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FROM CART TO LAYERED ARCHITECTURAL TRANSSHIPMENT MODEL SUPPORTING SMALL AND MEDIUM ENTERPRISES FOR ROAD FREIGHT LOGISTICS

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Keywords: road freight logistics, transshipment, layered architecture, small and medium enterprises.
Abstract: This study proposes a layered architecture of a transshipment model for small and medium enterprises (SME) that supports road freight logistics using rice farmers in Thailand as a case study. The rationale is three folds. First, road freight logistics transportation usually does not apply to SME. Second, existing supply chain logistics models are not appealing to SME in that SME do not have abundant resources to exploit the fullest extent of redeeming features of the models. Third, road freight logistics and transshipment are often incorporated as an integral service operation of a distribution centre to transport goods items from source to destination, which most SME cannot afford the entire service charge. The notion of layering is to make each layer transparent to one another, covering specific transshipment activities that do not overlap with adjacent layers yet keep their operating characteristics closely related. The case study of Thai rice farmers can thus operate and adjust to fit their working scenarios. Contributions of the proposed model are flexible and resilient operations that SME can benefit at less investment but more options to fall back on. Future work should emphasise on transshipment routing research and integration of the proposed model into distribution centre operations management.

1 Introduction

Ploughing has and is the basic farming operation to cut, break up, lift, and turn over the soil in preparing a seedbed. The good old buffalo pulling the plough was long gone in many parts of the world yet is still used in some countries. It is a cheap way, always works, and most important of all, environmentally friendly. Many farmers resort to mechanisation using a manual gasoline plough (aka 'iron-buffalo') or tractor-pull plough for transplant seeding. In this study, we will focus on rice farming. Farmers prepare a seedbed in April before the rainy season arrives in May to signal the plantation (rice is grown year-round in some fertile areas). When harvest time arrives, rice paddies are gathered on a cart pulled by a buffalo or a gas-operated cart to the shelter and subsequently transported to the mill by pick-ups or trucks. This family-style farming is slow, labour-intensive, and has low yields, but it is still practised in Thailand. As the number of farmers grows, a cooperative association for rice farmers is formed to assist and pool available resources together for larger-scale production. Higher bulks of paddies require more transportation trips to the mill, market, and consumers. This process is depicted in Figure 1, where the farmer begins at the cooperative association (1) to deposit their paddies. The paddies are dried, packed, and transported to market via gas-operated carts or private trucks (2). Transportation costs may vary depending on the rates charged by individual transportation businesses. The market includes agriculture outlets, middlemen, and wholesale (3) that distribute rice to consumers. Each transporting stage (1,2,3) is performed and kept track of manually on paper bookkeeping. At present, the shipment suffers from cost variation that raises the cost of goods sold. Unfortunately, farmers have no control on transportation costs to curb their expenditure.

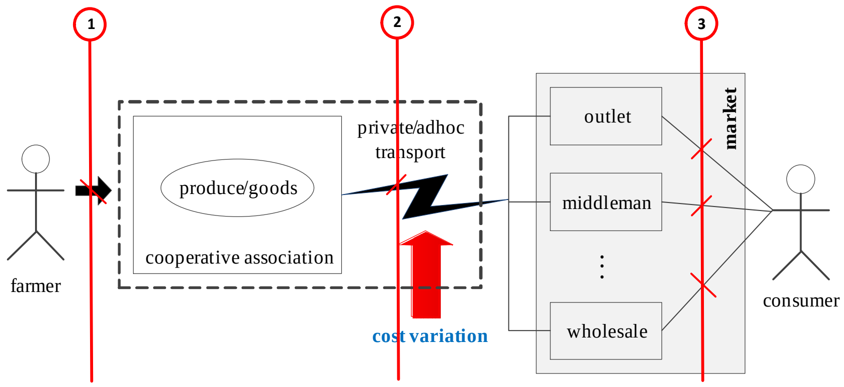

Figure 1 Manual rice farming and transport process

In today's world, buying the desired goods items is usually done online. The good old shopping from brick-and-mortar stores practice is less attractive for many reasons. Produce from the fields or products manufactured from the factories are delivered to consumers as efficient and timely as possible through various means and methods such as centralised and decentralised supply chain, joint distribution and transportation, vendor-managed inventory (VMI) [1] system, online shopping logistics [2], etc. Smaller logistics firms in the form of small and medium enterprises (SME) are popular transporters in the transportation business in many developing countries, such as the Association of Southeast Asian Nations (ASEAN), which will be further addressed in the next section.

As urbanisation grows, logistics sprawl [3] follows, as well as environmental laws and regulations are enforced to manage the safety of goods transport systems. Thus, logistics facilities must move farther away from populated areas. This inevitably incurs additional transportation charges to compensate for longer distances to and fro the sources of goods and destination recipients. To reduce such costs, high-capacity shipment by large container trucks is employed to save the transporting charge per goods item per trip. The need to set up transshipment points (TP), distribution centres (DC), or Urban Consolidation Centers (UCC), hereafter will be referred to as DC for brevity, for transferring the shipment using trucks (*Tr*) and pick-ups (*Pu*) to inner-city is necessary. This situation is shown in the third stage of Figure 1. Thus, this research work will focus on two issues as follow:

1. Serve to transport needs to and fro the city and rural areas, and
2. Utilise available data that can be locally deployed.

The rationale for each focus is straightforward. (1) There are many cost variables involved for DC that are too high a cost for any rice farmers or SME to bear such as building and equipment, rent, depreciation, goods damage claim, insurance, quality of service, digitisation of operations [4], environmental expenses, taxes, etc. (2) High-capacity cargo carried by truck or train from rice fields or rural manufacturing plants must end at DC on the outskirts of the urban area because limiting the capacity of urban transshipment is usually a mandate of today's urban planning. Concerns about the logistics sprawl [3] and environmental issues [5] call for a light-weighted and flexible model that permits operation or routing change for transportation logistics. More details will be elaborated in the sections that follow.

