6 Changhwa	190					16,197			22,655		1,370	860		347			6,442
7 Nantou	3,883						18,416										
8 Yunlin							21,752										
9 Chiayi																	
10 Tainan		11,260		20,173	13,034	11,306	8,526	4,078							1,547		
11 Kaohsiung					6,743												
12 Pingtung			34,909		12,599												
13 Taitung																3,928	
14 Hwalien																	
Total Quantity	35,494	11,260	34,909	20,173	32,376	27,503	48,694	4,078	22,655	11,640	1,370	860	1,0432	347	1,547	3,928	6,442
A=T.M.T.C.	18,856	7,319	13,964	24,208	12,950	28,145	21,609	4,894	9,062	6,456	548	344	6,781	312	619	0	2,577
B=T.C.T.C	42,303	10,134	13,964	20,257	17,376	14,016	28,006	1,631	9,062	4,656	548	365	11,967	139	619	0	2,577
D=B*TA/TB	38,042	9,113	12,557	18,217	15,626	12,604	25,185	1,467	8,149	4,187	493	329	10,762	125	556	0	2,317
D-A	19,186	1,794	-1,407	-5,991	2,676	-15,541	3,576	-3,427	-913	-2,269	-55	-15	3,981	-187	-63	0	-260

Factory / Area(Hsien)	18 6	19 11	20 12	21 8	22 14	23 5	24 14	25 6	26 1	27 3	28 11	29 5	30 6	31 7	32 4	33 11	Total
1 Taipei									1,920								5,204
2 Taoyuan																	20,112
3 Hsinchu																	7,430
4 Miaoli										432					291		15,596
5 Taichung																	7,794
6 Changhwa						200						187					48,448
7 Nantou																	3,883
8 Yunlin	2,188			6,338				376					38	4,983			32,339
9 Chiayi																	21,752
10 Tainan		2,187															72,111
11 Kaohsiung			9,884								4,145					1,701	22,473
12 Pingtung									0								47,508
13 Taitung																	3,928
14 Hwalien					503		587		4,426								5,516
Total Quantity	2,188	2,187	9,884	6,338	503	200	587	376	6,346	432	4,145	187	38	4,983	291	1,701	314,094
A=T.M.T.C.	875	875	3,954	2,535	0	80	0	150	6,964	173	1,658	75	15	1,993	116	680	178,787
B=T.C.T.C	1,006	875	3,953	2,535	0	130	0	151	6,297	173	1,712	75	15	3,474	116	680	198,812
D=B*TA/TB	905	787	3,555	2,280	0	117	0	135	5,662	155	1,539	67	14	3,124	105	612	178,788
D-A	30	-88	-399	-255	0	37	0	-15	-1,302	-18	-119	-8	-1	1,131	-11	-68	

*,** the number indicates are same as the number in table 1

Unit of A, B, and D is NT$ 1,000

A=T.M.C.=total minimum transportation cost of each factory

B=T.C.T.C.=total current transportation cost of each factory

D=B×Total of A/Total of B=B×(178,787/198,812)

D-A=Difference amount which each factory should pay (when D-A is positive) or receive (when D-A is negative)

factories as the follow.

Approach system applied to the practice

First, we calculate 90 percent of original transportation cost for each factory (we can get this figure 89.93% by computing least transportation cost divided by total current transportation cost showed in table 5), then figure out every factory's difference (in table 5 indicated in row of "D–A") between 90% of its original transportation cost and transportation cost under optimum routes. If the difference of some factory turns out to be positive, it means efficiency under optimum system for this factory. This factory can also offer the difference amount to the factories which difference are negative. Otherwise, the factories with negative difference can receive difference payments. Finally, every factory can save 10 percent of transportation costs if the system can be operated effectively. The only way is that all of factories need to cooperate well with each other to adjust their transportation routes and to allocate the difference payment rationally.

CONCLUSION

We specified the classical transportation problem to find out the least cost solution for both raw milk shipping quantity and shipping routes in Taiwan. We also illustrated how to effectively implement the least cost solution. In this case, dairy industry in Taiwan can save about 10 percent of raw milk transportation cost under least cost solution. To reach the goal, we need to create an appropriate system to allocate those 10 percent save to each factory and areas for implementing the least cost efficiently. Otherwise, we will not be able to realize those 10 percent save without organizing appropriate system to allocate it effectively.

According to the similar studies in Japan, they show that Japan dairy industry will be able to save about 11.9 percent of raw milk transportation cost in September 1995, 17.1 percent in November 1996, and 28.8 percent in December 1996 (Kawaguchi, 1997), if the least cost solutions of transportation problems are practiced effectively by appropriate systems to allocate those saves.

There are still some problems cannot be overcome in our study. For example, in this case we assume all of transportation fee are paid by the factories, but actually some factories pay only part of it. Another problem is regarding the method of distance measurement, in this study we use the length of highway to measure the distance between two area (Hsien). For that reason, it may be a little different from the actual driving distance. In such cases, we need to use other appropriated method to allocate those 10 percent save to each factory and to each areas. We will try to measure the actual driving distance to improve our analyses in future study.

The most important remark to make about this paper's model is that we specified the model in short–run under the assumption of given demand and supply. However, both demand and supply may vary in the long–run following the price change and other related changes. Therefore, in next paper, we are going to discuss the spatial equilibrium in the long–run and to find out the equilibrium solutions for each supply area and each factory demand as well as equilibrium prices.

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