ASEAN Journal of Management & Innovation
Vol. 6. No. 1, 102 - 117

DOI: 10.14456/ajmi.2019.8
ajmi.stamford.edu
Received: February 27, 2019
Revised: May 30, 2019
Accepted: June 4, 2019

Generalized Markov Method for Ranking Supplier Performance in the Herbal Industry: A Case Study of a Herbal Village in Thailand

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Abstract
The Thailand herbal market is expected to grow 10 percent a year, but it grew more than 30 percent in 2017. There are more than 11,861 acres of herbal farms, but this is not enough for the Thai herbal market. The government plans to promote supply chain, both upstream and downstream. This study measures the supplier performance of the households in Thapthim Siam 05 herbal community in Thapthim Siam 05 village which supplies Wang Namyen Hospital. Households have planted herbs and already received Good Agricultural Practices (GAP) certificates. Four supplier selection criteria were selected. They include cost, productivity are employed to evaluate and rank performances. The ranking is divided into three levels, which are excellent, good, and moderate. Performances at the excellent level can be further improved in order to receive a higher ranking in the future. Recommendations for each level of performance are also discussed., quality, and time. In addition, in-depth interview of suppliers were conducted and quantitative data collected. The Generalized Markov (GeM) method and the Power method

Keywords: Generalized Markov Method (GeM), Power method, Ranking, Supplier performances, Thapthim Siam.

1. Introduction
Today, a growing number of people concentrate on their health and wellbeing by using fewer chemical products and consuming organic and products, for instance, concoctions made from herbs. In Thailand, many people use herbs in their daily lives, be it in their food or as traditional treatments. The use of herbal products, however, is not only increasing in Thailand but also in many parts of the world. As reported by Tawichaphat, the chairman of the Thai herbal association and the director of Thai Health and Beauty Federation, in 2015, the exports of Thai dietary herbal supplements accounted for USD 11.43 billion; a 5 percent rise from 2014. Satisfying the domestic and international consumer demands generates massive revenue for Thailand. According to Choklumlert, the Rector of the Department of International Trade Promotion (DITP), Ministry of Commerce of Thailand, (2016), the global herbal supplements and remedies market is around USD 83 billion. This market is predicted to reach USD 110 billion by 2020, encouraged by a growing aging population and increasing consumer perception of general health and well-being.

In 2016, the Public Health Ministry announced that the Thai government had adopted a policy to develop Thai herbs in a systematic manner and on a sustainable basis so that Thai herbs would be grown with higher efficiency. The strategy outlined in the National Plan for Thai Herbal Development Volume 1 (2017-2022) aims to promote the production of Thai herbal plants in response to the market demand in Thailand and overseas and to make Thai herbs competitive in the international market. Among the measures adopted, specifications and criteria for land or areas for organic herb farms have been designed. This is meant to make herbal medicine in health services widely recognized and add economic value to them. The plan also establishes role models for medium-sized hospitals, which are to provide both physician and traditional Thai treatments.

There is, however, no study of herb farms supplying these community hospitals, a gap which this research study aims to bridge as it focuses on the herb farms that sell their products directly to such hospitals. More specifically, the farms involved in this research include herb farms supplying Wang Namyen Hospital, a community hospital selected as one of the eight pioneer role-model hospitals. Operating since 2010, this hospital provides traditional Thai treatments and Thai herbal products and manufactures the herbal products used as oils and drugs. The hospital distributes them to all government hospitals in Sa Kaeo. The hospital purchases the herbs directly from Thapthim Siam 05 herbal community. This enables the people in the community to have additional income from the herbs sold to the hospital. The herbal farm community does not use any harmful substances, such as insecticides and chemical fertilizers. The herbal farm are 1,600 square meters, and they can plant herbs freely.

Since there is to date no assessment of the performance of the households growing herbs in that community, the objective of this study is to evaluate household performances and develop a framework of ranking using the Generalized Markov (GeM) method. To do so, this research determines the critical factors for constructing a ranking model in order to rank the performance level of each participating household. Policy recommendations are proposed to improve the effectiveness of the supply chain performance. The assessment of upstream supply chains will help to improve productivity while maintaining the traditional benefits of each herb.

2. Literature Review

The literature review identifies criteria for measuring supply chain performance in SMEs and agricultural businesses.

2.1 Criteria Based on Supply Chain Performance Measurement

Performance strategy should be continuously improved by identifying contributing criteria for enterprises to consciously know their own competencies and weaknesses (Maarof & Mahnud, 2016). It is critical to understand the criteria of the enterprises in order to improve their performance and sustain their competitiveness (Banomyong & Supath, 2011). In addition, the primary market of dairy, food, brewery, pharmaceutical, chemical, and allied process industries should manage the upstream supply chains or focus on their raw material suppliers (Thakkar et al. 2009). As indicated by the relevant body of literature, the main factors that influence supply chain performance are time, cost, quality, production/productivity, technology and innovation, information, and reliability. Each factor is briefly discussed. The time criterion includes lead time (Lusine et al., 2007), which is a time interval for beginning and completing the production process. There is also the performance time of each process, to define the shortest manufacturing lead time (Huin et al., 2002; Chow et al., 2008) depending on the characteristics of the products or materials (Banomyong & Supath, 2011).

In the agricultural sector, the reduction of the processing time is essential in areas with several cropping seasons, where early crop establishment can contribute to higher yields for the following crop (Food and Agricultural Organization of the United Nations, 2018. Cost, another of the main criteria in business activity performance and processing evaluation, includes operational costs for controlling expenses and asset management (Banomyong & Supath, 2011) for cost control in the processes (Maarof & Mahmud, 2016) and in spending (Huin et al., 2002). Other expenses incurred include raw material cost, (Banaeian et al., 2015; Hassan et al., 2014), machinery/equipment cost, inspection/quality checking cost, maintenance cost (Anuar & Yusuff, 2011), transportation cost, and inventory cost (Anuar & Yusuff, 2011). In agriculture, operational costs chiefly consist of seeds, fertilizers, sprays, sundries, and labor cost (Caskie, 2017).