Contributions and benefits from the proposed model are two folds. From a research standpoint, future investigation on intelligent supporting operations and techniques are viable such as Artificial Intelligent based Global Positioning System or AI-based GPS, near-field communication technology (such as powerful and innovative RFID gadgets), and dynamic/capacitated vehicle routing problems (DVRP/CVRP) [6], etc. From a practical standpoint, several techniques and management precipitated from previous research can be implemented to accommodate, in this case, rice (or other products), transportation and transshipment that achieve efficient management of balanced fleet scorecard, backhaul assignments, collaborative distribution, and horizontal coalition management.

This paper is organised as follows. Section 2 recounts some related prior studies and the background of the research. Section 3 describes the research design that includes the relevant variables and cost functions. Empirical results and evaluation are demonstrated in Section 4. Some noteworthy points are discussed in Section 5. Section 6 concludes the study with some final thoughts and future work.

2 Literature review

This section will describe transportation logistics concerns, logistics scenarios for rice farmers, and their supply chain.

2.1 Transportation logistics concerns

Logistics transportation is an important component of the supply chain which involves many stakeholders. Transporting firms are minimising their expenses to keep the business afloat, while their customers (suppliers or manufacturers) are looking for inexpensive and trustworthy companies to send the goods to retailers and consumers. As technology progresses, it enriches transportation operations, planning of freight forwarding coalitions to improve profitability [7], flexibility and cost allocation mechanisms for optimisation, and cheaper distribution plans [8].

The redistribution of transporting across organisations with the help of digitisation would encapsulate operations and supply chain management such as additive manufacturing that enabled design, manufacturing, delivery, and use [4]. From finer organisational logistics granularity, transporting among (material) suppliers themselves, suppliers and manufacturers, wholesalers and retailers could be viewed as a buyer's role who utilised logistics companies as a supplier role to move their products through various logistics channels. This buyer-supplier relationship would call for a mechanism of operational coordination and financial collaboration. Cheung et al. [9] found that the presence of Common Institutional Investors (CII) improved suppliers' operating and market performance. As companies grow, innovation activities within their supply networks increase. They could exchange products, services, R&D data, and other resources to balance the efficiency and resilience of network characteristics, network mechanisms, and innovation outcomes.

To better understand the environment, business, strategy, process, and information systems, Osterwalder et al. [10] proposed the business model ontology that supported a design science approach. Issues such as legal and social environments, customer's demand, technology change, and competitive forces were important considerations to heed. Aljohani et al. [3] defined logistics sprawl, freight sprawl, and logistics polarisation, reviewing their effect on environment of local community due to truck traffic congestion, noise, air quality, and safety. On the other hand, for logistics companies and freight industry, facility location impacted on transport costs and efficiency of operations. Taniguchi et al. [5] surveyed several pertinent UCC and TP cost factors in Tokyo and Bordeaux for sustainable and liveable city logistics. They were cost reduction, congestion alleviation, noise reduction, greenhouse gas (GHG) emission reduction, fuel consumption reduction, empty move reduction, travelled distance reduction, service quality improvement, and fill rate improvement. The size, weight, composition, and many special requirements also imposed additional mandate to the transporting form such as bulky materials, over-sized shipment, perishable items, hazardous liquid or gas composition, etc. These environmental and social responsibilities posed the capital dimension to suppliers especially for multinational companies [11].

One minor but specific factor that affects logistics transportation is weather risk for the coordinating supply chains, reducing cash-flow uncertainty, potential lost sales to the next tier [12], and rice quality if they are wet. The application of their proposed methodology led to the selection of the critical day and temperature as the most influential variable on sales. These influential transportation factors would be taken into account for the transshipment model that fits SME logistics industries in Thailand since it is located in the tropical region.

A regional transportation mandate that affects cost consideration of the proposed transshipment model is truckload (TL) driver issue. Kutac et al. [13] investigated the impact of personnel costs on road freight transport companies that would be considered for the proposed model design. Unlike most industrialised nations where the driver is the sole operator of a given TL transport, Thailand, as well as the ASEAN, utilises an additional driver helper to improve transport service quality and safety which are required by "Service Quality Standard for Truck Operation" (Q-mark handbook) [14] of The Department of Land Transport (DLT), Ministry of Transport (MOT). The standard complies by The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) Resolution 48/11 on Road and Rail Transport Modes in Relation to Facilitation Measures for operations in the sub-regional transport under The Greater Mekong Subregion (GMS) Program, GMS Cross-Border Transport Agreement (CBTA). Figure 2 shows the transportation routes in the region. All routes connect only those countries located on the Southeast Asia peninsular, namely, Thailand, Myanmar, Laos, Vietnam, Cambodia, Malaysia, and Singapore. The remaining ASEAN members are islanders and not connected by land routes, i.e., Brunei Darsussalam, Indonesia, and the Philippines.

