Decision Support System of Supply Chain Management with SCOR model for GAP Vegetables in Thailand

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Abstract. This study aims to construct management efficiency models for GAP vegetable with the Bayesian Belief Networks (BBNs) according to supply chain operations reference model (SCOR model). The data were obtained through standardized questionnaire interview with 166 growers of vegetables in the GAP system identified by stratified random sampling method, and from focus group discussions with 58 famers, 13 middlemen, 12 exporters, and 5 government officers involved in the supply chain mangement identified by purposive random sampling technique. It can be concluded that management efficiency of all GAP vegetable groups was at a high level with the highest probability of occurrence of 35.4% and at a medium level with the second highest probability of occurrence of 24.2%. Furthermore, some SCOR processes were found more crucial in influencing the management efficiency such as soure and delivery from farm to market processes. Hence, the management should focus on certain key SCOR processes already contributing to the effective management and improve the other processes by proposing new management practices that can lead to a better management efficiency.

Keywords: Good Agricultural Practice (GAP) vegetables, SCOR variables, Bayesian Belief Networks (BBNs)

1 Introduction

GAP is a set of guidelines prepared and recommended by the Food and Agriculture Organization of the United Nations with the main aim to ensure food safety. Produces grown and handled according to the GAP manuals are generally inspected by authorized agencies for Q Mark certification. In Thailand, GAP was introduced in 1998 to produce safe food from the reduction of chemical use [11]. Thailand in the past attempted to increased food crop productivity to feed the growing number of its population by encouraging high use of yield enhancing inputs such as chemical fertilizers and other agro-chemicals (herbicide, insecticide, and fungicide). From 2005 to 2017, herbicide and insecticide use increased with the average growth rate of 34.75 and 19.22 percent per year, respectively while fungicide use increased with the average growth rate of 5.44 percent. Also in this period, Thailand imported chemical fertiliz-

adfa, p. 1, 2011.

ers with an average annual growth rate of 5.58 percent. In 2017 alone, it imported 5.82 million tons of chemical fertilizers [8], probably due to the expansion of cropping areas into the less fertile lands. It can be concluded that the increased supply of food sources in Thailand in the past was assisted by the heavy use of chemical fertilizers and herbicide, insecticide, and fungicide.

Of all food crops, vegetables are likely to expose high health risk to both production and consumers from chemical contaminants because of farmers' production practices and consumers' consumption behavior [6]. While farmers favored using chemical inputs to improve yield of their short-seasoned vegetable crops, certain segments of consumers began to address health and environmental concern about impacts from chemicals. Although the introduction of GAP to Thailand has help lower the application of agro-chemicals, pesticide use in the past 10 years (1997-2010) was up to more 11% of total quantity [13] and in terms of pest control and pesticide handling, no significant differences were found between farmers who do and do not follow the Q-GAP guidelines [14]. It meant that all famers in this study who produced vegetables under GAP and non-GAP standard used synthetic pesticides. Recently, Thailand has also exported fruits and vegetables. The main export market of vegetables was in the EU market with a value of 1,542 million baht in 2010. However, in 2010, European Union customs officials detected excessive amount compared to the maximum residue limits (MRLs) of pesticide residues from planting, contamination of microorganisms such as *Salmonella sp.* and *Escherichia coli*, and pests in 5 groups of GAP vegetables imported from Thailand, i.e., ocimum, capsicum, goat and guinea pepper, *solanum melongena*, and momordica charantia group and eryngium foetidum groups [12]. To prevent the problem mentioned above, the Thai government must continue to improve the GAP supply chain management. At the same time, support for farm management should be emphasized and alternative choices to farmers should be added to eliminate pests and chemical residue in the outputs before being distributed.