It is also essential to control the quality of the product (Banaeian et al., 2015). Service quality and product quality should be quality criteria (Takkar et al., 2009) in order to regain the capabilities of a process and get better quality (Quayle 2003). A quality inspection may include procedural inspection and final inspection testing and procedure for handling, storage, and packaging (Anuar & Yusuff, 2011). Therefore, quality control measures must ensure that food products meet certain safety and quality standards and play a key role in agricultural processing (Saak, 2016). Quality can be measured based on either intrinsic or extrinsic indicators. Intrinsic indicators include: flavor, texture, appearance, shelf life, and nutritional value (Mutonyi & Gyau, 2013; Aramyan et al., 2006).

In the Thai agricultural industry, quality is guaranteed by the Good Agricultural Practice (GAP) (Peni, 2018). Monitored by the National Bureau of Agricultural Commodity and Food Standard of Thailand, the GAP contains 8 principles for agricultural procedures: (i) no hazardous contamination water resources: (ii) no hazardous contamination in agricultural sites/crops; (iii) farmers/practitioners must have knowledge of agrochemicals use, (iv) follow a cultivation process and pre-harvest practices for ensuring specified agricultural product standard; (v) harvesting methods and post-harvest practices must not affect the product quality and must not contain contamination which affects consumer safety; (vi) sites are hygienically and products are transported to storage for protecting the quality of products from hazards affecting consumer safety; (vii) farmers/practitioners are trained to perform procedures correctly and hygienically; and (viii) data are recorded to evaluate and identify the resources, use of agricultural hazardous substances, agricultural procedures, and information of merchandisers.

Productivity is a good indicator of the land conditions, since it directly reflects changes in the quality and limitations of the land. Sustained productivity goes hand in hand with good management practices (Food and Agricultural Organization of the United Nations, 2018). Therefore, the performance of productivity should be identified at a high level due to the limited resource (Thakkar et al., 2009; Hudson et al., 2001). Crop yields are the harvested production per unit of harvested area for crop products. The farm size can be small, medium, and large with more than 100 hectares, between 100 and 200 hectares, and more than 200 hectares, respectively (Taylor & Grieken, 2015).

Most small enterprises use limited and old technology, and few manufacturers have modern equipment (Hassan et al., 2014). Innovation and learning measures should be introduced for resolving obstacles and identifying processes and problems (Souse et al., 2006). Technology and innovation in agribusiness can combine human resources and knowledge of technology and innovation, to develop farms that adapt to future changes and increase performance (Lee & Nuthall, 2015).

The sharing of information between a producer and a supplier can help in the planning of the production processes and benefit both harmoniously (Maarof and Mahmud, 2016; Chow et al., 2008). Information criteria thus involve developing a close relationship with customers. (Maarof and Mahmud, 2016). Knowledge resources are especially critical for a supplier. Exchanging information between a purchaser and a supplier can motivate them to learn new knowledge. This can also reduce perceived risk by sharing goals and values for short and long-term commitments (Lee & Nithall, 2015).

The reliability criteria should be evaluated for improving an SMEs' performance (Banomyong & Supath, 2011). This includes, for instance, the reliability of delivery (Moon et al., 2014; Chow et al., 2008). Delivering products on-time is essential in the agricultural industry (Maarof & Mahmud, 2016).

A summary of these criteria is shown in Table 1. Although the number of criteria discussed is higher, only four will be selected for this study as they account for 75 percent of the frequency analysis. They include time, cost, quality, and productivity. The reason technology and innovation were not selected is because they are minimally used in herbal farms.

Table 1: Summary of Reviewed Criteria

No.	**Year**	**Author**	**Time**	**Cost**	**Quality**	**Production**	**Technology/ Innovation**	**Information**	**Reliability**	**SME Manufacturing**	**Agricultural Business/ Industry**
1	2018	Amegnaglo		*	*	*					*
2	2017	Lethra et al.	*	*	*	*	*				*
3	2016	Maarof & Mahmud	*	*			*			*	
4	2015	Lee & Nuthall			*		*	*			*
5	2015	Banaeiam et al.	*	*	*		*				*
6	2014	Hussan et al.	*	*	*		*			*	
7	2014	Moon et al.	*	*	*	*	*	*		*	
8	2013	Michael et al.	*	*	*	*				*	
9	2013	Mutonyi & Gyau			*	*		*			*
10	2011	Banomyong & Supath	*	*		*			*	*	
11	2011	Anuar & Yusuff	*	*	*	*	*	*		*	
12	2009	Thakkar et al.	*	*	*	*	*			*	
13	2008	Chows et al.	*	*		*		*	*	*	
14	2007	Bhawat & Sharma	*	*	*	*	*	*		*	
15	2007	Lusine et al.	*	*	*	*			*		*
16	2006	Sousa et al.	*		*	*	*			*	
17	2003	Quayle	*	*	*	*				*	
18	2002	Huin et al.	*	*	*	*		*		*	
Count			15	15	15	14	10	7	3	12	6
Percent (%)			19	19	19	18	13	9	4		
Cumulative Percent (%)			19	38	57	75	87	96	100		

2.2 The Generalized Markov (GeM) Method

The ranking of an object is its relative importance compared to other objects in a finite set of size n. For instance, for any two items, the first item is either ranked higher than, lower than, or equal to the second item. Ranking models have been applied for a long time. Ranking models produce ratings, rankings or arranging of the objects from a given scenario. The ratings can be calculated from selected criteria. The use of mathematical methods to develop rankings of supplier selection is indeed not a new idea. There have been many models for predicting the ranking of suppliers. A general approach to develop a mathematical ranking method is to create a matrix with entries that are determined by the results of criteria for each supplier. This study introduces a method that can be utilized for predicting the ranking of the herbal supplier selection. It also uses the GeM method, which is similar to the PageRank algorithm. The PageRank algorithm was developed by Brin and Page in 1998. PageRank produces a rating score for each of the identified web pages on the World Wide Web (www).