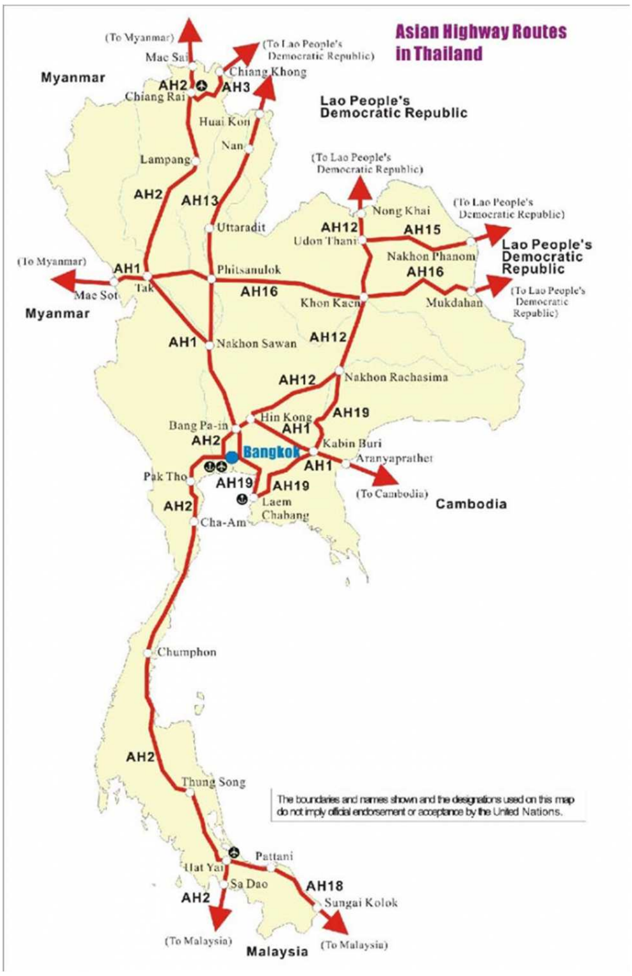

Figure 2 CBTA transportation routes

Miller et al. [15] unveiled the relationship between TL motor carrier size and productivity. They proposed (1) increasing returns to scale for carriers with low technical efficiency, (2) constant returns to scale for carriers with average technical efficiency, and (3) decreasing returns to scale for carriers with high technical efficiency. Their findings contributed valuable implications for the logistics literature, carrier management, and other industry stakeholders.

2.2 *Logistics environment for rice farmers*

Logistics has been playing an important role in supply chain management (SCM) ever since myriad of modern SCM tools and techniques are put into practice. Effective logistics management offers up-to-date status tracking that drives the cost of transportation down. Bramel et al. [12] addressed the technologies that motivated the management of logistics systems, namely, mobile communication and overnight delivery. This matched the heightened demands with short-notice order placement to get timely shipments of fresh produce to market. In general, truck and rail transports are the main vehicles of agricultural goods shipment. Nonetheless, small trucks or pick-ups are preferred means by Thai farmers since they conveniently move goods directly from source (farm) to destination (market).

There are several small-sized transshipment logistics service providers (LSP) that run their business to and fro DC and inner city. Most of them bundle their resources and cooperate with larger-sized LSP to serve a wide array of logistics operations, ranging from packaging in omni-channel [4] to large items. As they tender on large items, they can resort to horizontal cooperation for handling this temporary contract. For example, transshipping rice sacks is done by mid-sized trucks carried out by one of the larger-sized cooperating LSP. This is akin to omni-channel retailers who guide their customers about product availability across channel into physical store [16]. Son et al. [1] studied the incentive-aligned contractual arrangement between vendor and multiple retailers and reallocation of fixed shipping cost could benefit the vendor managed inventory (VMI) system. The dynamics of different supply chain design and policy parameters could be applied to inventory and replenishment decisions at locally managed inventory (LMI) installation in a decentralised manner. This essentially resembles rice farming and transport process of Figure 1.

2.3 *The supply chain of rice*

The supply chain of rice has a straightforward flow categorised by Sowcharoensuk [17] as shown in Figure 3. We will describe the flow in three stages, namely, (*i*) upstream representing activity in rice field, (*ii*) midstream representing production process of rice mill, and (*iii*) downstream representing broker, domestic and export markets. Stage (i) is the ploughing until harvest. Stage (ii) encompasses three buying channels, i.e., agriculture cooperatives, paddy rice centre market, and paddy rice collectors that independently buy rice paddies and feed to rice mills. Stage (iii) illustrates polished rice from mill to be transported to broker/distribution centre, exporter, wholesaler, and rice packer. The broker in turn could either sell to exporter or wholesaler, while wholesaler can either sell to retail stores or rice packers, both of whom sell to final consumers.

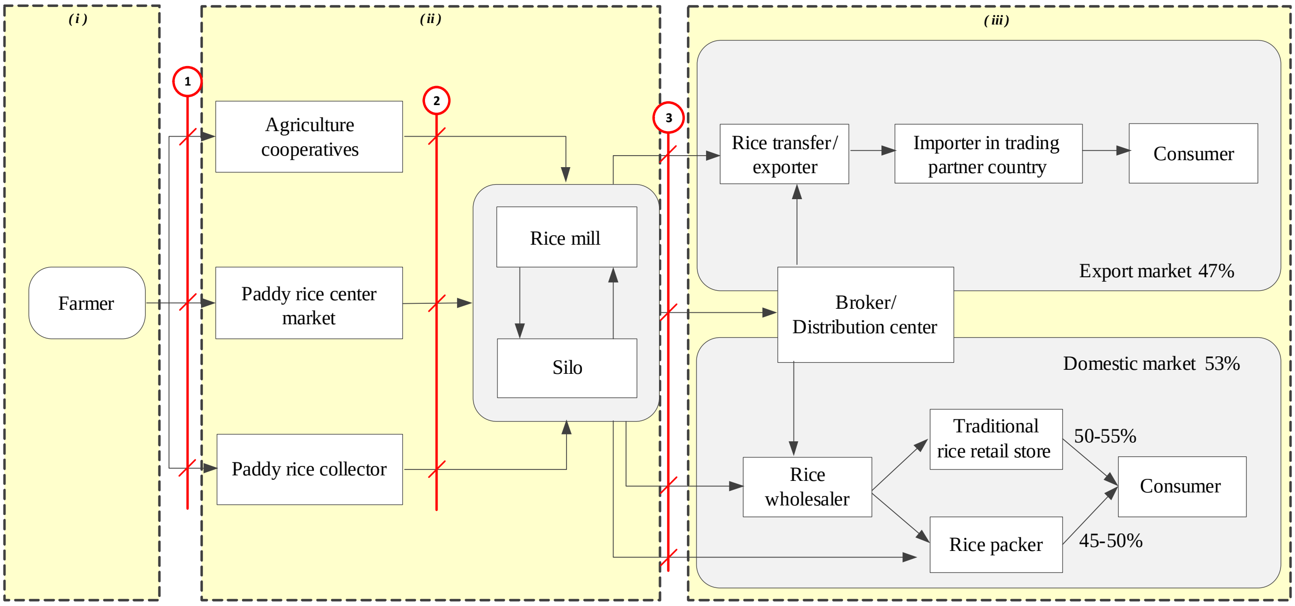

Figure 3 Thai rice supply chain
Source: Trade map, Ministry of Commerce (MOC) and compiled by Krungsri Research [17]

