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THE IDENTIFICATION OF EXPERT OPINIONS BETWEEN EU AND THAI COMPANIES ON  
THE DIFFERENT IN IMPACT OF LEAN PRODUCTION ON SUPPLY CHAIN



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**ABSTRACT**

Lean production and sustainability of supply chains management has been adopted in Thailand for a period of time with small amount of research to assess the impact of lean production on supply chains as opposed to manufacturing or distribution conducted, due to the inadequacy of quantitative data. This study attempts to identify the impacts of lean production on the sustainability of supply chains, investigate similar or different impacts caused by lean production between European and Thai companies. Qualitative and Quantitative data analyses are conducted in this study. Delphi survey technique for qualitative analysis is applied with online data survey to address two panels: 1) Thai expert panel and 2 ) EU expert panel, where major finding lies in the areas of: partner relationships, location, scheduling, cost, information technology, warehouse, delivery transport, and environmental impacts. Preliminary result of Delphi survey shows the importance of long term relationship between suppliers and manufacturers. As for quantitative analysis, Classification tree is implemented to identify key factors that impact panels' decision for both Thai expert panel and EU expert panel. The result demonstrates different perspective between European and Thai companies such as ICT investment, Milk-run transport, empty run transport, inventory management, and relationship management.

**Keywords:** lean production, Delphi study, Classification analysis

**INTRODUCTION**

Lean Manufacturing was designed by Toyota in Japan during the 1950's and 1960's. Lean uses variety of techniques which are intended to eliminate all kinds of waste during the production process. Lean Manufacturing focus on customer needs by using the pull system. Thus, the waste can be eliminated and the response to customer is rapid. During the second half of the 20th century, Eastern innovations such as Just-In-Time (Sahoo, Singh et al. 2007) have become worldwide production systems in the automotive. JIT is a one of Lean techniques, which aims to minimize the inventory level by requiring a small batch size from suppliers. To ensure the quality of Lean production, the organization is required to create a long term relationship with trusted suppliers in order to form a reliable supplier network (Greasley 2009). Lean production in Thailand is generally implemented in manufacturing sector. The gross domestic product (GDP)

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in manufacturing sector since 1993 has grown from 32% to 40% of overall GDP in Thailand, which imply that Thailand's economic has been driven by manufacturing sector, and thus, Lean production is an important key to success in Thai Manufacturing.

In 2015, ASEAN Economic Community (AEC) shall be integrated. To utilize the full advantage of AEC, a study regarding lean production in Thailand comparing to lean production in other Economic Communities and their transition period is necessary. European Union (EU) is one of the recognized unions in term of politics and economics. Therefore, EU would be a good candidate to conduct a comparison study regarding lean production. Little research on the significance of lean production has been conducted in Thailand. Moreover, there is no research conducted to compare the different impacts caused by lean production between European and Thai company. To understand the impacts of lean production on supply chain in economic communities as well as prepare to shift into the AEC, this study aims to investigate the concepts, issues, factors, and impacts of Lean production on the supply chain in the developed (Europe) and developing (Thailand). The scope and focused of this study lie on the impact of Lean production on supply chain in transport sector. Two main phases which are 1) the investigation of the impacts of lean production on supply chain, and 2) the investigation similar or different impacts caused by lean production between European and Thai companies are included in this study. In the first phase, the literature review reveals the impacts of Lean production on supply chain. Delphi method was adopted to gather opinions from the expert. Internet survey was conducted to collect expert opinions from different locations. In the second phase, classification tree, one of the most widely used classification analysis, was employed to identify key factors of lean concept.

## DATA COLLECTION

Online questionnaires were sent to Delphi panel. Kaplan et al. (1950) defined Delphi panel as a person who has reputation, influence, and skills in managing interpersonal. In this study, a listed of Delphi panel in EU is obtained from Newrail contact list while listed of Delphi panel in Thai is obtained from Thai logistic directory (2007, 2008). Since our study interest in impact of Lean production on supply chain, the Delphi panel list is drawn from experts involve in freight and logistics, automotive manufacturers, 3PLs, consultants. From the first round Delphi, 33 EU experts and 31 Thai experts expressed their opinions on the impacts of lean production on supply chain where the EU panel composed of experts in transport services or regulation (33%), academics (23%), rail and transport industry (12.5%), and automotive (10.0%) while the Thai panel composed of experts in automotive (56%), academics (12%), rail and transport industry (9%) and transport policy (9%). Note that, there is no standard requirement for the size of Delphi panel. Dalkey and Helmer (1963) stated that the minimum requirement for panel size lies between 15 to 20 members while Tersine and Riggs (1976) suggested that, to deliver effective results, a number of panel members between ten and fifteen is satisfactory.