These rating scores are then used to rank the web pages. The algorithm is based on the elegant theory of graphs and the theory of GeM method (Mayer, 2000). The concept of PageRank is as follows. The initial step is to represent the www using a directed graph where web pages are the nodes and hyperlinks between the web pages the directed edges. Each directed link represents a hyperlink from one web page to another. An adjacency matrix of order *n*, *A*, is formed to summarize the web graph structure as:

$$A_{ij} = \begin{cases} 1 \; if\ here\ exists\ a\ link\ from\ node\ i\ to\ node\ j \\ 0 \; otherwise, \end{cases}$$

where n is a number of web pages. After that, the normalized hyperlink matrix, *H*, is constructed as:

$$H_{ij} = \begin{cases} 1/r_i \; if\ here\ exists\ a\ link\ from\ node\ i\ to\ node\ j \\ 0 \; otherwise, \end{cases}$$

where r_i is the i^{th} row sum of adjacency matrix *A*.

For the dangling nodes (a page that has no link), the *H* matrix is not a stochastic matrix. Brin and Page (1998) proposed a way to fix the row of zeros in *H* by replacing the normalized row vector that each element is set to (Langville & Meyer, 2011). This procedure is equivalent to adding directed edges, each with a weight, from node *i* to *j* and every other node in the directed web graph. After the modification of matrix *H*, a stochastic matrix *S* is determined. A non-negative matrix is stochastic if its row sums are equal to 1. Assuming *e* is a column vector of all ones and *a* a column vector such that a_i is zero if row *i* of *A* is nonzero and a_i is 1 otherwise, the matrix *S* can then be expressed as:

$$S = H + 1/n\, ae^T \quad (1)$$

To use the concept of GeM and the theory of nonnegative matrices, it is necessary to form an irreducible matrix *G*. A non-negative matrix is called irreducible if and only if the corresponding directed graph is strongly connected. Using the rank 1 update and applying the convex combination to matrix *S* is the simplest way (it will still obtain all information of matrix *S*). The matrix *G*, the Google matrix, can be therefore be written as:

$$G = \alpha S + (1-\alpha) ev^T \quad (2)$$

where *v* is a positive probability distribution vector and $0 < \alpha < 1$. Since *G* is a nonnegative irreducible matrix, the largest eigenvalue of *G* is 1, and there exists a unique positive corresponding left eigenvector π such that:

$$\pi^T = \pi^T G. \quad (3)$$

Thus, using the GeM method, the probability distribution vector for matrix *G* and the i^{th} entry is the rating score of the i^{th} webpage. Even though the size of matrix *G* is huge, it is primitive, which means *G* has only one dominant eigenvalue on the spectral radius (Meyer, 2001).

The Power Method is used to measure the largest eigenvalue and its corresponding eigenvector of *G*. The power method can be used to find the stationary vector of a Markov chain. The power method applied to *G* and the equation can be expressed in terms of the very sparse *H:*

$$\pi^{(k+1)T} = \pi^{(k)T}G$$
$$\pi^{(k+1)T} = \alpha\pi^{(k)T}S + ({}^{1-\alpha}/n)\pi^{(k)T}\,\mathrm{ee}^{T}$$
$$\pi^{(k+1)T} = \alpha\pi^{(k)T}H + (\alpha\pi^{(k)T}\mathrm{a} + 1 - \alpha)\mathrm{e}^{T}/n. \quad (4)$$

Since it is an iterative method, the power method continues until some termination criterion is met. The traditional termination criterion for the power method is triggered when the residual is less than some predetermined tolerance, which is 10^{-16}, and the rate of convergence of the Power method on matrix *G* is affected by the value of α (Langville & Meyer, 2011).

3. Methodology

First, documentary research from literature surveys, journals, articles, and previous research works were analyzed for the selection of suppliers for small and medium enterprises (SME) performance. Data were collected from research published in credible international journals. Second, this research utilized a cluster sampling method by focusing on Thapthim Siam 05 herbal community. Data were collected from every household. In addition, in-depth interviews were conducted with all qualified farmers. The collected data from the interviews pertain to the related cost of production, inputs, and outputs for each household, the defect rate of outputs, and preprocessing time.

The instruments used in this study were a questionnaire survey and a topic of discussion for the in-depth interviews. Survey questionnaires were used to collect data from selected households that plant the herbs and have already received the Good Agricultural Practices (GAP) certificate at the selected period. The questionnaires for each household were divided into two parts as shown in Table 2. The questions addressed the performance-based outcomes by using obtained criteria affecting supplier selection. The first part covers some general information about each household and the second part information about the criteria.

Table 2: Study Questionnaire

Section	Question
General information	• Name of the household • Experience as measured by the number of years of planting herbs • Number of herb types currently grown at each house • Selling price of each herb • Total size of land used to grow herbs
Output	• Amount of planted herbs in kilograms • Yield of herbs in kilograms • Amount of herbs sold to the hospital in kilograms • Percentages number of herbs that pass the quality inspection
Cost	• Cost of land preparation, including labor and bio-fertilizer costs • Cost of cropping and planting the herbs • Cost of harvesting, including labor and transportation costs
Time	• Pre-processing (a period recorded in days for preparing each plot before planting the herbs). This period includes the rough plowing (for the first time) and the plowing in regular furrows (for the second time) in days

In addition, interviews were conducted with government officials at the hospital to obtain information on the demand side. The amount of purchased herbs from each household and their prices are recorded. The four criteria are shown in Table 3.

Table 3: Definition of Criteria

Criterion	Definition
Cost	The expenditure of the farmer from pre-processing to the post-processing; These costs include fertilizer cost, cropping cost, harvest cost, labor cost, transportation cost, and land preparation cost but exclude inspection cost since the primary inspection can be checked by the household without using extra equipment and additional labor.
Productivity	The crop yield is the harvested production per unit of harvested area for crop products as tons per hectare, used as the productivity in this study.
Quality	The percentage of primary inspection failure is checked by visual, taste and scent inspections before selling products to customers.
Time	This is the pre-processing time or land preparation time of the farm

Analysis of Generalized Markov (GeM) Method

After collecting the data, the GeM method is employed to classify each criterion and rank the overall performance of participating households. Table 4 shows the notation used to represent the model and equations of this study.

