Journal of Reproducible Research (JRR)
No. (2) – Volume (2) - 2024 - e- ISSN - 2948-5282

Thai Herbal Supply Chain Connectivity: Analyzing its Visibility via Process Capability.

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Information of Article

Article history:
Received: Jan 2024
Revised: Jan 2024
Accepted: Feb 2024
Available online: Mar 2024

Keywords:
Herbal Supply
Supply Chain
Processing
Herbal

ABSTRACT

The paper explores the impact of implementing an Enterprise Resource Planning (ERP) system on the efficiency of the Thai herbal supply chain, focusing on the visibility index as a measure of process capability. With the backdrop of the National Master Plan for Thai Herb Development and increased governmental focus on the herbal industry, this study investigates the effects of enhanced connectivity on supply chain operations. Methodologically, the research employs Lee and Rim's visibility quantification model, utilizing a Monte Carlo simulation approach to assess the visibility before and after ERP implementation. The study, situated in northern Thailand, specifically examines the supply chain of Limonella plants, a key medicinal herb. Results indicate a significant improvement in supply chain visibility following ERP implementation, leading to expedited delivery lead times. The findings underscore the pivotal role of ERP systems in fostering information sharing and coordination among supply chain stakeholders. While acknowledging limitations in data availability, the research underscores the need for further exploration using real-world data to enhance the realism of the findings. Overall, the study contributes to understanding the practical implications of ERP adoption in enhancing supply chain efficiency and underscores avenues for future research in this domain.

1. Introduction.

After establishing the National Master Plan for Thai Herb Development the Thai government pushed forward the initiatives to study and improve the value chain for herbal products in different parts of the country (The 2nd Charter on the National Health System B.E. 2559 (2016), n.d.)

Considering the strategic importance of this industry the state had allocated funds to conduct research and development in all aspects of the herbal industry including supply chain management. This article is a part of a wider research project to study the impact of information technology and connectivity on efficiency of the Thai herbal supply chain (Variskhanov, 2022). In this work the focus is dedicated to analyzing the impact of increased connectivity via ERP system implementation on the process capability as defined by visibility index.

The paper applies methodology proposed by Lee and Rim (Lee & Rim, 2016) to quantify the visibility by breaking down the supply chain into process units and calculating their visibility index individually first. After each process unit is assigned its own visibility index the visibility of the entire supply chain can be found based on the individual visibility values.

The significance of the research can be summarized as:

1) Need for quantitative models to analyze the impact of the enhanced connectivity via ERP system.
2) Demonstrate a practical application of the process capability.
3) Integrate process capability methodology with simulation method to get insights into the visibility under two scenarios: before ERP connectivity and after ERP connectivity implementations.

Objective of the paper is to:

1) Find visibility index of the overall supply chain via process capability methodology and simulation method before ERP connectivity was implemented
2) Find visibility of the overall supply chain via process capability methodology and simulation method after ERP connectivity was implemented.

2. Literature review.

2.1 Supply chain connectivity

Lee and Rim (Lee & Rim, 2016) provide a reference to the definition of supply chain visibility as a level at which actors or stakeholders have access to information that is crucial for business operation. According to Fawcett and Cooper (Stanley E. Fawcett & M. Bixby Cooper, n.d.) such visibility can be enabled by improving the connectivity between stakeholders within the supply chain.

Hoffman and Hellström (Karolin Hoffman & Daniel Hellström, 2008) argue that information technology (internet, EDI, management softwares) provides infrastructure for effective connectivity to take place. Enterprise Resource Planning (ERP) software is a very widely used business management system to improve key performance indicators.

2.2 Monte Carlo simulation.

Supply chains are complex and have many interacting parts. To replicate and model such systems it is necessary to incorporate the element of randomness (stochasticity). Monte Carlo simulation is the concept in which such stochasticity can be introduced into the model by drawing a different set of values from a particular sampling distribution (P L Bonate, 2001).

Monte Carlo simulation's advantages are that they are straightforward, it provides an approximate solution and relatively inexpensive to use it (A.I. Adekitan, 2014)

2.3 Visibility as Process capability.

To be able to analyze effectiveness of the connectivity the research will measure visibility variables. Lee and Rim (Lee & Rim, 2016) highlighted the need for non-ambiguous quantification methods to increase the supply chain visibility. They propose a quantitative model that uses a Z-score and Six-sigma methodology to evaluate the visibility of the supply chain. However, the study approaches the concept of visibility from the perspective of the capability of the supply chain to execute the plan and objectives rather than the amount of information shared or how well the entities are connected via information technology. Eventually authors suggest that process capability performance is impacted by processes that are highly visible. Hence improved visibility results in improved process capability. In other words when a particular supply chain member can adequately control the output of the process then it is possible to achieve a high level of supply chain visibility.