## MATERIALS AND METHODS

### Overview

As stated earlier, the main purpose of this study is to investigate the concepts, issues, factors, and impacts of lean production on the supply chain in the developed (Europe) and developing countries (Thailand). The proposed approach consists of two main steps: (1) The first round Delphi survey and (2) Classification Tree.

In the most applications of Delphi survey, the first round survey conducts with open questions where answers and comments are invited. The steps in of first round Delphi survey are as followed: 1) design a team to attempt and monitor Delphi on a given subject, 2) select panels associated with the observation, 3) develop the first round questionnaire, 4) test the questionnaire, 5) distribute the questionnaire to panelist, and 6) analyze the first round responses. If consensus is reached in both panels, there is no further step required. Otherwise, feedbacks of first round survey are reformulated and used as input to a classification tree. A classification tree algorithm was employed to investigate questions used to discriminate specific criteria, i.e. EU vs. Thai, position of panel members, business categories.

### Delphi survey

The Delphi technique is a group communication among an expert panel. The technique allows experts to share their opinion with a complex problem or task. It includes a series of questionnaire survey sent either by mail, email or via online survey tools. The questionnaires are conducted to obtain and expand individual responses to the problems posed (Adler and Ziglio 1996). The main purpose of most Delphi application produces the valuable information to for decision-making.

The first round questionnaire is in the mixed form of open-ended and close-ended style, a semi-structured questionnaire. Open-ended question allow participants to explain and describe their opinion in full detail. This allows the panel members to give their expert opinions on the subject. Nevertheless, a closed-ended question is necessary in this research in order to obtain quantitative data. The questionnaire consists of three sections. Section I is collection of personal information which is disclosed due to the confidentiality agreement, however; it is necessary to collect this information for validation purpose. Section II is the identification of lean production implemented in the industry sector. Section III is the verification of factor effected supply chain.

Typically, feedbacks of the first round survey are summarized and used to conduct the second round survey. However, the major disadvantages of Delphi survey are such that it does not demonstrate a strong analytical position. Goldschmidt (1975) and Wellington (2003) stated that the validity of Delphi techniques has never been scientifically demonstrated as the result of analysis is not base on traditional empirical methodology. Delphi technique processes without theory and that it focuses on consensus irrespective of historical truth. Thus, this study proposes the use of classification tree as additional tool to analyze the second round Delphi survey data. Classification tree demonstrates a strong analytical ability in order to evaluate expert opinions.

### Classification Tree

Classification tree is one of the widely used classification methods that partitions the input (feature) space into disjoint hyper-rectangular regions according to performance measures such as misclassification errors, Geni index, and cross-entropy and then fit a constant model in each disjoint region (Breiman 1984). Consider a classification problem with categorical response  $Y$  and inputs  $X_1$  and  $X_2$ , the recursive binary partitions split the first space into two regions. Variable and split-point are selected to achieve the best fit. Then one or both of these regions are split into two more regions, and this process is continued, until some stopping rule is applied. Majority class of each node models the response in each terminal node. The corresponding classification model predicts  $Y$  as the majority class in node  $m$  (in region  $R_m$ ), that is,

$$\text{class } k(m) = \operatorname{argmax}_k \hat{p}_{mk} \quad (1)$$

$$\hat{p}_{mk} = \frac{1}{N_m} \sum_{x_i \in R_m} I(y_i = k), \quad (2)$$

Where  $\hat{p}_{mk}$  represents the proportion of class  $k$  observations in node  $m$  and  $N_m$  represents number of observations in node  $m$  (Hastie, Tibshirani et al. 2009)

The best binary split is typically found in term of total minimum of node impurity. For a given node  $m$  and splitting point  $t$ , we define a pair of the binary partition as

$$R_1(j, s) = \{X \mid X_j = t\} \quad \text{and} \quad R_2(j, s) = \{X \mid X_j \neq t\}. \quad (3)$$

Then we seek to find the splitting variable  $j$  and split point  $s$  that solve

$$\min_{j,s} [\min_{x_i \in R_1(j,s)} Q_1(j,s) + \min_{x_i \in R_2(j,s)} Q_2(j,s)] \quad (4)$$

Where  $Q_m$  represents different measures of node impurity. In this study, the Gini index is selected because of differentiable property which amends to the numerical optimization and the Gini index are more sensitive to changes in the node probabilities than the others

$$\sum_{k \neq k'} \hat{p}_{mk} \hat{p}_{mk'} = \sum_{k=1}^K \hat{p}_{mk} (1 - \hat{p}_{mk}). \quad (5)$$