Table 4: Notation Used in this Research

Symbol	Description	Symbol	Description
n	Total number of households	i	Households in the matrix in horizontal
C	Cost matrix	j	Households in the matrix in vertical
P	Productivity matrix	c_{ij}	Cost for each household in matrix C
Q	Quality matrix	p_{ij}	Productivity for each household in matrix P
T	Time matrix	q_{ij}	Quality for each household in matrix Q
CS	Cost-stochastic matrix	t_{ij}	Time for each household in matrix T
PS	Productivity-stochastic matrix	α_c	Weight of cost
QS	Quality-stochastic matrix	α_p	Weight of productivity
TS	Time-stochastic matrix	α_q	Weight of quality
S	Statistic of household matrix	α_t	Weight of time
H	Herb household matrix	e	Column vector
		v	Transpose of vector e

The value of c_{ij} can be 3, 1, and 0 and is based on the three conditions. These are the cost of household i, which is less than household j ($c_i < c_j$); the cost of household i, which is equal to household j ($c_i = c_j$); and the cost of household i, which is greater than household j ($c_i > c_j$). c_i represents the value of each household cost (vertically) and c_j the value of each household cost (horizontally). In addition, the values of q_{ij}, and t_{ij} are also based on the same conditions as the value of c_{ij}.

The value of p_{ij} can be 3, 1, and 0 and is based on the three conditions. These include the productivity of household i, greater than household j ($p_i > p_j$); the productivity of household i, equal to household j ($p_i = p_j$): and the productivity of household i, less than household j. p_i represents the value of each household productivity (vertically) and p_j the value of each household productivity (horizontally).

The statistical data can be used to form the adjacency matrix *A*, which can be utilized to construct a nonnegative irreducible matrix *H*. Under the GeM theory, the matrix *H* ensures that there is only one left dominant eigenvector π^T corresponding to the largest eigenvalue (the entry π_i^T is the rating score of the household *i* in the matrix). The strength of the *H* matrix lies in its capacity to have several inputs at once. Several stochastic matrices can be built and summed into a convex combination, as in Equation (5):

$$S = \alpha_c CS + \alpha_p PS + \alpha_q QS + \alpha_t TS \quad (5)$$

where: *CS* is the stochastic matrix of cost, *PS* the stochastic matrix of productivity; *QS* the stochastic matrix of quality and *TS* the stochastic matrix of time. Since matrix *S* is the convex combination of the stochastic matrices, it is a stochastic matrix. The weight of each criterion is represented by α_c, α_p, α_q, and α_t and is usually calculated by the largest eigenvalue of matrices *C*, *P*, *Q*, and *T*, respectively. The herbal household Matrix *H* can be computed using Equation (6):

$$H = \alpha S + (1\text{-}\alpha\ ev^T \quad (6)$$

In this equation, the personalization vector *v* is set to the vector e^T. As a result, vector *v* is a uniformly distributed row-vector.

The Power method is applied to matrix *H* by using the personalization vector *v* as the initial vector. The Power method creates a rating vector which is the stationary distribution vector for the herbal household matrix *H*. In addition, the termination criteria are set to 10^{-16}.

4. Results

Descriptive Statistics

Eight households in Thapthim Siam 05 herb community were willing to participate in this study. These households have already received the Good Agricultural Practices (GAP) certificate for the selected period. In addition, all the seeds were cost-free (paid by the government). The households planted different amounts of the various herbs depending on the herb garden size. The collected data are shown in Tables 5 and 6.

Table 5: Household Yields in USD

	Price	**H1**		**H2**		**H3**		**H4**		**H5**		**H6**		**H7**		**H8**	
	per Kg	Kg	USD	Kg	USD	Kg	USD	Kg	USD	Kg	USD	Kg	USD	Kg	USD	Kg	USD
Rosella	0.20	490.00	98.00	-	-	125.00	25.00	345.00	69.00	-	-	1,694.50	338.80	-	-	140.00	28.00
Laurel Clockvine	0.71	26.00	18.57	-	-	-	-	-	-	95.00	67.86	-	-	9.00	6.43	20.50	14.63
Kaffir Lime	0.29	-	-	14.00	4.00	-	-	-	-	0.50	0.14	8.00	2.29	-	-	4.50	1.29
White Crane flower	0.13	-	-	37.00	5.29	-	-	20.00	2.86	-	-	18.00	2.57	-	-	-	-
Sea Holly	0.29	-	-	5.00	1.43	-	-	-	-	-	-	-	-	-	-	-	-
Turmeric	0.29	-	-	4,079.50	1,165.57	-	-	-	-	130.00	37.14	270.00	77.14	1,622.00	463.43	-	-
Cissus	0.20	-	-	-	-	784.00	156.80		-	-	-	-	-	-	-	165.00	31.80
Butterfly Pea	0.85	-	-	-	-	536.00	480.57	2.50	2.50	-	-	-	-	-	-	-	-
Candle Bush	0.29	-	-	-	-	50.00	14.29	-	-	-	-	17.00	10.57	-	-	22.50	6.43
Ngai Camphor Tree	0.29	-	-	-	-	25.00	11.14	-	-	11.00	3.29	93.50	26.71	-	-	-	-
Indian Gooseberry	0.57	-	-	-	-	91.00	52.00	-	-	-	-	-	-	-	-	-	-
Green Chirayta	0.43	-	-	-	-	154.00	67.43	149.00	63.86	-	-	-	-	-	-	-	-
Little Ironweed	0.29	-	-	-	-	-	-	-	-	1.00	0.29	-	-	-	-	-	-
Long Pepper	0.29	-	-	-	-	-	-	-	-	-	-	6.00	1.71	-	-	-	-
Total		**516.00**	**116.57**	**4,135.50**	**1,176.29**	**1,765.00**	**807.23**	**517.50**	**138.22**	**237.50**	**108.71**	**2,101.00**	**459.80**	**1,631.00**	**469.86**	**352.50**	**82.14**