Lee and Rim (Lee & Rim, 2016) quantify visibility of a certain supply chain process by calculating the v index (or visibility index). They propose doing it by following below steps:

(1) Find Z bench in is used to evaluate the process capability at Sigma level with a Z score according to Six Sigma methodology. LSL is lower specification limit and USL is upper specification limit. If LSL is not restricted then it can be omitted.

$$Z_{\text{bench}} = \min\left(\frac{(\bar{x} - \text{LSL})}{\sigma}, \frac{(\text{USL} - \bar{x})}{\sigma}\right).$$

(2) Sigma level shifted by 1.5sigma:

$$Z_{\text{bench}} + 1.5$$

(3) And v index

$$v_i = \min\left(\frac{(Z_{\text{bench}} + 1.5)}{6}, 1\right),$$

$$\text{where } 0 \le v_i \le 1.0,$$

(4) To expand the visibility index to the entire supply chain (not only a single process unit) the following formula can be used, where *su* is a process unit *nsu* is number of process units and *v* is a visibility index.

$$v_{\text{overall}} = \sqrt[nsu]{\prod_{su} v_{su}}$$

3. Methodology.

3.1 Supply chain connectivity

The research case represents a Herbal supply chain located in northern Thailand in a mountainous area. There are multiple stakeholders that contribute to the value creation of herbal products (Figure 1). The product of focus is a Limonella plant, Zanthoxylum *limonella* (Dennst.) that is known as one of the medicinal plants in Thai traditional medicine.

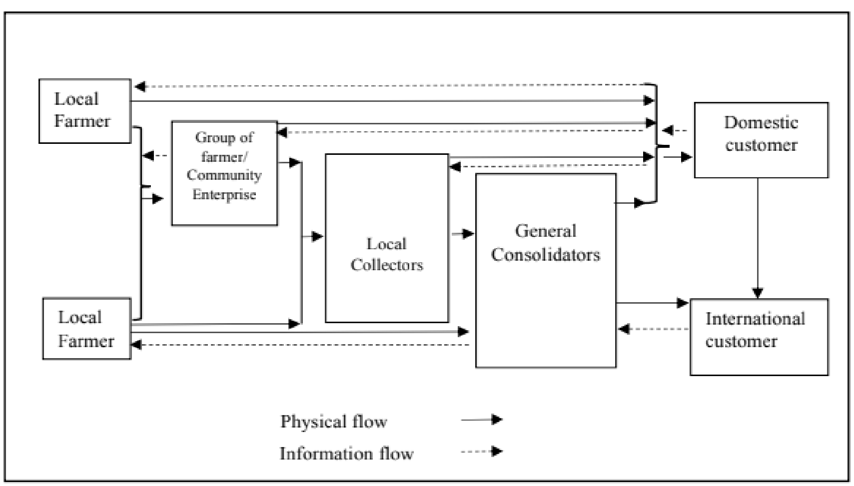

Figure 1. Supply Chain Mapping of Herb Businesses in the North of Thailand (Variskhanov, 2022)

The research was carried out in Nan province to study the impact of implementing ERP systems in order to achieve higher visibility.

3.2 Model.

The figure 2 defines system boundaries within the supply chain. Insightmaker was used as a simulation tool to model and simulate different scenarios.

a) LT1 is a lead time between Cluster of Farmers (COF) and Local Collector Warehouse (LCW)
b) LT2 is a lead time between Local Collector Warehouse (LCW) and General Collector Warehouse (GCW)

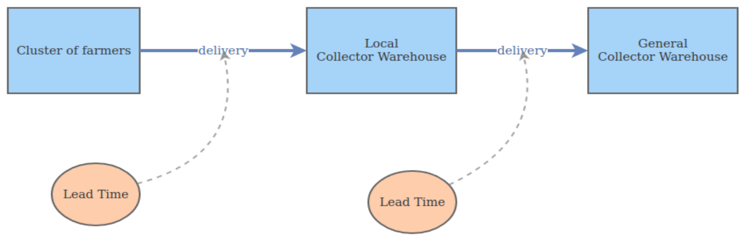

Figure 2. System boundaries.

