The Process Capabilities Analysis for a Logistics Management of Agricultural Products: A Case Study of Phayao Province

Thitirath Cheosuwan[1]
Phitchaya Wannaphongcharoen[2]
Baramee Wannaphongcharoen[3]
Department of Business Computer, School of Information and Communication Technology University of Phayao[1]
Faculty of Business Administration
Vongchavalitkul University[2,3]
E-mail: thitirath.ch@up.ac.th[1]
E-mail: phitchaya_wan@vu.ac.th[2]
E-mail: baramee_wan@vu.ac.th[3]

Received: May 25, 2020; Revised: June 2, 2020; Accepted: June 10, 2020

ABSTRACT

This article presents an analysis of the logistics management process capability of agricultural products, a case study of Phayao Province, Thailand. It also provides the development of logistic management information system for rice, lychee, longan, and banana to replace the traditional logistics management system. Then, it presents a comparative analysis of the capabilities between the traditional logistics management process and the proposed logistics management process under the principles of the Six Sigma methodology. This paper deploys the calculation of a Sigma level, which is based on the number of Defects per Million Opportunities (DPMO), to prove the proposed system that is better than the previous one. As a result, by surveying data from a sample of farmers and logistics operators in Phayao Province, the process capability ($\hat{C}_p$)has increased from 0.67 to 1.33, which is clearly illustrated that the proposed system has better process capability than a traditional system and has proven to be effective to reduce the transportation time, the expenses, and the spoilage of agricultural products in the processes of the logistic system in Phayao Province.

KEYWORDS: Logistics System, Process Capability, Six Sigma, Defect Opportunity

Introduction

One of the main factors that enables agricultural products to be of high quality and be able to compete with traders in other countries is having a good and efficient logistics system. It will support both farmers and logistics providers to deliver the agricultural products to consumers on a planned schedule and to fulfil existing customer needs more effectively. An effective logistics system will enable farmers or logistics operators to predict the quantity of agricultural produce that consumers want to purchase. This will allow farmers to plan their harvest more effectively, reducing the damage from the spoilage of agricultural goods caused by the oversupply.

The Six Sigma Process has been chosen for this research to create the proposed logistics management system. By this technique, the systems development has to follow a five-step method, known as DMAIC (Define, Measure, Analyze, Improve and Control), for improving existing process problems. By developing and designing the logistics system according to the five phases of the Six Sigma Process, it will reduce the repetition and confusion of procedures, resulting in the proposed logistics system to be effective at a level that is accepted worldwide (Mihnea-Dorin Bloj et.al., 2020). With biodiversity in Phayao Province, Thailand, the local farmers cultivate many agricultural products such as rice, lychee, longan, and banana. All agricultural products are distributed and shipped by logistics operators in the province using traditional logistics systems that do not rely much on information technology (IT) to support their logistic processes. This research, therefore, presents a modern logistics management system, combined with the full potential of IT, to support farmers and logistic entrepreneurs in Phayao Province to be able to deliver agricultural products to the destination on schedule efficiently.

The most important aspect in the development of a logistics management system is the collection of information in the target area, then to be analyzed and create a map. From a previous developed logistics study, the authors found in many cases that the old logistic system retrieves a low-resolution map, so truck drivers were not able to know the details of the route to deliver agricultural products effectively. Moreover, some existing logistics systems retrieve satellite imagery displaying areas that are not important. Hence, it causes a large amount of data to be analyzed in the system leading to the delay analysis and navigation of the system.

The current theory in supply chain management may cover all agricultural production processes planning, implementing and controlling procedures, transportation, and storage of goods. All these processes will be handled from the beginning of the production of agricultural products to the destination. They can be grouped into three main logistics: inbound logistics, internal logistics, and outbound logistics respectively (Joshi Vijay, 2018). The decision support system in the logistics management system is used to support logistic operators to track the conditions on the transportation routes in real-time, then they can choose the best route for delivering their agricultural products without delay. As a result, farmers can deliver agricultural products to the customers in time, reduce shipping cost of agricultural goods to the destination.