One of the problems contributing to ineffective supply chain is the lack of silo on the farmers' part. As they cannot afford building their own silo, they must sell their produce after harvest. The process of transporting paddy rice is inefficient and costly. We added three vertical lines 1,2,3 to denote our focus on transportation logistics at the slash-mark intersecting points. Line 1 denotes transportation logistics of paddy rice from rice field to primary buyers. Line 2 denotes transportation logistics of paddy rice from primary buyers to rice mill. Line 3 denotes transportation logistics of polished or milled rice from rice mills to all downstream resellers and consumers. Albertzeth et al. [18] evaluated four mitigation strategies in supply chain disruption for distribution centre and retail stores. They identified six types of supply chain disruptions, namely, supply, demand, transportation, facilities, and communications. These will be used in costing assessment of the proposed model.

3 Research design

We propose a working model encompassing operation strategies that prioritise resilience of the logistics structure, resource planning, and costs. Details are described below.

3.1 The cost of transportation

The issues pertaining to agricultural supply chain logistics have been investigated in-depth by Bae et al. [19] that identified internal orientation and market orientation. Their findings coincided with existing practices that made considerable progress in logistics SCM for rice farming. Figure 4 further elaborates on the cost of transportation from Figure 3 where farmers sell paddies (1) to rice mill. These milled rices are kept in the silo and subsequently packed in different weighing sacks (2). Transporting rice sacks is then arranged to many DCs for further distribution to retailers, grocers (3), and eventually consumers. The important accounting process is the cost function encompassing fixed costs (storage, equipment), variable costs (number of sacks, labour), and transportation cost. This study focuses on transportation cost structure and characteristic with the logistics supply chains, i.e., shipment from rice mill to DC and retail stores.

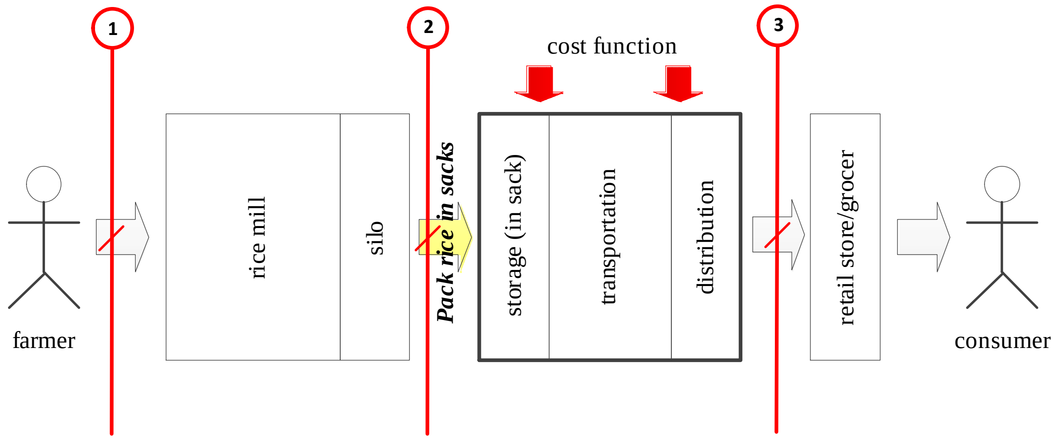

Figure 4 Cost of rice transportation logistics

3.2 Initial development

A number of operational variables to be used in the proposed model are established as follows:

1. Objective of transport
2. Region of coverage
3. Transport distance
4. Transport volume
5. Allocation of transshipment vehicle

These variables are directly or indirectly tied based on fixed cost and variable cost involved in administering the transshipment. Derivation of the cost function will be described in the next section.

The first variable denotes the purpose of transport to be set up in two operations, namely, regular and special transport operations. Regular transport handles all types of requests except special transport requests such as perishable goods items or express packages that must be air freighted or rapid delivery. The second variable designates regions of transportation coverage. There are only two regions in this study, i.e., rural and city. The former represents goods items from trucks hauling bulk shipment from supplier or manufacturer to DC, while the latter represents *Pu* transporting goods items from DC to city warehouse, store, or consumer. The third variable denotes distance of goods items to be transported. The fourth variable denotes volume or payload of goods items per trip. The fifth variable denotes allocation or assignment of transshipped vehicles.

We propose a transshipment model incorporating the above operational variables into multi-relation variables that are prioritised as shown in Figure 5. Design considerations are divided into two views, namely, *vertical view* denoting management of regional coverage and information system and *horizontal view* denoting operational classifications. Details are described below.

The vertical view is divided into three sections, namely, left, middle, and right. The left section represents input data to the proposed model such as large/periodic, small/frequent, and air freight. The middle section represents activities and operations in DC. The right section represents the outputs such as long, short, inner city, and special. Note that this flow process can be reversed because items (rice sacks, products, etc.) can be sent from right side (input) back to left side (output) for returned items or special request situation.

The DC is divided into two sides, namely, rural and city sides. Transfer operations of goods items passing through DC include drop-off, pick-up, and temporarily storage. Scheduling and transport precedence are performed by DC which are beyond the scope of this study but will be demonstrated by a case of scheduling precedence relation below.

The horizontal view is divided into four operation layers. The first layer is a special transshipment service that

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requires, in most cases, special/express transshipment and delivery. Inputs are usually air freighted and transshipped by *Pu* to the destination, which may or may not be transshipped at the DC depending on the imposing requirements such as urgent shipments or perishable goods items. The dotted connecting line and dotted region boundary depict this DC bypassing scenario. The transport direction can go both ways since the reversed input (dotted input arrow) depicts shipment from city to rural side for out-of-town air freighted request.

The second layer represents frequent but small load of transport between inner city and rural areas. This set up serves the purpose for a rapid and efficient goods movement. Note that the arrows between the first layer and this second layer are management provisions for sharing individual *Pu* to transship late arriving special/express items, thereby maintaining smaller operating fleet.