Moreover, these problems must be solved by an integrated management from upstream, midstream, to downstream levels in the supply chain of GAP vegetables under Supply Chain Operations Reference Model (SCOR model) version 5. The SCOR model is the standard tool to manage production and marketing processes related to cultivation in fields, harvest, postharvest (trimming, grading, and packing), and distribution in both domestic and international markets. The SCOR model comprises 5 processes. i.e., plan, production, source, delivery, and return [16]. The study is a challenge leading to new practices in a management efficiency models in which the SCOR processes are linked by means of the Bayesian Belief Networks (BBNs). The BBNs are the causal probabilistic networks to evaluate management efficiency models which are approved methods for creating models related to uncertain and complex systems surrounding interactions under changing condition [17, 15]. The models can indicate whether any process should be maintained or improved with certain key SCOR variables, resulting in the better management efficiency regarding the decision making in production and marketing planning.

2 Methodology

2.1 Sample size, survey design and data collection

This study focused on 4 types of stakeholders namely farmers, middlemen, ex-porters, and government officers which are involved in the management of five groups of GAP vegetables detected to be contaminated with pests and chemical residue, i.e., (1) ocimum group (basil and sweet basil), (2) capsicum group (bell-pepper), (3) goat and guinea pepper group (chili), (4) solanum melongena (purple eggplant), and (5) other GAP vegetables (momordica charantia, eryngium foetidum, yard long bean, and brassica). The data needed for the present study was obtained by means of questionnaires from 166 farmers identified by stratified random sampling from the database of the Office of Agricultural Research and Development Region 1 (OARD 1) [9] to get representative producers of GAP vegetables in the five problematic groups. The farmers were distinguished into 22, 16, 41, 45, and 42 in each GAP vegetable group, respectively. Furthermore, 58 farmers, 13 middlemen, 12 exporters, and 5 government officers involved in the GAP vegetable management were identified by purposive sampling method for focus group discussions.

Chiang Mai Province was selected as the study area since it has the largest GAP vegetable areas in the country: 178,000 rai from 1.05 million rai (17% of all GAP vegetable areas). There are also a large number of farmers who receive the GAP certification in Chiang Mai: 28,000 farmers from 127,000 farmers nationwide (22% of all GAP vegetable farmers) [4].

2.2 Data Analysis

The supply chain model contains GAP vegetable management variables from upstream, midstream, to downstream levels to arrive at the new practices. It portrays the interaction among the management variables according to SCOR processes which consisted of plan, production, source, delivery, and return; and these management variables are called "SCOR variables". Many variables involved in the SCOR processes were used in this study to create management efficiency models through BBNs. BBNs are associated with expected probability of outcomes given particular combinations of events. They are developed as essentially graphical models in which probabilities of certain outcomes given certain situations or observations can be assigned. These probabilities are generally based on combinations of expert opinion and stakeholder participation [10, 15] and values of SCOR variables are calculated as probability distributions. Additionally, BBNs consist of two main nodes, i.e., parent and child nodes which a child node is determined by a parent node [3]. As shown in Fig. 1, node 1 and 2 are parent nodes of node 3 which is in turn a parent node of node 4. Therefore, node 4 is a child node of the relationship.

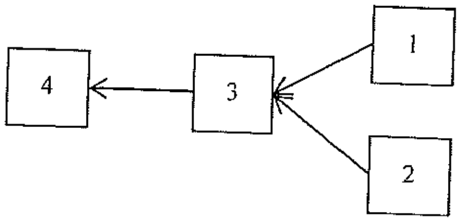


Fig. 1. Relationships between the parent nodes and a child code

The data concerning SCOR variables in each SCOR process were linked to create the management efficiency model which could explain relationship between the child and parent nodes through the probability values shown in conditional probability tables (CPTs) through input, intermediate, and output nodes [7].