One of the most effective and competitive methods for farmers is to provide farmers with useful information that enables them to increase their crop productions. This will increase farmers' income and improve the lives of farmers.Thus, the application of information technology by using the Internet to send all necessary information to farmers is very important (Hung Gia Hoang, 2020). Also, the information technology combined with the cultivation of agricultural products will reduce the complicated and unnecessary processes of farmers. It helps farmers know the kind of their customer demands at the destination. Therefore, they will be able to grow agricultural products that meet the needs of a target market. Farmers can reduce unnecessary costs during the cultivation process and increase marketing efficiency (Alavion, Allahyari, Al-Rimawi, & Surujlal, 2017). Nevertheless, the un-updated data and the uncertainty in the agricultural market are still a major condition for agricultural entrepreneurs, especially in rural areas (Pham C. N., 2018). Many pieces of research put forward logistics distribution model to solve this condition such as Aroca et.al., 2017., Amelec V., 2015., Viloria A. et.al., 2018., Soca, E.B. and El Trabajo, 2015., Vanyolos E, 2017., and Tortorella, 2017 respectively.

The purpose of this research is to develop a logistics management process capability of agricultural products based on the Six Sigma Level theory to provide the most complete logistics management system for farmers and logistics operators in Phayao Province. The proposed system is to prove that it is more effective than the traditional logistics systems used by farmers and logistics operators in Phayao Province and is suitable for replacement of existing traditional systems.

Purposes

1. To analyze and develop the logistics management system of agricultural products for local farmers and logistics providers in Phayao Province, Thailand.

2. To compare the traditional logistics management process with the proposed system

Benefit of Research

The logistics management information system is to reduce the transportation time, the expenses, and the spoilage of agricultural products in the processes of the logistic system in Phayao Province.The proposed decision support system could relatively reduce logistics expenses due to optimization of supply chain management, especially local farmers.

Research Process

The proposed system is developed based on the Six Sigma Steps, which has five phases: Define, Measure, Analyze, Improvement and Implementation, and Control respectively.

First, the Define phase is to know what the project is all about. To know the project, the researchers must have sufficient know-how about the process as well. Then, when knowing all system processes, the researchers have insight into the causes of inefficiency and frustration so that improvement plan could be made. A Process Flowchart map or Standard Operating Procedure (SOP) document should deploy to assist this study drill-down into the processes.

Second, the Measure phase involves more numerical studies and analysis of data than the study in the Define phase. This phase focuses on the validation of the measurement system and the collection of root causes.

Third, the Analyze phase of DMAIC requires researchers to identify problems that cause agricultural product defects in the production process. This phase is loaded with many tools to detect the problems in the manufacturing process and determine if these problems are the root causes of the defects.

Fourth, the Improvement and Implementation phase is where the researchers get into the problem-solving cycle, namely creating solutions, pilot the process change as planned and collect data from experiment to confirm a measurable difference made. This phase is very difficult, but provides great benefits. If all experiment processes done correctly, they provide a chance to create innovative and effective solutions. Thus, it will provide a positive effect on the baseline measure, create a better process for both farmers and logistics operators and better agricultural goods or service experience for customers.

Finally, the Control phase involves implementing the actual changes, updating procedures and job instructions, retraining both farmers and logistics operators on new procedures, setting up the proposed system in place to measure and monitor the new process (J.P. Costa, et.al., 2019; S. Krishna Priya, et.al., 2020).

According to T. Yamane, this research provides a Taro Yamane's rule to collect and analyze the data that is beneficial to the development of the proposed logistics management system (T. Yamane, 1973). For the quality control of the developed software, the authors follow Li and Fan's method to determine how to develop software based on the systems development life cycle. This is necessary to create the application of the proposed system (Li and Fan, 2012). For the improvement and enhancement of the proposed system, this research follows all procedures presented by K. Srinivasana, et.al. This research modifies the rule of DMAIC to control errors and unnecessary costs occurred in the system. It relies on geographic statistics to point out all mistakes that happen in the system. Currently, many companies have applied the DMAIC to control their quality of services to the maximum satisfaction to customers (K.Srinivasana, et.al., 2014). Moreover, Alexandra Teneraa and Luis Carneiro Pinto have applied the Lean Six Sigma (LSS) to increase the efficiency of management processes in system development by using a Case Study based on a real enterprise environment. Both the DMAIC and the LSS have a similar process, which is only slightly different in detail (Alexandra Teneraa and Luis Carneiro Pinto, 2014). Lastly, Miller provides the Activity-based Costing (ABC) to reduce the cost of transportation of agricultural products by using historical data to correct all mistakes causing the unnecessary costs in the transportation (Miller, 1996). By using the ABC technique, many cooperation can reduce trade costs from transportation from the competition in today's modern business world (Ishter Mahal, Md. Akram Hossain, 2015).