Table 6: Collected Data for Each Criterion

	Household	H1	H2	H3	H4	H5	H6	H7	H8
C	Pre-processing ($)	28.50	-	11.42	26.99	-	-	-	9.00
	Harvested ($)	-	220.45	5.72	10.50	-	65.99	230.95	9.00
	Transportation ($)	7.50	59.99	-	9.00	18.00	23.99	18.00	18.00
	Total Expenses ($)	**36.00**	**280.44**	**17.14**	**46.49**	**18.00**	**89.98**	**248.95**	**36.00**
P	Yield (Tons)	0.52	4.14	1.77	0.52	0.24	2.10	1.63	0.35
	Crop area (Hectare)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
	Productivity (Tons/Hectares)	**3.23**	**25.85**	**11.03**	**3.23**	**1.48**	**13.13**	**10.19**	**2.20**
Q	**Quality inspection failure (%)**	**10.00**	**5.00**	**5.00**	**10.00**	**5.00**	**5.00**	**10.00**	**5.00**
T	Pre-processing I (days)	30	30	15	30	30	30	30	30
	Pre-processing II (days)	12	13	13	14	13	13	15	12
	Total (days)	**42**	**43**	**28**	**44**	**43**	**43**	**45**	**42**

All households have the same herb plot size (1,600 square meters). The herb plots consist of sand and organic substances, which are suitable for planting herbs. Households grow herbs as seasonal crops and rotate the herbs every season in order to maintain the quality of their lands. They grow herbs without using any harmful chemical substances. As shown in Table 5, the fourteen herbs planted include: Rosella, Candle Bush, Cissus, Kaffir Lime, Laurel Clockvine, Turmeric, White Crane Flower, Sea Holly, Green Chirayta, Ngai Camphor Tree, Butterfly Pea, Little Ironweed, Indian Gooseberry, and Long Pepper.

Criteria

The criteria for each household were checked and previous data were used to construct an 8 by 8 adjacency matrix. Adjacency matrix *C* describes the score of each match. For instance, the match result between Household 1 and Household 4 is USD 36.00 and USD 46.49, respectively. Therefore, the number in the fourth row and the first column is three (Household 1 spends less money than Household 4).

C =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0	0	3	0	3	0	0	1
H2	3	0	3	3	3	3	3	3
H3	0	0	0	0	0	0	0	0
H4	3	0	3	0	3	0	0	3
H5	0	0	3	0	0	0	0	0
H6	3	0	3	3	3	0	0	3
H7	3	0	3	3	3	3	0	3
H8	1	0	3	0	3	0	0	0

Productivity matrix *P* describes the points for each household. The winner gains three points. If the result is equal, both households gain one point. The loser does not gain any point. The size of productivity matrix *P* is the same as adjacency matrix *C*, which is the 8 by 8 productivity matrix *P* as shown below. For instance, the match result between Household 1 and Household 4 is 3.23 and 3.23, respectively. Therefore, the number in the fourth row and the first column is three (Household 1 productivity value is higher than Household 4).

P =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0	3	3	1	0	3	3	0
H2	0	0	0	0	0	0	0	0
H3	0	3	0	0	0	3	0	0
H4	1	3	3	0	0	3	3	0
H5	3	3	3	3	0	3	3	3
H6	0	3	0	0	0	0	0	0
H7	0	3	3	0	0	3	0	0
H8	3	3	3	3	0	3	3	0

Quality matrix Q describes the points for each household. The winner gains three points. If the result is equal, both households gain one point. The loser does not gain any point. The size of quality matrix Q is the same as adjacency matrix C, which is 8 by 8. For instance, the match result between Household 1 and Household 4 is 10 percent and 10 percent, respectively. Therefore, the number in the fourth row and the first column is one. Quality inspection is at the same level in Household 1 and Household 4.

Q =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0	3	3	1	3	3	1	3
H2	0	0	1	0	1	1	0	1
H3	0	1	0	0	1	1	0	1
H4	1	3	3	0	3	3	1	3
H5	0	1	1	0	0	1	0	1
H6	0	1	1	0	1	0	0	1
H7	1	3	3	1	3	3	0	3
H8	0	1	1	0	1	1	0	0

Lastly, time matrix T describes the points for each household. The winner gains three points. If the result is equal, both households gain one point. The loser does not gain any point. The size of time matrix T is the same as adjacency matrix C, which is 8 by 8. For instance, the match result between household 1 and household 4 is 42 days and 44 days, respectively. Therefore, the number in the fourth row and the first column is three. The pre-processing time is the same in Household 1 and Household 4.

T =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0	0	3	0	0	0	0	1
H2	3	0	3	0	1	1	0	3
H3	0	0	0	0	0	0	0	0
H4	3	3	3	0	3	3	0	3
H5	3	1	3	0	0	1	0	3
H6	3	1	3	0	1	0	0	3
H7	3	3	3	3	3	3	0	3
H8	1	0	3	0	0	0	0	0

The largest eigenvalue of each criterion was calculated to find the weights of the four criteria by using the values of the four prior matrices. The results are 1, 1, 0.2500, and 0.500 for cost, productivity, quality, and time criteria, respectively. These weights were applied in order to find the appropriated weight for each criterion. The appropriate weights are 0.318, 0.318, 0.080, and 0.159, for cost, productivity, quality, and time criteria, respectively. Consequently, the herbal household matrix H can be defined as follows (7):

$$H = 0.125(^1/_8)ee^T + 0.318CS + 0.318PS + 0.080QS + 0.159TS \quad (7)$$

Herbal household matrix H is the probability matrix. Equation (1) from GeM method has been ignored since any row of adjacency matrix A does not contain all zeros (Carl, 2001). Moreover, the prior matrices are transformed into a stochastic matrix. The cost-statistic matrix CS, productivity-statistic matrix PS, quality-statistic matrix QS, and time-statistic matrix TS are shown below.

CS =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0.0000	0.0000	0.0000	0.0000	0.7500	0.0000	0.0000	0.2500
H2	0.1429	0.0000	0.1429	0.1429	0.1429	0.1429	0.1429	0.1429
H3	0.2500	0.0000	0.0000	0.2500	0.2500	0.0000	0.0000	0.2500
H4	0.3333	0.0000	0.0000	0.0000	0.3333	0.0000	0.0000	0.3333
H5	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250
H6	0.2000	0.0000	0.2000	0.2000	0.2000	0.0000	0.0000	0.2000
H7	0.1667	0.0000	0.1667	0.1667	0.1667	0.1667	0.0000	0.1667
H8	0.5000	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000	0.0000