The lead Time variable is generated via simulating a large number of lead time samples to calculate visibility index v. This is explained later in the next section.

3.3 Scenarios.

The randomness for our simulation is sampled from triangular distribution. There are a number of reasons for that. According to Peck and Finke (Peck & Finke, 2019) triangular distribution is very accommodating when considering specific outcomes and very well known for lay people and those working on the shop floor. Another reason for selecting a triangular distribution is that this distribution is often chosen when very little data is available (Wanke et al., 2016).

3.3.1 Scenario 1: No Connectivity via ERP system

After interviewing a local cluster of farmers (3 farmers) it was found that the worst case of lead time was 25 days. Whereas the fastest that the farmers would be able to send the limonella product was found to be on average 10 days with the most likely scenario of being 2 weeks (14 days). So triangular distribution could be represented as (min:10, mode:14, max:25)

For LCW (3 local collector warehouses) the worst scenario to deliver their order to GCW before implementing ERP connectivity was 20 days, best case was 3 days and most likely is 7 days.
Triangular distribution would be (min:3, mode:7, max:20)

The research simulated 10000 lead time samples for COF and 10000 lead time samples for LCW.

3.3.2 Scenario 2: With Connectivity via ERP system.

After interviewing a local cluster of farmers (3 farmers) it was found that the worst case of lead time was 17 days. Whereas the fastest that the farmers would be able to send the limonella product was found to be on average 5 days with the most likely scenario being 10 days. So triangular distribution could be represented as (min:5, mode:10, max:17).

Worst case scenario after ERP implementation for the delivery from LCW to GCW was 15 days, best case 3 days and most likely was 5 days. Triangular distribution would be (min:3, mode:5, max:15).

The research simulated 10000 lead time samples for COF and 10000 lead time samples for LCW.

USL in both scenarios was defined as 20 days for COF lead time. It indicates that COF was given this lead time as their maximum allowed delivery window time.

USL in both scenarios was defined as 15 days for LCW lead time.It indicates that LCW was given this lead time as their maximum allowed delivery window time.

4. Results and discussion.

After running simulation of 10000 lead time samples for COF and LCW for the scenario before implementing ERP connectivity we get the following result:

Table 1: Simulation results before ERP implementation

Processes	mean delivery (days)	standard dev (days)	USL(days)	Z bench	Z st	v-index
COF lead time	16.304	3.124	20.000	1.183	2.683	0.447
LCW lead time	10.011	3.639	15.000	1.371	2.871	0.478

After running simulation of 10000 lead time samples for COF and LCW for the scenario after implementing ERP connectivity we get the following result:

Table 2: Simulation results after ERP implementation

Processes	mean delivery (days)	standard dev (days)	USL(days)	Z bench	Z st	v-index
COF lead time	10.710	2.486	20.000	3.738	5.238	0.873
LCW lead time	7.688	2.626	15.000	2.785	4.285	0.714

As mentioned by Lee and Rim the higher is the v-index the better is the improvement in visibility at that particular process unit. It can be observed that improvement in the mean impacts the visibility index much higher than the improvement in standard deviation.

The overall supply chain visibility can be calculated by applying formula (4):

Before ERP connectivity implementation:

$$\sqrt[2]{0.447 * 0.478 = 0.462}$$

After ERP connectivity implementation:

$$\sqrt[2]{0.873 * 0.714} = 0.790$$

Overall supply chain visibility index has improved almost by 70% after improving supply chain connectivity via ERP implementation.

This result indicates that COF and LCW participants achieved faster delivery lead time due to improvements in visibility that was quantified by using process capability.

5. Conclusion.

ERP implementation facilitated better information sharing and coordination between supply chain participants.

In practical terms information sharing and coordination can suggest access to inventory location and quantity information within the entire supply chain. Moreover, existence of a centralized platform to communicate and follow the same documentation standards also can expedite completion of deliveries (higher process capability). Ability to track deliveries and location of the stock at any point within the supply chain also plays a crucial role in the speed of executing a particular task within the process unit.

This research lacks a large amount of real-life data if accuracy is of paramount importance. However, the research tries to compensate for this shortcoming by generating a large number of samples that follow triangular distribution. This distribution provided us with approximate data acquired via interviews with local farmers and collectors.

Authors suggest exploring the methodologies mentioned in this paper by using non-simulated data acquired from the field to further approach maximum realism.

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