Population and Sample

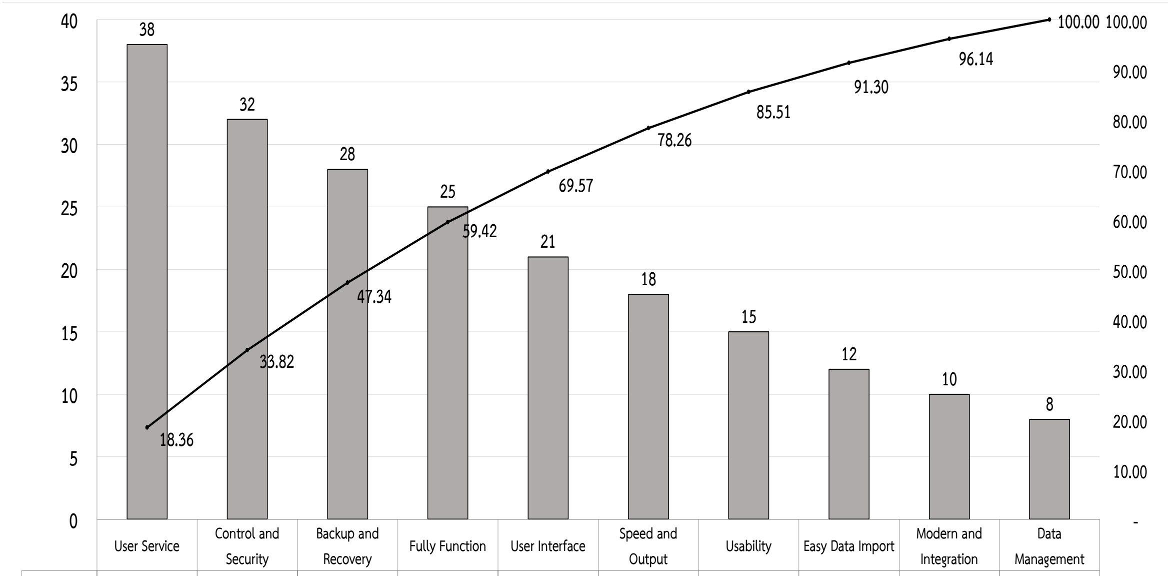
The purposive sampling technique was employed by selecting the sample of farmers and logistics operators who were unsuccessful in farming business, by using non-probability sampling (Boonchom, 2002). The purposive sampling is 329 farmers and 50 logistics operators in Phayao Province, totally 379 samples.

Instruments

The fundamental problem-solving approach is done by following the DMAIC (Define-Measure-Analyze-Improve-Control) of Six Sigma theory in order to reduce the process variation and improvement process results.

Data Analysis

The aim of data collection from both farmers and logistics providers is to develop the logistics management system that has been created to the highest quality and standards. The proposed system is designed and developed based on the Six Sigma process. It can reduce mistakes in the system development process based on statistical information (K.Srinivasana, et.al., 2014). The measurement process relies on the tree diagram to measure the important values of the proposed logistics management system. It is also used to analyze the quality of the process to find the most suitable value for the system (Sittisak Prukpitikul, 2003).The system indicator of the proposed system is used for improving and developing the system through the Process Output Variable (KPOV), which consists of a business indicator, a project indicator, and a theme indicator respectively. The proposed system will be evaluated by users of all 10 topics: User Service, Control and Security, Backup and Recovery, Fully Function, User Interface, Speed and Output, Usability, Easy Data Import, Modern and Integration, and Data Management. As shown in Figure 1, through the analysis of data, all evaluated scores can be shown in the Pareto Charts based on the Six Sigma Process standard.