PS =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0.0000	0.2308	0.2308	0.0769	0.0000	0.2308	0.2308	0.0000
H2	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250
H3	0.0000	0.5000	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000
H4	0.0769	0.2308	0.2308	0.0000	0.0000	0.2308	0.2308	0.0000
H5	0.1429	0.1429	0.1429	0.1429	0.0000	0.1429	0.1429	0.1429
H6	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H7	0.0000	0.3333	0.3333	0.0000	0.0000	0.3333	0.0000	0.0000
H8	0.1667	0.1667	0.1667	0.1667	0.0000	0.1667	0.1667	0.0000

QS =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0.0000	0.1765	0.1765	0.0588	0.1765	0.1765	0.0588	0.1765
H2	0.0000	0.0000	0.2500	0.0000	0.2500	0.2500	0.0000	0.2500
H3	0.0000	0.2500	0.0000	0.0000	0.2500	0.2500	0.0000	0.2500
H4	0.0588	0.1765	0.1765	0.0000	0.1765	0.1765	0.0588	0.1765
H5	0.0000	0.2500	0.2500	0.0000	0.0000	0.2500	0.0000	0.2500
H6	0.0000	0.2500	0.2500	0.0000	0.2500	0.0000	0.0000	0.2500
H7	0.0588	0.1765	0.1765	0.0588	0.1765	0.1765	0.0000	0.1765
H8	0.0000	0.2500	0.2500	0.0000	0.2500	0.2500	0.0000	0.0000

TS =

	H1	H2	H3	H4	H5	H6	H7	H8
H1	0.0000	0.0000	0.7500	0.0000	0.0000	0.0000	0.0000	0.2500
H2	0.2727	0.0000	0.2727	0.0000	0.0909	0.0909	0.0000	0.2727
H3	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250
H4	0.1667	0.1667	0.1667	0.0000	0.1667	0.1667	0.0000	0.1667
H5	0.2727	0.0909	0.2727	0.0000	0.0000	0.0909	0.0000	0.2727
H6	0.2727	0.0909	0.2727	0.0000	0.0909	0.0000	0.0000	0.2727
H7	0.1429	0.1429	0.1429	0.1429	0.1429	0.1429	0.0000	0.1429
H8	0.2500	0.0000	0.7500	0.0000	0.0000	0.0000	0.0000	0.0000

The experiments indicate that the rating scores for each household are steady after 235 iterations. Table 7 shows the household ranking from best to worst.

Table 7: Ranking of Households

Rank	Household	Rating
1st	H3	0.241388651509588
2nd	H5	0.212557556050539
3rd	H8	0.151137859361751
4th	H1	0.148490477051793
5th	H4	0.079822482216975
6th	H6	0.073688537529635
7th	H2	0.063445426597521
8th	H7	0.045555212809413

5. Discussion

This study empirically investigated herbal farm performance on GAP guaranteed farms. Its primary purpose was to identify appropriate criteria, evaluate household performances, and develop a framework of ranking using the GeM method. This study determined that the suitable performance criteria to evaluate the performance of herbal farms should be cost, productivity, time, and quality. The stochastic process obtained the largest eigenvalue, which is referred to as a weight for each criterion. Both cost and productivity received the highest value, which is 0.381. Therefore, they have the highest impact on the overall performance followed by time (0.159) and quality (0.080). The Power method was employed to analyze the rankings. The results indicate that the different rating scores (rounded to three decimal places) range from 0.045 to 0.241. The highest rating score is 0.241, which implies that this particular household has the most outstanding performance. For the gaps in rating scores (Table 8), two relatively large gaps are found (those highlighted). The overall performances can therefore be divided into three different levels: excellent, good, and moderate. Two households rank in the top level (excellent) with rating scores greater than 0.2.

Table 8: Rating Gaps for Each Household

Group	Rank	Household	Rating	Rating Gaps
Excellent Level	1st	H3	0.2414	
	2nd	H5	0.2126	0.0288
Good Level	3rd	H8	0.1511	**0.0614**
	4th	H1	0.1485	0.0026
Moderate Level	5th	H4	0.0798	**0.0687**
	6th	H6	0.0737	0.0061
	7th	H2	0.0634	0.0102
	8th	H7	0.0456	0.0179

Both Households 3 and 5 (H3 and H5) are able to control their processing cost as it is lower than in the other households. Even though the productivity criteria of the households are not excellent, the ability to keep the processing cost low can certainly have a substantial impact on their performances. As a result, if households focus on improving their productivity, they would receive a higher rating since productivity has the highest weight on the performance rating. Both H3 and H5 grow a variety of herbs. They enjoy a significant advantage as they can manage their harvesting period from different herbs. They can harvest a crop each month after the first four months and therefore have a steady income flow each month.

For the second tier (good level) performance, both H8 and H1 receive relatively similar rating scores. Their processing cost is double that of the first-ranked households. However, the productivity of H8 and H1 is better than that H5, which is ranked in the excellent group. As to H1, even though it has a higher productivity level than H8 and H5, it has one major quality control issue. The rejection rate of the output of H1 is 10%, higher than that of H8 (5%). Households in this group should focus on cost reduction as the top priority.

The performances of the remaining households (H4, H6, H2, and H7) point to the need for some improvements with regard to processing costs. The costs to these households are much higher than to all the others. Even though they grow more than one type of herbs, they are not able to harvest simultaneously.

6. Conclusion and Recommendations

The households that participated in this study are major suppliers of herbs to Wang Namyen Hospital. Each household has the same amount of crop area and can choose which herbs they plant in each season. Their annual performance is evaluated based on four different criteria (the rating scores or the largest eigen values are obtained through the Power method). The findings indicate that processing cost and productivity are two important criteria as the ability to keep costs low leads to more effectiveness. Timing and harvest management are also key factors for success. A household that chooses to grow a variety of herbs must be able to manage their harvesting times. Furthermore, selecting the right choice of herbs to grow leads to better harvesting and higher productivity as seen in Households 3 and 5.

Moreover, the irrigation system is important for reducing costs and increasing productivity. It is therefore essential to satisfy the water requirement of crops. Correctly irrigated crops offer the best yields. Conversely, if a plant does not receive sufficient water, the quality and quantity of the yield are impaired. Household 3, which has the best performance, takes advantage of this concept by using adequate irrigation equipment to control the amount of water discharged. This equipment is also economical for water use. Equally important, the irrigation system, which is connected directly from a public water source or a dam in the area, has allowed a shorter time for land or soil preparation.