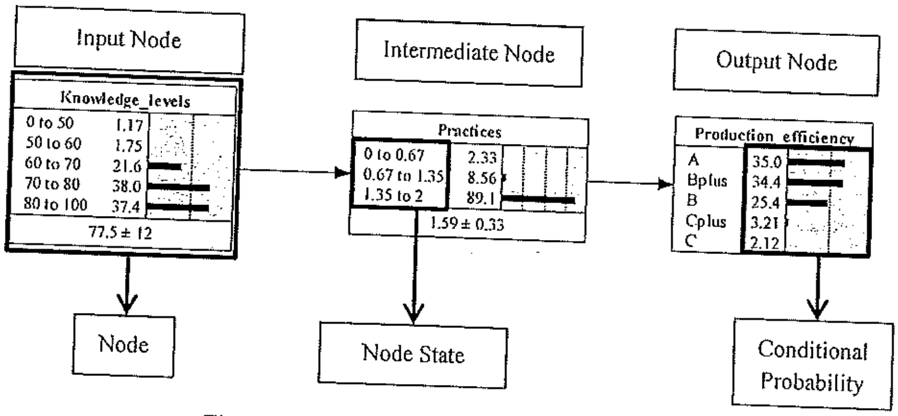


Fig. 2. Elements of Bayesian Belief Network (BBN)

As shown in Fig. 2, the links between input, intermediate, and output nodes indicate a mechanistic relationship in the direction of the arrow and it can be concluded that BBNs compose of three elements [7]:

- A set of nodes representing SCOR variables, i.e., knowledge level node defined by unconditional probability distributions which are the range of states found in nature.
- A set of links representing causal relationships between these nodes instead of arrow from left to right hand side.
- A set of probabilities, one for each node, specifying the belief that a node will be in a particular state given the states of those nodes which affect it directly (its parents). These are called conditional probability tables (CPTs) and can be used to express how the relationships between the nodes operate. In Fig. 2, intermediate and output nodes are defined by conditional probability tables, with the probability for the node being in a specific state given by the configuration of the states of "parent" nodes.

Bayes' theorem can be written as [1, 2]:

$$P(B|A) = \frac{P(A|B) \bullet P(B)}{P(A)} \tag{1}$$

Where: P (A) = the probability of event A occurring
P (B) = the probability of event B occurring
$P(B|A)$ = the probability of event B occurring giving that the event A has already occurred.
$P(A|B)$ = the probability of event A occurring giving that the event B has already occurred.

3 Empirical Results

Bayesian Belief Networks (BBNs) was used to evaluate the management efficiency model in supply chain of each GAP vegetable group with SCOR variables. Considering relationships within the management structure, SCOR variables were determined as the parent nodes measured by satisfaction levels of plan, source, delivery, and return processes and production efficiency. These satisfaction levels and production efficiency influenced the child node called SCORBau presenting the management efficiency evaluated by satisfaction levels at business as usual. To obtain the management as it is supposed to be, a new approach to design and manage GAP vegetable supply chain could be introduced through SCOR processes according to BBNs model. Besides, the processes consist of five processes and each process is related to management variables as follows [16]:

1. Plan process is the balance between demand and supply, depending on product order, production, and product delivery and was evaluated by satisfaction levels (very high, high, medium, low, and very low) from feasible plan and adjustable plan determined by production types and agreement types (Fig. 3).

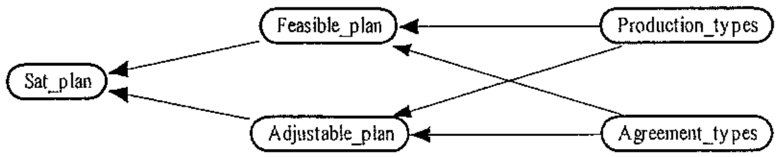


Fig. 3. Relationships between the parent nodes and satisfaction level node of plan

2. Source process is input provision to produce products to respond to the production plan or demand with reasonable price, in high quality, and punctuality and was evaluated by satisfaction levels (very high, high, medium, low, and very low) from input provision and input source recommendation (Fig. 4).

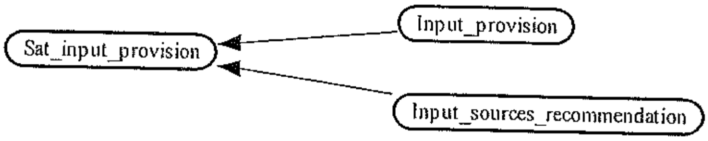


Fig. 4. Relationships between the parent nodes and satisfaction level node of source

3. Production process is the change from inputs to products corresponding with demand and was evaluated by production efficiency (A, B+, B, C+, and C grades) from suitable levels of practices evaluated by knowledge levels of farmers who produced the vegetables under GAP standard (Fig. 5).