	User Service	Control and Security	Backup and Recovery	Fully Function	User Interface	Speed and Output	Usability	Easy Data Import	Modern and Integration	Data Management
No. of Defect	38	32	28	25	21	18	15	12	10	8
Defect Cumulative	18.36	33.82	47.34	59.42	69.57	78.26	85.51	91.30	96.14	100.00

Figure 1 The Pareto Chart of the proposed system based on the Six Sigma Process standard

According to the Pareto Chart in Figure 1, user satisfaction scores are sorted in descending order (from left to right). In other words, the User Service receives the most user satisfaction, and the Data Management receives the least user satisfaction.

For the DMAIC evaluation process, the data is collected in the system and is interpreted by comparing the traditional logistics system and the proposed system based on the Baseline Sigma Quality Principles. Then, the defect opportunities of logistics management system will be searched by four steps as follows: First, the criteria weighting technique is used for creating an indicator account. Second, a check sheet is employed for collecting information in the logistics process testing (Kitisak Ploypanichcharoen, 2005). Third, from the information in a check sheet, it is manipulated to seek all flaws and mistakes in the processes. Fourth, the analyzed information from the processes based on baseline sigma is used for finding the system mistakes, which is randomly compared with the Defects per Million Opportunities (DPMO). It can be obtained from the following equations:

$$DPMO = \frac{Defect\ Counted}{Unit\ Counted + Defect\ Opportunity}. \qquad (1)$$

The Defects per Opportunity (DPO) is a metric that indicates the number of defects in a process per opportunity. It is calculated by the number of defects divided by the number of opportunities. The DPO is an important value to calculate the DPMO. It can multiply the DPO by 1 million to receive the DPMP. After that, the sigma level is indicated and calculated from the number of both the solvable problems and the unsolvable problems in the system. In the case of counted information, it can be calculated from $\bar{P}$ proportion as:

$$\bar{P} = \frac{\sum np}{\sum p}, \qquad (2)$$

where $\sum np$ is the total number of defect products, and $\sum p$ is the total number of determine products.

The processing capacity in the logistics management system is limited in the analysis of various data based on the variance that occurs for the measurement of data from a sample. If this variance is greater, it will result in slower processing. The long-term process capability index, $\hat{C}_p$, of the proposed system can be calculated from the specification limits divided with the Six Sigma level, $6\hat{\sigma}$. The $\hat{C}_p$ can be calculated from the following equations:

$$\hat{C}_p = \frac{USL - LSL}{6\hat{\sigma}}, \qquad (3)$$

where USL is the upper specification limit, and LSL is the lower specification limit.

The Z benchmark methodology is used to calculate the Six Sigma level to estimate the searching performance all information. It also can be used to calculated the P_p indicator, which is used for evaluating the efficacy of the process. It can be shown as:

$$P_p = \frac{1}{3} Z_{Bench}, \qquad (4)$$

proposed logistics management system is as efficient as an industry that is accepted internationally. For the old logistics management system, the collected non-technical data is 65 times that have found 15 errors and 5 defect opportunity per one time. The DPMO is 46,153.85, the short term value is 3.20 sigma, and the long term value is 1.70 sigma respectively. TheSigma Level is 2σ, the $\bar{P}$ proportion is 0.11538, and the $\hat{C}_p$ is less than 0.67. It means that the performance of the old logistics management system is very low. The results is shown in Table 1.

For the proposed logistics management system, the collected technical data is 1,850 times that have found 9 errors and 12 defect opportunity per one time. The DPMO is 405.41, the short term value is 4.80 sigma, and the long term value is 3.30 sigma respectively. The Sigma Level is 4σ, the $\overline{P}$ proportion is 0.00486, and the $\hat{C}_p$ is equal or higher than 1.33. It means that the performance of the proposed logistics management system is the high standard. The results are also shown in Table 1.

Table 1 The comparative calculation of the DPMO, Sigma Level and Process Capability of the traditional logistics management system and the proposed logistics management system

Item	Process Capability of the Traditional LMS	Process Capability of the Proposed Logistics MIS
Defects Per Million Opportunities (DPMO)	46,153.85	67.57
Defects Per Million	45,500.124	63.372
Waste Proportion ($\overline{P}$)	0.23076	0.00486
Defect Opportunity	0.05769	0.00243
Sigma Level	2 Sigma	4 Sigma
Process Capability (P_p)	0.666666667	1.33333333
Process Capability Rate ($\hat{C}_p$)	< 0.67	≥ 1.33
Process Capability Level	Non-competitive	Industry average