The third layer or short haul denotes large but periodic transporting of goods between rural but close to city area. The short haul may deploy *Pu** from the rural pick-up point if the volume is not too large. The exploded view depicts how request exchange, either regular or chartered (special or ad hoc) request, is handled at the DC during transshipment from *Tr* or *Pu* to the designated *Pu**.

The fourth layer or long haul is usually large and high volume but periodic that requires trucks to transport to save transportation cost per trip. The arrows in the DC designate transshipment from *Tr* by unloading goods on to a *Pu*, or reloading from *Pu* to *Tr* in case shipping from city to rural area. This principally incurs the heaviest transshipment activities as noted by dotted circles. The rationale is straightforward. The sooner large volume of goods is out of DC, the more savings of transportation and storage costs will be.

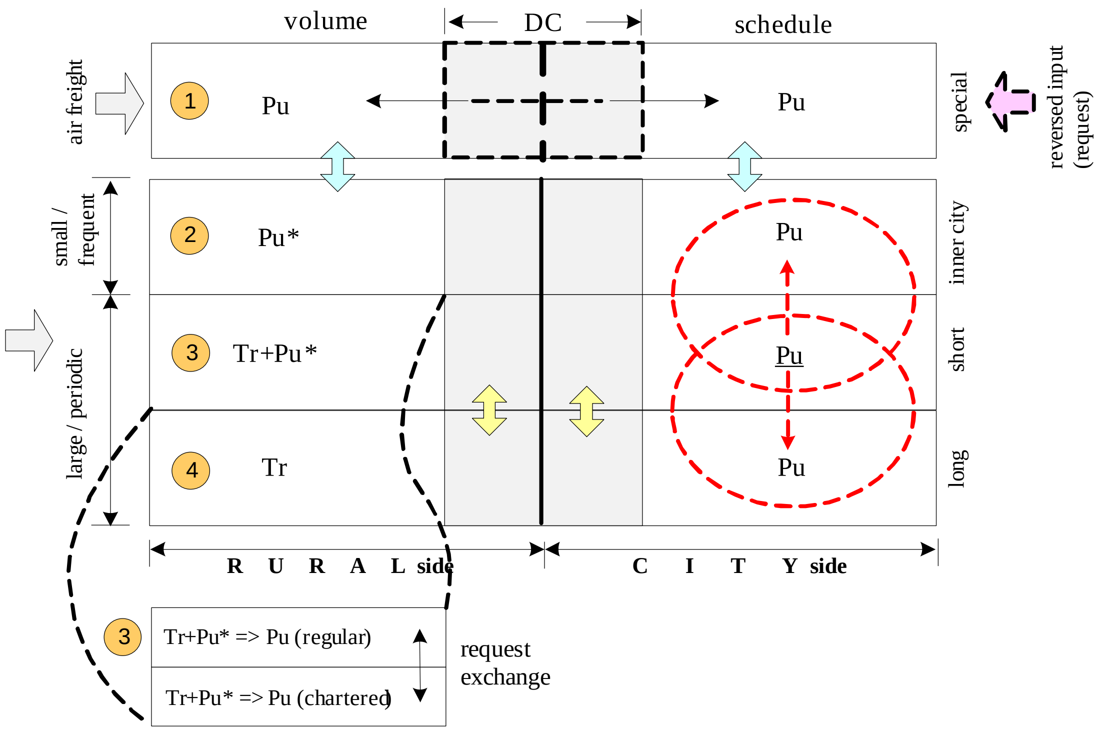

Figure 5 The proposed transshipment model

This layer organisation makes individual layer transparent from one another. It also offers resilient fallback between adjacent layer should the immediate layer encounter any transshipment problems. For example, a moderate sized DC might not need to setup the third layer or short haul so as to scale down its operation for cost savings. In which case, the *Tr+Pu** input could be split by moving the truck sub-fleet to combine with those of the long-haul layer, while the *Pu** which are routinely shared with the second layer could entirely move to serve that layer. Thus, only three layers remain in operation, that is, 1, 2, and 4. At any rate, managing transporting fleet schedule, DC operating manpower/schedule, personnel administration, equipment and facilities utilisation, etc., are beyond the scope of this study.

A loose end notes on the above vertical view of DC transport precedence that imposes a transshipment item to be dropped off and re-scheduled for transshipment is elaborated here. The order of item precedence regulates the schedule of transshipment. That is to say, operational serialisation must be strictly observed, with the exception of the special transshipment service (first layer) that requires direct end-to-end transport without stopping over at DC. Consider a DC time window schedule problem [20] demonstrated below (denote: +get/-retrieve [operation time window]: service time).

A ⟶ $r1^+$[0,10]:10 – $r4^-$[50, 150]:10
B ⟶ $r4^+$[0,20]:10 – $r1^-$[60, 100]:10
$r5^+$[0,20]:10 – $r6^-$[65, 120]:10

Two schedules {A – $\mathbf{r1^+}$ – TP – $\underline{\mathbf{r4^-}}$ – A} and {B – $\mathbf{r4^+}$ – TP – $\underline{\mathbf{r1^-}}$ – $\mathbf{r6^-}$ – B} mean A gets $\mathbf{r1^+}$ no later than 10, transports it to TP, and retrieves $\mathbf{r4^-}$ from TP no sooner than 50, while B gets $\mathbf{r4^+}$ and $\mathbf{r5^+}$ no later than 20, transports them to TP, and retrieves $\mathbf{r1^-}$ and $\mathbf{r6^-}$ from TP no sooner than 60 and 65, respectively.

If we imposed the transport schedule precedence among $\mathbf{r1^-}$, $\mathbf{r4^-}$, $\mathbf{r5^-}$, and $\mathbf{r6^-}$, B could retrieve $\mathbf{r1^-}$ and $\mathbf{r6^-}$ from TP, reducing delays of 60-50=10 and 65-50=15 units of the latest schedule, respectively. This time window scheduling could be theoretically easy to adjust but somewhat difficult to work out in practice because of driver's tardiness, traffic congestion, and other unexpected delay situations that could throw out such a tight transshipment time window at TP and worsen the operating schedule of the transporting fleet.