Fig. 5. Relationships between the parent nodes and production efficiency

4. Delivery process is the transportation of products to customers under budget and time constraints concerning the management of order, delivery, and distribution and was evaluated by satisfaction levels (very high, high, medium, low, and very low) of suitable delivery from farms to assembly sources (1), from assembly sources to markets (2), and from farms to markets (3). Satisfaction levels of suitable delivery of each route were assessed by trading types and delivery adequacy levels determined by trimming and grading and delivery types, respectively (Fig. 6).

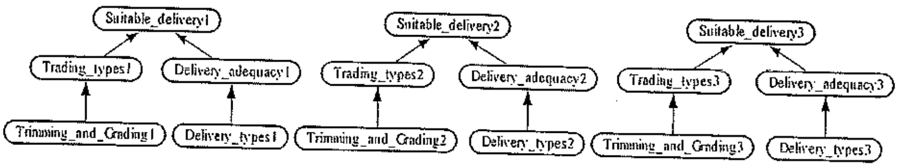


Fig. 6. Relationships between the parent nodes and satisfaction level node of delivery in each route

5. Return process is the action of giving the products back to marketing channels since they are low in quality, do not correspond with demand, and are delivered later than the time designated. This process was evaluated by satisfaction levels (very high, high, medium, low, and very low) of output distribution in each market with the difference of levels of strictness from officers to identify output correspondence with GAP standard and recognition of GAP importance (Fig. 7).

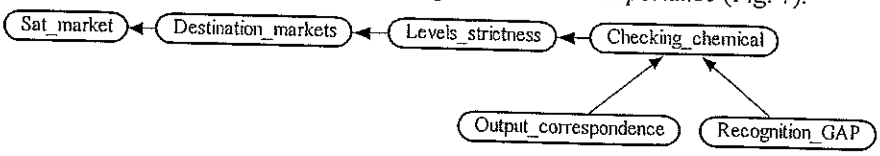


Fig. 7. Relationships between the parent nodes and satisfaction level node of return

The supply chain models containing GAP vegetable management variables from upstream, midstream, to downstream levels shows the interaction among SCOR variables to find the new practices. Moreover, the models created by BBNs can assess the management efficiency of each GAP vegetable group. Each BBNs model indicates the relationship between child and parent nodes when a child node is determined by a parent node. The evaluation of their relationship is measured through the probability values shown in Conditional Probability Tables (CPTs). CPTs are properly estimated to get the number of nodes equaling the number of states and show the probability of occurrence in each state of parent node. The probability values state that the probability of occurrence in each combination of input node called parent nodes could be appropriately adjusted by experts which are defined by marginal (unconditional) probability distributions defined by the range of states found in nature [7]. Finally, all of the SCOR variables obtained from the interview and focus group of stakeholders in each SCOR process were linked together to create the management efficiency models by means of BBNs through software package called Netica. The models could describe efficiency for supply chain management of each GAP vegetable group at the present time and in the future. In addition, the models could indicate improvement or maintenance in the SCOR process to create the new practices, leading to the better management efficiency. The models could describe the relationship among the SCOR variables of all GAP vegetable groups as shown in Fig. 8.

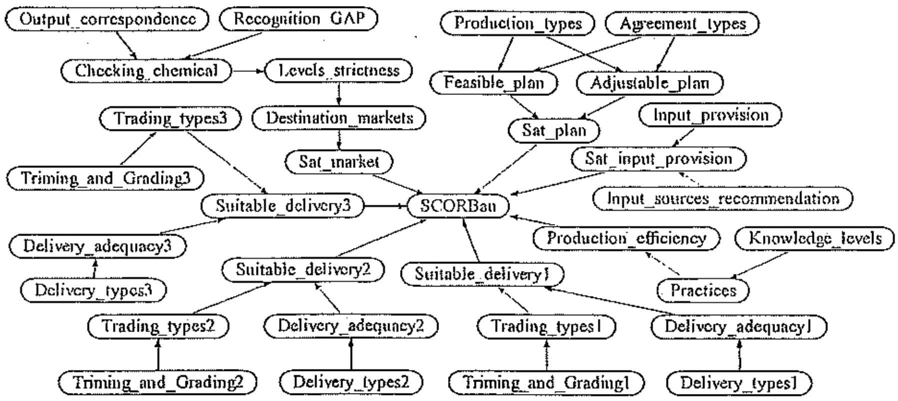


Fig. 8. Relationship structure among variables in each SCOR process for all GAP vegetable groups