## RESULTS AND DISCUSSIONS

### Result from Delphi survey

The first round responses were analyzed in the following way. First, the average percentage of majority opinions (APMO) was calculated as

$$\text{APMO} = ((D_o + D_d)/D_t) \times 100 \quad (6)$$

where Da represents aggregate of majority agreements, Dd represents aggregate of majority disagreements, and Dt represents total opinion expressed including unable to comments in order to determine whether consensus has been reached. The APMO of EU and Thai surveys for the first round are approximately 64% and 73%. The result from the first round survey can be grouped into five categories as: partner relationship, location management and planning and scheduling, cost and information technology, warehouse and transportation delivery, and environmental impacts.

Table 1: Analysis of expert opinions for partner relationship (First round)

|            |                                                                             | EU panel (APMO 64%) |              |                       | Thai panel (APMO 73%) |              |                       |
|------------|-----------------------------------------------------------------------------|---------------------|--------------|-----------------------|-----------------------|--------------|-----------------------|
| Statements |                                                                             | Agree (%)           | Disagree (%) | Unable to comment (%) | Agree (%)             | Disagree (%) | Unable to comment (%) |
| 1          | Long term supply relationships are essential for implementing Lean concept. | <b>65</b>           | 20           | 15                    | <b>90.32</b>          | 0            | 9.68                  |
| 2          | Multinational companies do not trust local suppliers                        | 14.71               | <b>64.71</b> | 20.59                 | 22.58                 | 58.06        | 19.35                 |
| 3          | Local suppliers do not trust multinational companies.                       | 20.59               | 50           | 29.41                 | 3.23                  | <b>83.87</b> | 12.9                  |
| 4          | Business partners in your country always meet customer requirement.         | 14.71               | <b>70.59</b> | 14.71                 | <b>80.65</b>          | 3.23         | 16.13                 |

Table 1 illustrates the result of expert opinions for partner relationship. For example, 65% of EU panel agree on statement-1. Since this number is higher than APMO for EU panel (64%), it can be say that EU panel reach consensus on statement-1. Similarly, 90.32% of Thai panel agree on statement-1 with higher percentage than APMO 73%), thus; Thai panel also reach consensus on statement-1. Because both EU panel and Thai panel are agree upon statement-1, there is no further analysis required. For statement-4, both panes reach their individual consensuses, but the consensuses are a strong contradiction between EU panel (agree) and Thai panel (disagree). Such case is considered as contradiction consensus and required no further analysis as well. In addition, EU panel disagree upon statement-2 while Thai panel disagree upon statement-3. Since both panels do not reach consensus for a given statement, further analysis required. Due to page limitation, the result for all five categories of the first round Delphi survey can be obtain from (Sriariyawat and Zunder 2010)

There are 18 statements developed for the first round Delphi survey. Six statements reach the similar consensus level by both EU panel and Thai panel while one statement reaches the contradict consensus. Six statements

reach a consensus either on EU panel and Thai panel. Five statements do not reach consensus neither on EU panel or Thai panel. Therefore, there are 11 statements reformulated in the second stage analysis.

### Classification Tree

1. statements from the first round survey were developed into 38 new statements (appendix A). The questionnaires were sent to similar group of experts. Only 20 questionnaires were response from EU panel and 29 responses from Thai panel for a total of 49 responses. Classification tree attempts to identify statements which affect expert decisions. Three models are proposed: 1) Regional Classification, 2) Occupation Classification.

### Regional Classification

Regional classification identified the statements, which affected the decisions of both the EU and the Thai experts. The regional classification employed a response from each question to construct a classification tree model. Three different responses could be chosen for a given question: disagree; agree; and unable to comment, incorporated in the classification tree as 0, 1, and 2, respectively. Figure 6.1 illustrates the results of the regional classification model. Each tree node specifies the conditions which split an existing region. For example, the first split appears with regard to statement-6 (x2.6 in Figure 1).