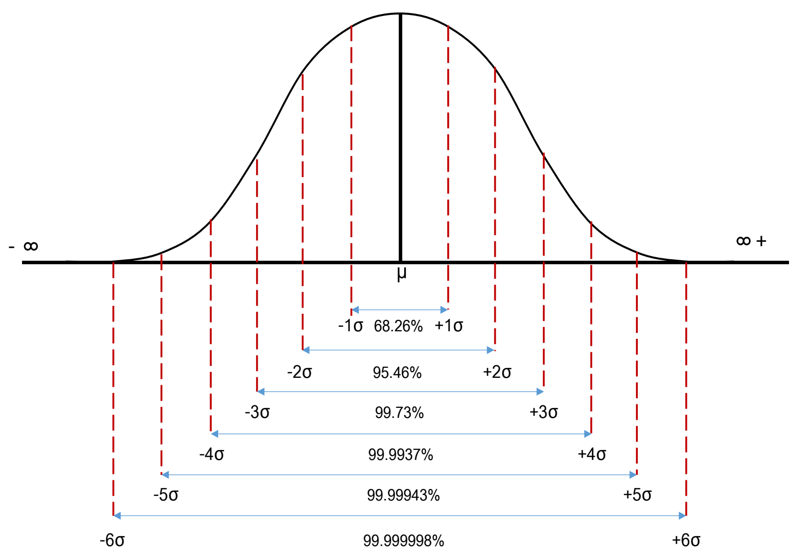
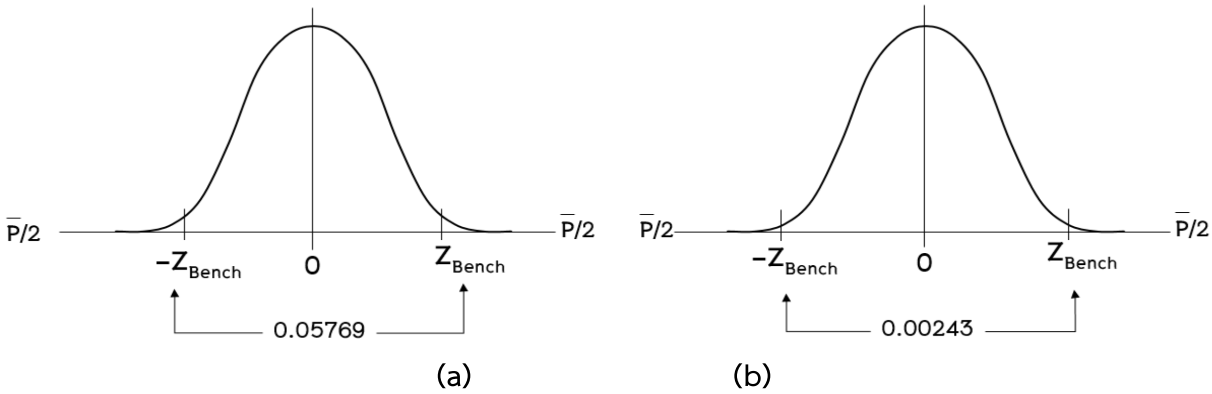


Figure 2 The normal distribution of process capability and defects



(a) The traditional logistics management system

(b) The logistics management information system

Figure 3 Defect opportunity rate

Conclusion and Recommendation

This paper presented the analysis of the logistics management process capability of agricultural products in Phayao Province, Thailand. The proposed system was designed and created by using the Six Sigma methodology, which was used to control the quality of the system. It provided the logistic management information system for both farmers and logistics operators to ship their products such as rice, lychee, longan, and banana to the destination on time. It is a useful tool for them to manage time, budget, and resources related to the cultivation of agricultural products more effectively. Consequently, it helps them reduce unnecessary expenses and increase their income that raises their living standards.

Acknowledgements

This work was supported by research grants to the author from the University of Phayao. We gratefully acknowledge all colleagues for their skilled technical assistance, essential works and critical comments on the manuscript.

References

Alavion, S.J., Allahyari, M.S., Al-Rimaw, A.S.,& Surujlal, J. (2017). Adoption of agricultural E-marketing: Application of the theory of planned behavior. *Journal of International Food & Agribusiness Marketing*, *29*(1), 1-15.