3.3 Cost consideration

One of the principal transportation costs of the proposed transshipment model is *Tr* and *Pu* driver and helper rates. As Miller et al. [15] described several reasons for driver helper and the aforementioned Q-mark handbook requirements, we procedurally incorporate these driver and helper rates into transportation cost consideration. The general cost function of the proposed transshipment model is setup by separating *Tr* and *Pu* factors for explicit costing classification and subsequent analyses as follows.

$$C_1 = D \times w_1 + T \times w_2 + V \times w_3 + L \times w_4 + F \qquad (1)$$

where C_1 denotes the transshipment cost; D = {D_p, D_t}, D_p and D_t denote distance (km) covered by *Pu* and *Tr*, respectively; T = {T_p, T_t}, T_p and T_t denote time (hr) spent by *Pu* and *Tr*, respectively; V = {V_p, V_t}, V_p and V_t denote volume of payload (cu.m) carried by *Pu* and *Tr*, respectively; L = {L_p, L_t}, L_p and L_t denote weight (ton) of payload carried by *Pu* and *Tr*, respectively; F = {F_p, F_t}, F_p and F_t denote fixed depreciated cost (Munit) of *Pu* and *Tr*, respectively; and w_i, i=1, 2, …, 4 denote Munit/km, Munit/hr, Munit/cu.m, and Munit/ton fixed charges that are applicable to *Pu* and *Tr*, respectively. Note that these factors are not broken down into finer details so as to keep cost analysis flexible for subsequent adjustments to fit the regional or domain of applications. For example, in Thailand, factor T may include weather conditions influence [12] when 'monsoon' arrives in May and ends in late October. Often time this flash flood will cause paralying traffic to and fro the city and DC. Similarly, road detour due to maintenance, special events, accidents, will result in routing and schedule change to accommodate the adhoc situation, thereby affecting both D and T factors.

The wages of driver and transport assistance are setup as follows.

$$C_2 = R \times D + S \times T \qquad (2)$$

where C_2 denotes the wages; R = {R_p, R_t}, R_p and R_t denote *Pu* and *Tr* fuel and maintenance expenses (Munit/km) handled by the driver and helper; S = {S_{p1}, S_{p2}, S_{t1}, S_{t2}}, S_{p1}, S_{p2}, S_{t1}, and S_{t2} denote *Pu* driver's, *Pu* transport assistance wages (Munit/hr), and *Tr* driver's, *Tr* transport assistance wages (Munit/hr), respectively. Care must be taken for wage increase since it will impact labour productivity in terms of sales per employee and company's profit [13].

The overall fleet allocation cost to be fed in DC for further detailed breakdown is as follows.

$$C_3 = O_pN_{pE}H_{pE} + [O_pN_{pCS}H_{pCS} + O_tN_{tS}H_{tS}] + O_tN_{tG}H_{tG} \qquad (3)$$

where O_p denotes proportional *Pu* allocation; O_t denotes proportional *Tr* allocation; N_{pE}, N_{pCS}, N_{tS}, and N_{tG} denote the number of *Pu* and *Tr* to be allocated for express (special) delivery(E), inner city and short haul(CS) *Pu pool*, short haul(S) truck, and long haul(G) truck, respectively; H_{pE} denotes the first layer *Pu* allocation costs that set aside for express delivery; H_{pCS} denotes second and third layer *Pu pooling* allocation costs, wherein the *Pu* pool can be shared between inner city and short haul services; H_{tS} denotes third layer (short haul) *Tr* allocation costs, and H_{tG} denotes the fourth layer (long haul) *Tr* allocation costs, respectively. This setup permits provision for outsourcing of the *Pu* pool (and optionally *Tr* pool in short haul operation) by various SME logistics which is a common practice in many countries, while those SME can still run their own express and long haul truck operation. Thus, the second and third terms of Eq(3) can be combined into one lump sum as shown in Eq(3)'.

$$C_3 = O_pN_{pE}H_{pE} + X_S + O_tN_{tG}H_{tG} \qquad (3)'$$

where X_S denotes the external sourcing expenses as the result of resilient operational consolidation. Hence, the total cost (TC) becomes

$$TC = C_1 + C_2 + C_3 \qquad (4)$$

3.4 Preliminary cost evaluation

To demonstrate computations of the total cost, let's consider a *Pu* transshipment from rural area to inner city request. The cost analysis is determined as follows (in monetary term denoted by Munit).

$$\begin{aligned} C_1 &= D_p \times w_1 + T_p \times w_2 + V_p \times w_3 + L_p \times w_4 + F_p \\ &= 30 \times 3.5 + 1 \times 5 + 2 \times 2 + 1.2 \times 4 + 2.08 \\ &= 105 + 5 + 4 + 4.8 + 2.08 \\ &= 120.88 \quad \text{Munits} \end{aligned}$$

and

$$C_2 = R_p \times D_p + S_{p1} \times T_p + S_{p2} \times T_p$$
$$= 0.45 \times 30 + 5 \times 1 + 3 \times 1$$
$$= 13.50 + 5 + 3$$
$$= 21.50 \quad \text{Munits}$$

and

$$C_3 = O_p N_{pCS} H_{pCS}$$
$$= 0.02 \times 16 \times 2.4$$
$$= 0.77 \quad \text{Munits}$$

Therefore, we have

$$TC = 120.88 + 21.50 + 0.77$$
$$= 143.15 \quad \text{Munits}$$

where D_p=30 km, w_1=3.5 Munits/km, T_p=1 hour (rounded up to hour), w_2=5 Munits/hr., V_p=2 m^3, w_3=2 Munits/m^3, L_p=1.2 tons, w_4=4 Munits/ton, F_p=2.08 Munits (500Munits/30days/8hrs=2.08 Munits), R_p=0.45 Munits/km (0.31 gas+0.14 tire), S_{p1}=5 Munits, S_{p2}=3 Munits, O_p=0.02, N_{pCS} =16, H_{pCS}=2.4 Munits.