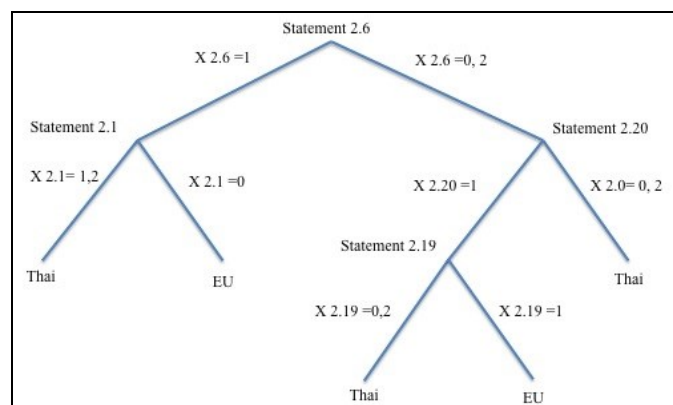


Figure 1 Regional Classification Tree

The respondents, who agreed on this statement ( $x_6 = 1$ ), were separated into one group, whilst the respondents who disagreed or were unable to comment on this statement ( $x_{2.6}$  in 0, 2) were separated into another. The process was repeated iteratively until we obtained the tree's final regions as specified by the terminal nodes (black dots in Figure 1). We could determine the criteria for each terminal node by backtracking up the tree to the top node. For instance, if the respondents agreed on statement-6 and disagreed on statement-1 ( $x_1 = 0$ ), the model concluded that the respondents were members of the EU panel (labeled "2" at the terminal node). On the other hand, if the respondents agreed on statement-6 but were unable to comment or agree on statement-1 ( $x_1$  in 1, 2), the model concluded that the respondents were members of the Thai panel (labeled "1" at the terminal node). The regional classification model

identified 30 responses from the Thai panel and 19 responses from the EU panel. This suggested that, with a 2.04% classification error, one EU panel member was misclassified as a Thai panel member.

### Occupation Classification

Establishing lean production requires all company members to have a similar understanding of the lean concept. The occupational classification model identified important statements which separated panel members into three groups. Top directors were labeled as “1” in the terminal node. Managers were labeled as “2”, whilst operators were labeled as “3”. The importance of the selected statements was that, based on their responses to a particular statement, they separated company members into groups. Since a similar understanding of the lean concept was required (Womack, 1996), the selected statements were those which organizations ought to focus on in order to ensure that all the organization’s members had a similar understanding. The statements’ importance could be ranked highest in the top node and reduced down as the tree continued to split.

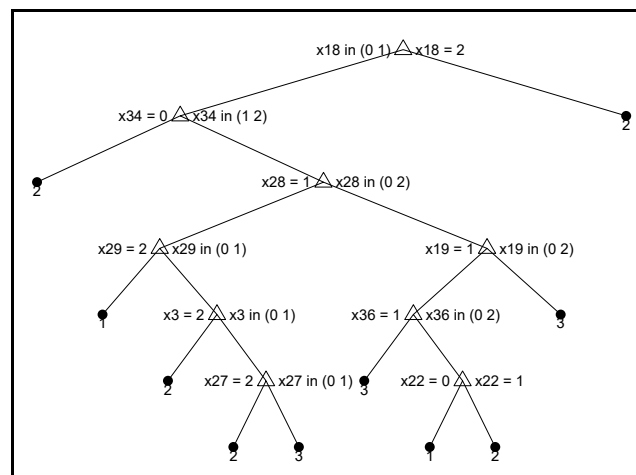


Figure 2 Occupation Classification Tree

Figure 2 illustrated the important statements from highest to lowest as: statement–18; statement–34; statement–.28; statement–29; statement–19; statement–3; statement–36; statement–27; and statement–22.

### Business Type Classification

The purpose of this model was to determine the different factors between business types. In order to establish the lean concept along the supply chain, it was necessary to have a vertical integration between the producer and the first tier supplier. (HUallacháin and Wasserman, 1999). This model classified respondents’ businesses into categories 1, 2, 3, and 4, which represented automotive, consultant, transport and distributor and manufacturer, respectively. Figure 3 shows the business type classification tree.

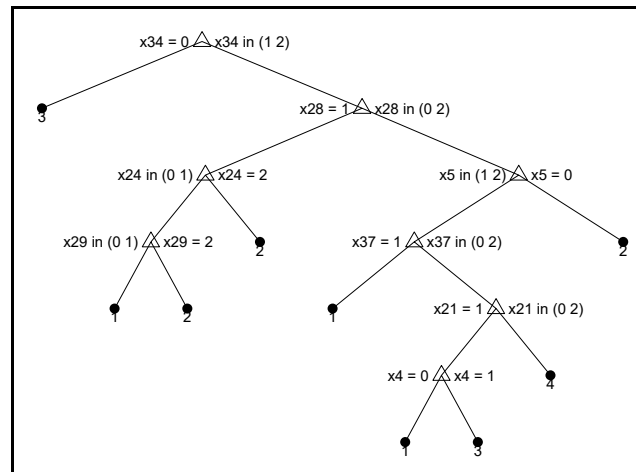


Figure 3 Business Type Classification

This classification tree process was similar to that of the two previous models. The respondents were separated through the use of second round statements. The highest level illustrated the largest gap between the opinions of each business type. Figure 3 . shows the important statements which represent the different opinions between each type of business. The top node began with statements 34, 28, 24, 5, 29, 37, 21 and 4 respectively.