Alexandra, T. and Luis, C.P. (2014). *A Lean Six Sigma (LSS) project management improvement model. Social and Behavioral Sciences, 119, 912-920*. Retrieved from: https://www.sciencedirect.com.

Amelec, V. (2015). Validation of strategies to reduce exhausted shelf products in a pharmaceutical chain. *Advanced Science Letters, 21(5), 1403-1405.*

Aroca, P., Gonzalez, P., and Valdebenito, R. (2017). The heterogeneous level of life quality across Chilean regions. *Habitat International, 68,* 84-98.

Boonchom Srisa-ard. (2002). *Preliminary Research Revised Edition.* Bangkok:Wattana Panich.

Hung Gia Hoang. (2020). *Determinants of the adoption of mobile phones for fruit marketing by Vietnamese farmers. World Development Perspectives.* Retrieved from: https://doi.org/10.1016/j.wdp.2020.100178

Ishter Mahal and Md. Akram Hossain. (2015). Activity-Based Costing (ABC) – An Effective Tool for Better Management. *Research Journal of Finance and Accounting, 6,(4).* Retrieved from: https://www.researchgate.net/publication/309398925_Activity Based_Costing_ ABC_-An_Effective_Tool_for_Better_Management.

J.P. Costa, I.S. Lopes, and J. P. Brito. (2019). *Six Sigma application for quality improvement of the pin insertion process.* International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2019). Retrieved from: http://www.sciencedirect.com

Joshi Vijay. (2018). An Analytical Study of Logistics Process at Logistics Park India Pvt. Ltd. Nagpur. *Asian Journal of Management, 9(1), 692-696.* Retrieved from: http://www. indianjournals.com/ijor.aspx?target=ijor:ajm&volume=9&issue=1&article=107.

K.Srinivasana, S.Muthub, N.K.Prasadc, and G.Satheeshd. (2014). *Reduction of paint line defects in shock absorber through Six Sigma DMAIC phases. Procedia Engineering, 97,* 1755-1764. Retrieved from: http://www.sciencedirect.com.

Mihnea-Dorin Bloj, Sorina Moica, and Cristina Veres. (2020). Lean Six Sigma in the Energy Service Sector: A Case Study. *Procedia Manufacturing, 46*,352–358. Retrieved from: http://www.sciencedirect.com.

Pham, C. N. (2018). *The regional characteristics of market information transfer system in the rice production in the Mekong delta, Gödöllő – Hungary.* Retrieved from: https://szie.hu/sites/default/files/pham_cong_nghiep_dissertation.pdf.

S.Krishna Priya, V.Jayakumar, and S.Suresh Kumar. (2020*). Defect analysis and lean six sigma implementation experience in anautomotive assembly line*. Elsevier Materials Today: Proceedings, 22,948-958, Retrieved from: www.elsevier.com/locate/matpr.

Sittisak Prukpitikul. (2003). *Quality jump with Six Sigma*. Bangkok: Technology Promotion Association Thailand-Japan.

Soca, E.B. (2015). El trabajo independiente en el proceso de enseñanza-aprendizaje*, Revista Cubana de Informática Médica, 7*(2), 122-131.

Tortorella, G., and P.A. Cauchick-Miguel. (2017). *An initiative for integrating problem-based learning into a lean manufacturing course of an industrial engineering graduate program*. Retrieved from: https://dx.doi.org/10.1590/0103-6513.224716.

Vanyolos, E., I. Furka, and I. Mikoy. (2017). How does practice improve the skills of medical students during consecutive training courses?, *Acta Cirurgica Brasileira, 32*(6), 491-502. Retrieved from: doi; https://dx.doi.org/10.1590/s0102-865020170060000010.

Viloria, A., Lis-Gutiérrez, J.P., Gaitán-Angulo, M., Godoy, A.R.M., Moreno, G.C., and Kamatkar, S.J. (2018). *Methodology for the Design of a Student Pattern Recognition Tool to*

Facilitate the Teaching – Learning Process Through Knowledge Data Discovery Retrieved from: DOI: 10.1007/978-3-319-93803-5_63.

Yamane, T. (1973). *Statistics: An Introductory Analysis.* New York, Harper and Row Publication.