Hence, improving the accessibility of public water source from a local dam is highly recommended for all households. Relying on only rainwater is not enough as drought is a common problem in the area. Since productivity can highly impact the performance, farmers should have access to quality seeds. Usually, these seeds are provided by the Department of Agricultural Extension, a local government agency. Research collaboration among agricultural and science experts should be supported by the government. Proper seed selections bring a higher quality of seeds; for instance, good quality seeds can grow faster, resist pest and diseases and be weather resistant. Good quality seeds ensure higher yields and lead to higher productivity.

A good knowledge of modern agriculture is recommended for farmers. Currently, they do not implement any of the new technological tools. Yet, technology can help farmers grow better crops while using fewer resources. Soil nutrients are the basic inputs for growing herbs. The right digital tools can help with soil health and fertility. The local agricultural agency has a great role to play as it can substantially contribute to better farming and equipment. New knowledge and technological skills sharing are recommended; in particular, nutrient data analysis, which should be emphasized. With the emerging of data science, research collaboration can assist in analyzing soil and making fertility decisions precisely.

This research, however, has limitations. Since it focuses on a particular crop area and technology, it may not be applicable to herbal farms in the entire country (Thailand). That siad, the model developed and the criteria used can be applied to other studies.

References

Amegnaglo, C. J. (2018). Determinants of maize farmers' performance in Benin, West Africa. *Kasetsart Journal of Social Sciences*. https://doi.org/10.1016/j.kjss.2018.02.011

Anuar, A., & Mohd Yusuff, R. (2011). Manufacturing best practices in Malaysian small and medium enterprises (SMEs). *Benchmarking: An International Journal*, *18*(3), 324–341. https://doi.org/10.1108/14635771111137502

Aramyan, L. H., Oude Lansink, A. G., Van der Vorst, J. G., & Van Kooten, O. (2007). Performance measurement in agri- food supply chains: a case study. *Supply Chain Management: An International Journal*, *12*(4), 304–315. https://doi.org/10.1108/13598540710759826

Banaeian, N., Mobli, H., Nielsen, I. E., & Omid, M. (2015). Criteria definition and approaches in green supplier selection – a case study for raw material and packaging of food industry. *Production & Manufacturing Research*, *3*(1), 149–168. https://doi.org/10.1080/21693277.2015.1016632

Banomyong, R., & Supatn, N. (2011). Developing a supply chain performance tool for SMEs in Thailand. *Supply Chain Management: An International Journal*, *16*(1), 20–31. https://doi.org/10.1108/13598541111103476

Bhagwat, R., & Sharma, M. K. (2007). Performance measurement of supply chain management: A balanced scorecard approach. *Computers & Industrial Engineering*, *53*(1), 43–62. https://doi.org/10.1016/j.cie.2007.04.001

Bourlakis, M., Maglaras, G., Aktas, E., Gallear, D., & Fotopoulos, C. (2014). Firm size and sustainable performance in food supply chains: Insights from Greek SMEs. *International Journal of Production Economics*, *152*, 112–130. https://doi.org/10.1016/j.ijpe.2013.12.029e

Brin, S., & Page, L. (1998). The anatomy of a large-scale hypertextual Web search engine. *Computer Networks and ISDN Systems*, *30*(1-7), 107–117. https://doi.org/10.1016/s0169-7552(98)00110-x

Choklumlert, M. (2016, August 14). Ministry of Commerce said that herbal market grows according to health trends. *INN News*. Retrieved from https://www.innnews.co.th/shownews/show?newscode=721248

Chow, W. S., Madu, C. N., Kuei, C., Lu, M. H., Lin, C., & Tseng, H. (2008). Supply chain management in the US and Taiwan: An empirical study. *Omega*, *36*(5), 665–679. https://doi.org/10.1016/j.omega.2006.01.001

Department of Agriculture, Environment, and Rural Affairs. (2017). *Northern Ireland Farm Performance Indicators 2016/17*. Retrieved from https://www.daera-ni.gov.uk/sites/default/files/publications/daera/NI%20Farm%20Performance%20Indicators%201617_0.pdf

Food and Agricultural Organization of the United Nations. Sustainable Agricultural Mechanization. Retrieved December 16, 2018, from http://www.fao.org/sustainable-agricultural-mechanization/guidelines-operations/crop-production/en/

Gurel, O., Acar, A. Z., Onden, I., & Gumus, I. (2015). Determinants of the green supplier selection. *Procedia - Social and Behavioral Sciences*, *181*, 131–139. https://doi.org/10.1016/j.sbspro.2015.04.874

Hassan, T. M. R. T., Yaacob, M. R., & Abdullatiff, N. K. (2014). Sustaining SMEs wood-based product manufacturing through best practices – The case of indigenous entrepreneurs in Kelantan. *Procedia - Social and Behavioral Sciences*, *115*, 221–234. https://doi.org/10.1016/j.sbspro.2014.02.430

Hudson, M., Smart, A., & Bourne, M. (2001). Theory and practice in SME performance measurement systems. *International Journal of Operations & Production Management*, *21*(8), 1096–1115. https://doi.org/10.1108/eum0000000005587

Huin, S., Luong, L., & Abhary, K. (2002). Internal supply chain planning determinants in small and medium- sized manufacturers. *International Journal of Physical Distribution & Logistics Management*, *32*(9), 771–782. https://doi.org/10.1108/09600030210452440

Langville, A. N., & Meyer, C. D. (2011). *Google's PageRank and Beyond: The Science of Search Engine Rankings*. Retrieved from https://press.princeton.edu/titles/8216.html

Lees, N. J., & Nuthall, P. (2015). Case study analysis on supplier commitment to added value agri-food supply chains in New Zealand. *Agricultural and Food Economics*, *3*(1). https://doi.org/10.1186/s40100-014-0024-z

Liang, L., Ridoutt, B. G., Wu, W., Lal, R., Wang, L., Wang, Y., Zhao, G. (2019). A multi-indicator assessment of peri-urban agricultural production in Beijing, China. *Ecological Indicators*, *97*, 350–362. https://doi.org/10.1016/j.ecolind.2018.10.040

Lohawattanakul, S. (2018, May 3). Supporting health & beauty smes join ASEAN beauty 2018 to open the world market. *Than Settakij*. Retrieved from http://www.thansettakij.com/content/278652

Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., & Garg, C. P. (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of Cleaner Production*, *140*, 1686–1698. https://doi.org/10.1016/j.jclepro.2016.09.078

Maarof, M. G., & Mahmud, F. (2016). A review of contributing factors and challenges in implementing Kaizen in small and medium enterprises. *Procedia Economics and Finance*, *35*, 522–531. https://doi.org/10.1016/s2212-5671(16)00065-4

Meyer, C. D. (2000). *Matrix Analysis and Applied Linear Algebra*. Philadelphia, USA: Society for Industrial and Applied Mathematics.