Fig. 8 shows the relationships among SCOR variables in each process determined as parent nodes influencing management efficiency which from what is called SCORBau. SCORBau stands for the satisfaction levels of management efficiency at business as usual, categorized into 5 satisfaction levels (very high, high, medium, low, and very low) for management efficiency of all GAP vegetable groups. Measured by SCORBau, the result of management efficiency in all GAP vegetable groups was at a high level with the highest probability of occurrence of 35.4% and at a medium level with the second highest probability of occurrence of 24.2% as shown in Fig. 9.

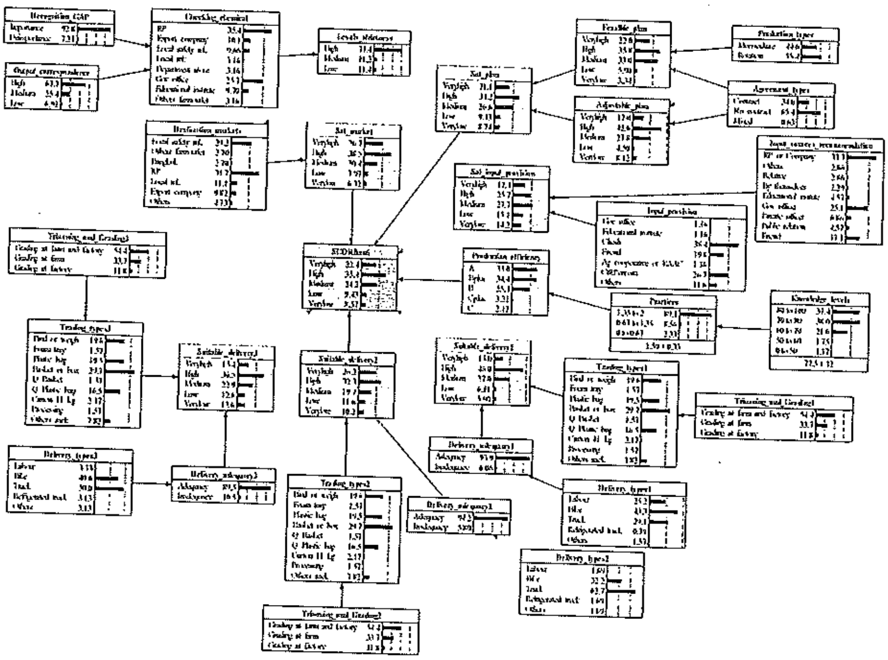


Fig. 9. Management efficiency model with SCOR variables assessed by BBNs of all GAP vegetable groups

Similarly, the relationships among SCOR variables in each process according to Fig. 9 were linked together to assess the management efficiency model of each GAP vegetable group and the individual model is called SCORBau 1, 2, 3, 4, and 5 for basil and sweet basil, bell-pepper, chili, purple eggplant groups, and other GAP vegetables, respectively (Fig. 10).