4 Empirical results

Due to confidentiality of personal and company data protection, we selected descriptive statistics being compiled from public reports of the Thai Transportation & Logistics Association [21], Transport Statistics Group, Department of Land Transport [22], International Transport Service Providers [23], and SME such as XYZ express, and ABC company [24], etc. (their identities were withheld for confidentiality and privacy reasons). Standard measurements of the statistics are given in Table 1, e.g., the dimensions of a 20 feet tunnel container are 6.06 × 2.59 × 2.44 cu.m, *Pu* and *Tr* fuel and maintenance expenses are 0.45 and 0.97 THB/km, respectively. Table 2 provides some basic conversions of rice sacks to be used in payload computations.

Table 1 Parameter constants

Variable	Value	Remark
V_p	6.48	$1.8 \times 2.0 \times 1.8$ cm^3
V_t	38.30	$6.06 \times 2.44 \times 2.59$ cm^3 (20 ft: $20 \times 8 \times 8.5$)
L_p	1.60	ton
L_t	30.00	ton
S_{p1}	166.67	THB
S_{p2}	150.00	THB
S_{t1}	292.05	THB
S_{t2}	262.84	THB
F_p	2358.33	THB
F_t	3787.88	THB
R_p	0.45	THB/km
R_t	0.97	THB/km

Table 2 Some basic data conversions

1 sack of rice	**100 kgs**	**1 Large truck**	**50 tonnage payload**
1 tonnage	**1000 kgs**	**1 Small truck**	**1.1 tonnage payload**

We utilised available data from local rice farmer's cooperative that operated as an SME of rice supply chain. We adapted the proposed model to analyse logistics of this cooperative by using three operating scenarios that fit road freight capabilities as follow: ({*n*} denotes the model's layer, *n*=1, 2, 3, 4)

a) Ran small/frequent transportation and transshipment in-house: {2},
b) Ran small/frequent transportation and transshipment by outsourcing: {2}, and
c) Ran short haul transportation and transshipment by coalition transshipment: {2} + {3}.

The first two scenarios (a) and (b) operated according to Figure 1 using moderate size *Pu* fleets. The bulky nature of rice paddies required more *Pu* to transport them from rice field to rice mill than from the rice mill to DC and community markets since milled rice were filled in sacks. Thus, the need for number of *Pu* varied depending on main or off harvest seasons since rice were grown year-round. This was apparent from boosted sales of pick-ups last year, i.e., 6,878,050 units [22]. Some farmers outsourced to local SME to curb their capital investment. Table 3 lists a few well-known local SME and international parcel delivery companies. Their service coverage includes drop off and pick up requests, price estimation, self-collection, online claims, etc. Most of them operate their own DC locating nation-wide. However, statistics pertaining to their operating costs are not made available to public. Thus, we employed the norm Eq(1) + (2) + (3) and Eq(1) + (2) + (3)’ in the cost consideration as shown Table 4.

The third scenario (c) represented conventional transshipment and logistics that transported to (i) domestic SME using small to moderate *Pu* and *Tr* fleets, and (ii) international companies in GMS region using moderate to large *Tr* fleet. However, we only focused on domestic SME in this study. These SME are usually small in terms of capital investment, resources, and service coverage. Some of them operated coalition service, particularly when transporting large number of rice sacks or bulky goods items. We considered such coalition services as outsourcing requests, wherein employing Eq(1) + (2) + (3)' in the cost consideration as shown in Table 5.

Table 3 Express service company list

Domestic	International
Thailand Post, Shippop [25], Inter Express Logistics, TP Logistics, Por Lor Express, Nim Express, Alpha Fast, Sendit [26].	**Kerry Express, FedEx Express, DHL, Yusen Logistics, Ninja Van, SCG Express, J&T Express, ZTO Express, CJ Logistics [26], Flash, FastShip.**

Table 4 Estimated operational statistics of SME of scenario (a) and (b)

d_p	d_t	t_p	t_t	v_p	v_t	l_p	l_t	C_1	C_2	N_E	N_{CS}	N_S	N_L	C_3	TC
77	328	5.9	7.5	3.7	33.4	1.2	25.8	8,146.3	6,382.8	2	16	8	13	268.9	14,771.4
87	342	5.7	7.6	4.6	35.1	1.0	27.9	8,354.2	6,393.0	4	19	6	11	219.8	14,947.1
86	293	6.2	7.7	3.8	31.6	0.9	26.6	7,932.9	6,558.9	3	20	7	14	272.2	14,740.6

Table 5 Estimated operational statistics of SME of scenario (c)

d_p	d_t	t_p	t_t	v_p	v_t	l_p	l_t	C_1	C_2	N_E	Xs	N_L	C_3’	TC
80	328	6.0	8.0	5.1	34.6	0.9	28.6	8,189.8	6,693.3	3	61.9	11	214.9	15,097.9
75	287	5.8	7.6	4.8	32.6	0.7	26.3	7,806.6	6,365.9	3	54.2	10	193.4	14,365.9
91	315	6.1	7.9	3.9	36.8	0.6	27.2	8,175.4	6,661.8	4	46.4	12	213.5	15,050.7

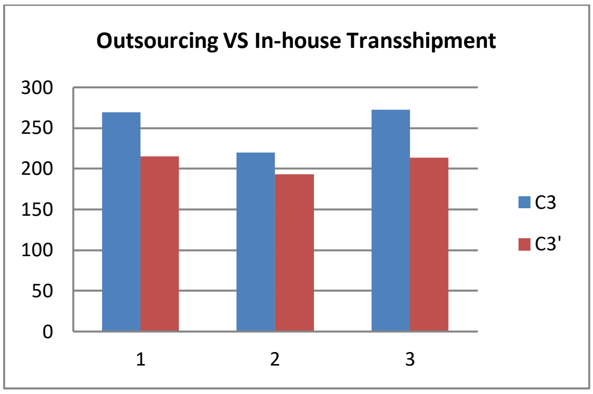

Figure 6 Outsourcing VS In-house cost comparison

Figure 6 depicts cost comparison between outsourcing and in-house transshipment consideration which do not reflect any significant savings, i.e., the costs of operating city *Pu* ($O_pN_{pCS}H_{pCS}$) and short haul trucks ($O_tN_{tS}H_{tS}$) obtained from Eq(C3) are slightly higher than outsourcing lump sum from Eq(C3'). Nevertheless, some indirect savings of outsourcing other than capital investment lie in the overhead such as car insurance, maintenance, depreciation, fuel, direct and indirect driver costs, labour relations and management, etc. Some of these overheads are out of the scope of this study.