Ministry of Industry of Thailand. (2017). *Thai Industrial Development Strategy 4.0 (2017 - 2036)*. Retrieved from http://www.oie.go.th/academic/ยุทธศาสตร์การพัฒนาอุตสาหกรรมไทย%204.0%20ระยะ%2020%20ปี%20%28พ.ศ.%202560%20-%202579%29

Ministry of Public Health of Thailand. (2017). *National Master Plan on Thai Herbal Development Volume 1, 2017-2021*. Retrieved from https://www.hsri.or.th/researcher/media/printed-matter/detail/7789

Moon, K. K., Tam, F., Lau, M., & Chang, J. M. (2014). Production outsourcing: Perspectives from small and medium-sized enterprises. *Research Journal of Textile and Apparel*, *18*(2), 65–83. https://doi.org/10.1108/rjta-18-02-2014-b009

Moongvicha, S. (2017). Thai SMEs herbal cosmetics in elderly market. *PSAKU International Journal of Interdisciplinary Research, 6*(2), 43-51. https://doi.org/10.12778/235108618X1545237

National Institute of Food Technology Entrepreneurship and Management of India. (2014). *Area, Production and Productivity of Fruits and Vegetables in Different States of the Country Year 2012-13*. Retrieved from http://www.niftem.ac.in/admin/NewsDocument/01492014024924_012FruitStateWiseData07-08-2014.pdf

Peni, N. Good Agricultural Process (GAP) of Thailand. Retrieved December 17, 2018, from http://www.acfs.go.th/news/docs/acfs_03-08-54-002.pdf

Polwichai, T. (2016, December 22). Reveals Top 10 Star Businesses - Fall Business of 2017. *Bangkok Biz News*. Retrieved from http://www.bangkokbiznews.com/news/detail/732981

Quayle, M. (2003). A study of supply chain management practice in UK industrial SMEs. *Supply Chain Management: An International Journal*, *8*(1), 79–86. https://doi.org/10.1108/13598540310463387

Rigby, D., & Cáceres, D. (2001). Organic farming and the sustainability of agricultural systems. *Agricultural Systems*, *68*(1), 21–40. https://doi.org/10.1016/s0308-521x(00)00060-3

Rigby, D., Woodhouse, P., Young, T., & Burton, M. (2001). Constructing a farm level indicator of sustainable agricultural practice. *Ecological Economics*, *39*(3), 463–478. https://doi.org/10.1016/s0921-8009(01)00245-2

Saak, A. (2016, March 20). Quality control in agricultural value chains and external certification. Retrieved April 8, 2019, from http://www.ifpri.org/blog/quality-control-agricultural-value-chains-and-external-certification

Sakolsattayatorn, P. (2016, May 10). Thailand aims to become the leading exporter of raw materials and herbal products in the ASEAN region in 2021. *AEC Tourism Connectivity*. Retrieved from http://th.aectourismthai.com/content2/3903

Sompopcharoen, M., & Sresumatchai, V. (2015, July). Systematic Review: Marketing Communication of Thai Herbal Products to Enhance Potential in Becoming Global Products. In *The 1st International Conference on Innovative Communication and Sustainable Development in ASEAN*. Retrieved from http://www.gscm.nida.ac.th/aseanconference2015/images/download/Proceeding2015/17.pdf

Sousa, S. D., Aspinwall, E. M., & Guimarães Rodrigues, A. (2006). Performance measures in English small and medium enterprises: survey results. *Benchmarking: An International Journal*, *13*(1/2), 120–134. https://doi.org/10.1108/14635770610644628

Tawichaphat, N. (2015, January 27). Thai Herb increase 5% in 2015. *Smart SME*. Retrieved from https://www.smartsme.co.th/content/5932

Taylor, B., & Van Grieken, M. (2015). Local institutions and farmer participation in agri-environmental schemes. *Journal of Rural Studies, 37*, 10–19. https://doi.org/10.1016/j.jrurstud.2014.11.011

Thai Traditional Medicine Development Center. (n.d.). Strategy to promote Thai herbs from upstream through downstream. Retrieved August 6, 2015, from http://tdc-herbarium.dtam.moph.go.th/activities.html

Thakkar, J., Kanda, A., & Deshmukh, S. (2009). Supply chain management for SMEs: a research introduction. *Management Research News, 32*(10), 970–993. https://doi.org/10.1108/01409170910994178

Torres, A., & Marshall, M. (2017, January). Fruit and Vegetable Farmer Surveys: Characteristics of Indiana Vegetable Farming Operations, Purdue Extension publication HO-270-W. Retrieved February 25, 2018, from https://edustore.purdue.edu/item.asp?Item_Number=HO-270-W

Wangtal, S. (2017, August 21). SMEs, the foundation of the 4.0 economy. *Forbes Thailand*. Retrieved from http://forbesthailand.com/commentaries-detail.php?did=1882

Warachit, P. (2011, August 6). Pilot of applying traditional Thai medicine and treatment in 9 hospitals. *Thairath*. Retrieved from https://www.thairath.co.th/content/191883

Wegener, T. (2017). Patterns and Trends in the Use of Herbal Products, Herbal Medicine and Herbal Medicinal Products. *International Journal of Complementary & Alternative Medicine, 9*(6). doi:10.15406/ijcam.2017.09.00317

Wester, P. A. (2018). Supply chain program. *Hazard Analysis and Risk Based Preventative Controls*. 113–132. https://doi.org/10.1016/b978-0-12-810500-9.00007-2