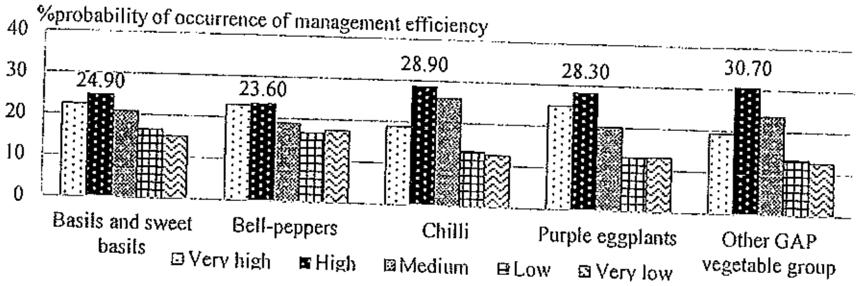


Fig. 10. SCORBau of each GAP vegetable group

It was found that management efficiency of each GAP vegetable group was in a high level with the highest probability of occurrence of 24.9%, 23.6%, 28.9%, 28.3%, and 30.7% in basil and sweet basil, bell-pepper, chili, purple eggplant groups, and other GAP vegetable group, respectively.

3.1 Discussion

Bayesian Belief Networks are used for the sensitivity analysis in knowledge assessment applications to show the expert judgment on changes of parameters. Therefore, the sensitivity analysis can result in scenarios which are particularly useful for uncertainty analysis to consider inadequate knowledge or understanding of system processes, inherent randomness, subjective judgment and vagueness in parameter estimation, disagreement, and measurement. Additionally, the determined scenarios are examined as reliable approach for the prediction of future activities in complex problems of environmental sciences [1].

Finding the key parent nodes with the highest sensitivity from sensitivity analysis is crucial as they exert the most significant influence on the management efficiency. The results of sensitivity analysis in all GAP vegetable groups are presented in Table 1. It was found that three parent nodes with the highest sensitivity values, which were satisfaction level node of input provision, suitable delivery from farms to markets, and suitable delivery from assembly sources to markets, highly influenced management efficiency.

Table 1. Sensitivity values of the parent nodes in each GAP vegetable group and all GAP vegetable groups

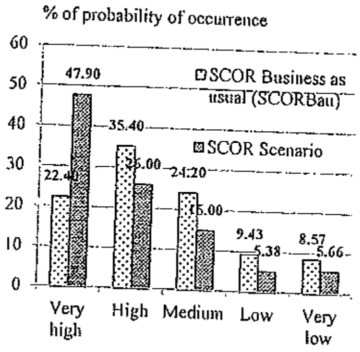
SCOR Process	Node	Sensitivity values in each group					
		Basil and sweet basil	Bell-pepper	Chili	Purple eggplant	Other GAP vegetables	All GAP vegetables
Plan	Sat_plan	0.0531	0.0524	0.0516	0.0529	0.0529	0.0499
Source	Sat_input_ Provision	0.0535	0.0528	0.0516	0.0540	0.0545	0.0589
Production	Production_ Efficiency	0.0463	0.0471	0.0452	0.0452	0.0427	0.0399
Delivery	Suitable_ delivery1	0.0513	0.0518	0.0484	0.0501	0.0487	0.0422
	Suitable_ delivery 2	0.0531	0.0532	0.0524	0.0545	0.0540	0.0530
	Suitable_ delivery 3	0.0539	0.0530	0.0555	0.0548	0.0528	0.0542
Return	Sat_ Market	0.0505	0.0524	0.0525	0.0479	0.0507	0.0463

Source: Calculation

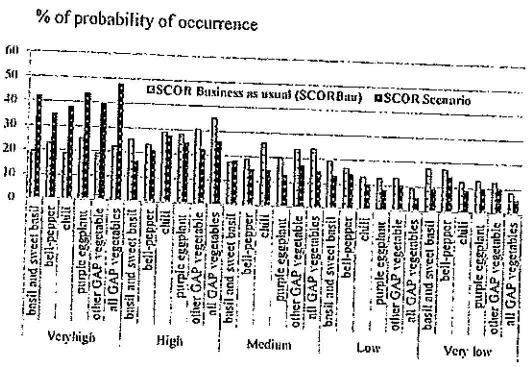
Therefore, creating the new practices could be considered from the sensitivity values, leading to the better management by changing some SCOR processes determined as scenarios. The scenarios could indicate what SCOR process has the most significant influence on the management efficiency called as SCOR scenario influencing the better management efficiency with the highest sensitivity values of the SCOR process. From the highest sensitivity values in all GAP vegetable groups, it indicated that input supply apparently should be provided and recommended by various Royal Project Development Centers or companies that are active in promoting GAP vegetables in northern Thailand. Regarding packing for delivery, a large number of outputs should be packed in baskets or boxes from assembly sources to markets while the outputs should be packed in plastic bags under "Q" mark from farms to markets. In terms of delivery types, trucks should be used to deliver the outputs from assembly sources to markets and adequately provided to deliver the outputs from farms to markets. Besides, the scenarios could be considered in each interesting SCOR variable which could be possibly managed in the supply chain of each GAP vegetable group.