5 Discussion

We have established a layered transshipment model operating flexible management schemes to cover road freight capabilities that are applicable to SME since they are the principal logistics service providers for Thai rice farmers. The model practical implication is to furnish resilient strategies that can be prioritised to suit the general use. There are several noteworthy issues to be further discussed.

Firstly, the proposed model was resilience and practical to utilise available data to be deployed. The hierarchical layered architecture permitted operational shift to adjacent layer that suits the service capability. For example, one multi-branch SME operated a small city sub-branch (limited by the available space) and a spacious sub-urban branch to handle layer 1 and layer 2, respectively. They could share the *Pu* fleet depending on the service load of each sub-branch. From time to time, shortage of *Pu* might occur during harvest season as the sub-urban branch was overloaded, but could not transfer all available *Pu* from the city branch to keep the service obligation of layer 1. Different course of actions could be taken such as adding new *Pu* (if budget permits), running for freight forwarding coalition, or hiring more drivers to fully operate existing *Pu* fleet. Truck driver issue has posted some occupation problems such as wages and demographic change, unfavorable social status, and working conditions [27]. Additional compensations could be paid but would increase personnel cost and decrease sale per employee and company profit. Consequently, personnel administration and operation management would be expensive and inevitably disruptive to road freight logistics.

Secondly, outsourcing and in-house issues had been studied extensively where outsourcing was practically suitable for certain scenarios. In addition to the above outsourcing cost comparison, the issue could be further explained by an operational case in point. A small sized SME in the second layer could operate on a handful of *Pu*, having only minimal IT equipment installed to meet local regulation mandate. They would be reluctant to add state-of-the-practice gadgets that helped meet the Q-mark handbook, thereby the operating cost was minimal. As technology progresses, so do regulations and standards change. Keeping abreast with these issues was expensive. They moved to outsourcing because it would offer more selections, price competitiveness, having no maintenance and other operating costs involved, no labour relation problems, employee benefits/compensations, and most important of all, the driver occupation problems. On the contrary, a moderate sized SME (having less financial limitations) in the same echelon might recognise service expansion opportunity and the urgency of digital transformation that brought about fast and innovative methods to improve existing operations and raise the quality of road freight transport. Thus, operating in-house transshipment by exploiting the layered architecture of the proposed model would allow more control and broaden their operational scope from local transportation to international transportation and logistics firm. As a result, they could become a quality LSP.

Thirdly, some local SME in layer 2 were still running an intangible 'family style' personnel administration. Their employees were on a life-time employment, receiving free of charge accommodations, subsidised meals in the company canteen, etc. Such offers might apply to immediate family members of the employee as well. Consequently, turn-over rate was low. What seemingly low incentive wage in Thailand by industrialised countries' standards was invaluably offset by the above tradition. Nonetheless, we only took the wage factor into cost consideration since this old-fashioned tradition was gradually diminishing.

Fourthly, the proposed model does not incorporate DC operations into consideration. Thus, complete analyses of logistics and transportation supply chain (such as schedule precedence demonstrated earlier) are not supported. This exclusion actually fits Thai SME logistics and transportation expenditure (which account for 15.7% of their total expenses) since SME constitute 99.5% of the country business establishments that make up 35.3% of Gross Domestic Product or GDP [28].

We have demonstrated the viability of the proposed layered architectural transshipment model that satisfies the above two research focuses, i.e., between city and rural areas by utilising local data with the help of a case study. Moreover, the applicability of the proposed model does not confine to rice or agricultural produce, but should fit well with general products. In fact, during the COVID-19 pandemic locked down that has created huge volume of online orders and deliveries, most of the express service companies (listed in Table 3) performed successfully to meet such escalating demands. Although we could not obtain any performance statistics owing to their trade confidentiality, we envisioned that the resilience of the proposed model would not only offer flexible and cost saving fleet management, but also would serve as an efficient SME road freight logistics framework.

6 Conclusion and future work

We presented a transshipment model for SME that was supposedly adjustable to different working scenarios. The layered architecture with resilience operations management and resource sharing furnished a realisable and practical framework for SME to co-exist with DC. Thai rice farmers data were compiled and plugged into the model for a preliminary validation. Although the savings turned out to be moderate, a few innumerable aspects of cost consideration and applicability were argued at length. Contributions to transshipment and logistics of road freight transport are many folds. For example, it will help raise service quality standard for *Tr* and *Pu* operations, foster the potential and capacity of transshipment and logistics systems in the hands of SME to support trade sectors, and serve as a tool for value added SME when seeking for better or new business prospectus. The resilience of the proposed model not only fits many SME operations in Thailand and GMS countries, but also is cost effective to SME in industrialised countries.

Future work should focus on some of the following open issues. (1) treatment in the V and L factors for extended coverage using other transshipment models such as DVRP, CVRP, Split VRP (SVRP), and multi-product cross-docking SVRP [6]. The outcomes will certainly be conducive toward efficient and cost effective planning and scheduling of *Tr* and *Pu* transshipment, logistics, and management of DC, such as elimination of scheduling delay or duplication, standardisation of route assignment, reduction of downtime and rework, etc.; (2) integration of transshipment logistics into DC as a one-stop operations management hub and the cost involved; and (3) transform the model into a software tool that will support service quality for the road freight industry and customers who are seeking for qualified logistics operators.

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