## CONCLUSION

This study attempted to identify the factors, which affected the differences in expert opinion between the members of the EU, Thai panels. The analysis showed that the level of trust between the multinational company and local suppliers, and the lean production inventory level were important factors which illustrated the different opinions between EU panel and Thai panel members. In addition, establishing lean principles and supplier relationships with or without ICT investment, represents a major difference of opinion amongst all levels of company staff. The organisations have to ensure that all members of staff have a similar understanding of this aspect. Moreover, the difference between businesses types showed that rail transport was rated as the top statement. This highlighted the difference between the transport and distribution cluster and the others clusters. This suggested, also, that the logistic service provider and distributor did not believe that rail transport was able to serve lean production.

## APPENDIX

### Second round Delphi statements

#### Original statement: Multinational companies do not trust local suppliers.

1. A service level agreement is important factor for partnership.
2. A limited knowledge of Lean/supply chain concepts affects the reliability of local suppliers.
3. Multinational companies do not trust small companies.
4. Sometimes, multinational companies take advantage of local suppliers.



5. All companies need to vendor assess their suppliers and have a strong auditing process in place wherever they are.

**Original statement: Local supplies do not trust multinational companies.**

- 6. Local suppliers trust larger multinational companies more.
- 7. The quality of product from multinational sources is higher quality than locally sourced.
- 8. It is difficult to audit multinational companies.
- 9. Personal relationships can be more important in business than cost, quality and efficiency.

**Original statement: Distance between producer and supplier location is not important to the implementation of the Lean concept.**

- 10. It is not the geographical distance that matters but fast and frequent connections between the partners.
- 11. The closer the better as it makes the logistic of moving materials more predictable: therefore reducing waste.
- 12. Lean is a workforce culture. It may be harder to implement the further the distance.

**Original statement: A foreign supplier is more trustworthy than a domestic supplier.**

- 13. Financial status of supplier is more important than nationality.
- 14. International suppliers from developed countries are more reliable than local suppliers.
- 15. It is more important that supplier and producer must be developed together than nationality.
- 16. Communication is an important factor of trustworthiness.

**Original statement: Lean production does not need extra investment in new information technology.**

- 17. The extra investment should be given if required as it may reduce cost in the long term and tighten up processes.
- 18. Lean principles and suppliers relationships can be established without additional ICT investment.

**Original statement: Only a small level of inventory is needed to support Lean production.**

- 19. It depends upon real demand variability.
- 20. Inventory can be reduced by good communication, short transport distances and repeatable quality.
- 21. It depends upon the complexity of product.
- 22. Lean inventory management means zero stock.
- 23. Due to uncertainty of production process, unpredictable delivery times, the company should collect a small inventory level.

**Original statement: Lean production requires more frequent supply.**

- 24. More frequent supply could drive up cost.
- 25. Small lot size requires high frequency supplies.

26. Synchronized planning is required for reducing frequent supply.

**Original statement: Lean production causes more partially empty transport trips.**

27. A milk-run concept can be applied for several pick-ups in a trip and optimise the transport trips.

28. Vehicle size for transport can be reduced therefore a lower transport cost.

29. In real situation, there are a lot of empty run back from delivery.

**Original statement: Lean production requires higher transportation cost than traditional mass production.**

30. Initial investment might be increased and overall production cost higher than traditional mass production.

31. Lean creates a clear logistic plan and cost reduction planning.

**Original statement: Rail transport is not suitable for Lean production in your country.**

32. The slow and non-integrated railway system in our country makes rail transport for Lean production unsuitable.

33. Railway network is not connected to areas of manufacturing.

34. Rail transport is able to help Lean implementation but should have intermediate depots or external warehouse to stock the parts.

**Original statement: Small and medium enterprise (SMEs) cannot support the costs for reducing environmental impacts.**

35. Establishing a SME group or network can solve empty run deliveries.

36. Size of company is not a matter for reducing environmental impacts.

37. SMEs can contribute in a smaller proportion than big companies.

38. SMEs are mostly devoted to their core businesses not environmental concerns.

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