According to scenarios of each GAP vegetable by considering the highest sensitivity value, the production plan of basil and sweet basil group could be feasible at a very high level. In addition, farmers could adjust production in the group at a very high level. Moreover, the management should address A grade of production efficiency related to knowledge levels and practices of farmers who produced bell-pepper under GAP standard. According to other GAP vegetable production, input supply should be provided by other sources such as training units, while government officers should also recommended input supply. Regarding the packing process, a large number of outputs should be packed in baskets or boxes from farms to assembly sources in bell-pepper and from assembly sources to markets in purple eggplant group while the outputs of chili group should be packed in plastic bags under "Q" mark from farms to markets. The delivery types should be adequately provided to deliver the outputs from farms to assembly sources in purple eggplant group and from farms to markets in chili group. Besides, local food safety market should be the destination market for the outputs of chili group. Hence, GAP vegetable management should emphasize the certain key SCOR processes consisting of the highest sensitivity values in each GAP vegetable group to achieve the better management efficiency in each GAP vegetable group.

To summarize, the comparison of different management efficiency between SCORBau and SCOR scenarios indicated that the SCOR scenarios led to the higher management efficiency than SCORBau at a very high level in all GAP vegetable groups (Fig. 11a) and the other groups (Fig. 11b). It meant that the scenarios could result in the management improvement to create the new practices in GAP vegetable supply chain.



a. All GAP vegetable groups



b. Other GAP vegetable groups

Fig. 11. Comparison of SCORBau and SCOR scenarios

4 Limitations and Conclusions

BBNs explain an interaction between the child and parent nodes among SCOR variables through probability values which are determined by conditional probability tables (CPTs). Although, the probabilistic elicitation of the occurrence of events in BBNs can be described in both quantitative data by using statistical analysis and qualitative data from experts in the event of unavailability of data or missing data access [5], BBNs can deal with continuous variables in only a limited manner which may lose statistical power. While Bayesian models are a useful way to model expert knowledge, it may prove difficult to get the knowledge out of the experts in a form that can be converted into probability distributions. And Bayesian networks are acyclic and do not support feedback loops to effect [17].

From management efficiency in Fig. 10, it could be concluded that the management according to SCOR processes of each GAP vegetable production could lead to the management efficiency to stakeholders from upstream, midstream, to downstream, reflecting all images of supply chain management clearly. Besides, the sensitivity analysis with respect to each SCOR process can lend a support to enhancing management efficiency, especially the processes with the highest sensitivity values as they are most influential for the improvement of the supply chain management efficiency, especially source of input provision in all GAP vegetable groups. Similarly, the management efficiency at SCOR scenario of basil and sweet basil, bell-pepper, chili, purple eggplant groups, and other GAP vegetables was also at a high level with the highest probability of occurrence. Considered from SCOR model, the management should focus on plan in basil and sweet basil group, source of input provision in other GAP vegetables, production and delivery from farms to assembly sources in bell-pepper group, delivery from assembly sources to markets in purple eggplant group, and delivery from farms to markets and return in chili group. It meant that when these SCOR processes were changed as guided by the highest sensitivity values, the management efficiency could rapidly be improved which could in turn be reflected by the higher satisfaction levels. In other words, the improved SCOR variables according to the highest sensitivity values can form a new and more effective supply chain management model of GAP vegetables that the stakeholders are willing to make changes following the new model as they could perceive the higher efficiency. However, the stakeholders can operate the management at business as usual without changing any SCOR variables which already have the highest probability values of occurrence.

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