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Supply chain management efficiency for the *Andrographis paniculata* (Burm. f.) Wall. ex Nees of the Bandongbang community enterprise in Prachinburi province, Thailand.

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Abstract The results showed that primary producers in the upstream supply chain, farmers engaged in systematic cultivation and collaborative planning with the Chaopraya Abhayabhubesorn Hospital Foundation. A two-year Memorandum of Understanding (MOU) instils farmers' confidence in *Andrographis paniculata* cultivation. Supply chain operations reference (SCOR) based on practices that exhibited a moderate level of implementation, reflecting a balanced approach. In the midstream supply chain, effective planning aligns production capacity with customer demand, ensuring the availability of quality inputs at fair prices. The midstream supply chain excels in product collection, on-time delivery, and structural damage control protocols. The Chaopraya Abhayabhubesorn Hospital Foundation played a crucial role in the downstream supply chain. Their strategy balanced production resources to effectively meet market demand. MOUs with various members, stringent quality checks, and defined return protocols to ensure product quality. In conclusion, the study found effective supply chain practices. It underscored the importance of stakeholder collaboration in optimizing *A. paniculata* production and distribution. Relevant government agency support for SCOR-based supply chain management practices could help to enhance the overall sustainability and efficiency of *A. paniculata* among community enterprises.

Keywords: Supply chain, Community enterprise, Production, Efficiency

Introduction

As a member of the Acanthaceae, *Andrographis paniculata* is a prominent medicinal plant utilized across South, Southeast, and East Asia for centuries. Traditional remedies harness their potential to treat various symptoms, including fever, colds, sore throats, diarrhea, infections, and inflammation. Suksawet and Chankaset (2015) confirmed its efficacy in reducing inflammation and diarrhea, bolstering the immune system, and offering antimicrobial and

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antiviral properties. In 1999, the Chulabhorn Research Institute (CRI) endorsed the cultivation of *Andrographis paniculata*, among other herbs like *Curcumin* and *Cassumunar ginger*, to economically uplift citizens by enhancing herb cultivation techniques and marketing. Its preference over other herbs stemmed from its higher market price and selective leaf harvesting, which, while costly, ensured premium quality. It was also incorporated into the National List of Essential Drugs in 1999, given its short harvesting period and frequent annual cultivation. Moreover, innovations in processing the herb into convenient forms like powder and capsules have made it more accessible (Satwiwat, 2021).

With the advent of the COVID-19 pandemic, researchers discovered the antiviral properties of *Andrographis paniculata*. However, it could not safeguard cells from COVID-19 infection. Consequently, Thailand's Department of Thai Traditional and Alternative Medicine initiated its use in treating COVID-19 patients, which increased demand. Farmers were keen on supplying *Andrographis paniculata* for medicinal extraction, highlighting its importance in supply chain management for enhancing product quality while minimizing costs. The Chao Phraya Abhaiphubet Hospital, an epicenter for Thai traditional medicine, promotes herbal remedies and is pivotal in educating people on local herbal customs and practices (Abhaiphubet Chaopraya Hospital Foundation, 2014).

The Bandongbang Organic Community Enterprise (BOCE) is the central hub for ancestral herbal knowledge in Prachinburi Province, Thailand. However, industrialization encouraged the community towards alternative agricultural activities, often involving chemicals, adversely impacting the environment and community health. The BOCE was established with significant support from governmental and private entities, recognizing the need for a paradigm shift in revitalizing the community's health and socio-economic landscape. The BOCE, having secured certification from the Organic Agriculture Standards Office (IFAOM), has evolved into a pioneering herbal learning hub in Thailand, attracting numerous scholars and institutions.

The research involved the supply chain management of *Andrographis paniculata* at the BOCE, adopting a comprehensive approach to integrate the supply chain management, logistics, and modeling based on the SCOR (Supply Chain Council, 2010). The objective was to streamline operations, optimize costs, and bolster sustainable competitiveness in alignment with Thailand's agricultural strategy.

Material and methods

Study area

Dong Khilek Subdistrict of the Mueang District in Prachinburi Province, Thailand (14°10'96.32'N latitude and 101°43'66.18'E longitude) as the study area was Thailand's first community distinguished to achieve organic farming certification by IFOAM standards. BOCE is a pioneer in sustainable and chemical-free agricultural practices. Beyond its agricultural role, the community also serves as a hub for agricultural tourism and education, allowing visitors to witness firsthand the production processes of various herbal products. Rich in natural resources, particularly fertile soil, the area is well-suited for cultivating medicinal plants, rice, orchards, and ornamental flowers.

Regarding collaboration and quality control, the BOCE is partnered with pharmacists from Chaophraya Abhaibhubejhr Hospital and the Bank for Agriculture and Agricultural Cooperatives to ensure adherence to stringent organic farming regulations. Farmers commit to two-year advance planting contracts that mandate 100% organic cultivation processes, including the exclusive use of organic fertilizers and manure. Though the community is small, consisting of only seven households, its members collectively managed an extensive 40 rai (approximately 16 acres) of land. Within this expansion, residents have grown various vegetables and over a hundred types of herbs, including *Andrographis paniculata*, *Murdannia loriformis*, and *Orthosiphon aristatus*. Notably, the farmlands have a three-tiered vegetation structure featuring tall trees, intermediate-height trees, and shrubs or smaller trees, exemplifying excellent land management practices (Siam Kubota, 2016).

Population and sample

This study included the supply chain management of *Andrographis paniculata* within the BOCE in Prachinburi Province. The scope of the investigation was from upstream production activities to midstream processes, and it concluded with downstream delivery mechanisms. For data collection, the research employed a multi-method approach, utilizing questionnaires and conducting in-depth interviews with key informants actively involved in distinct stages of the supply chain. The Supply Chain Operations Reference (SCOR) model serves as the conceptual framework for the study, encapsulating upstream, midstream, and downstream activities. The key informant pool was comprised of seven individuals representing the various stakeholders: BOCE, Chao Phraya Abhayabhubesorn Hospital Foundation, and an external agency supporting community enterprises. Descriptive data analysis and content analysis are employed. The collected data were then rigorously processed and evaluated using statistical software to provide a comprehensive overview of the supply chain dynamics.

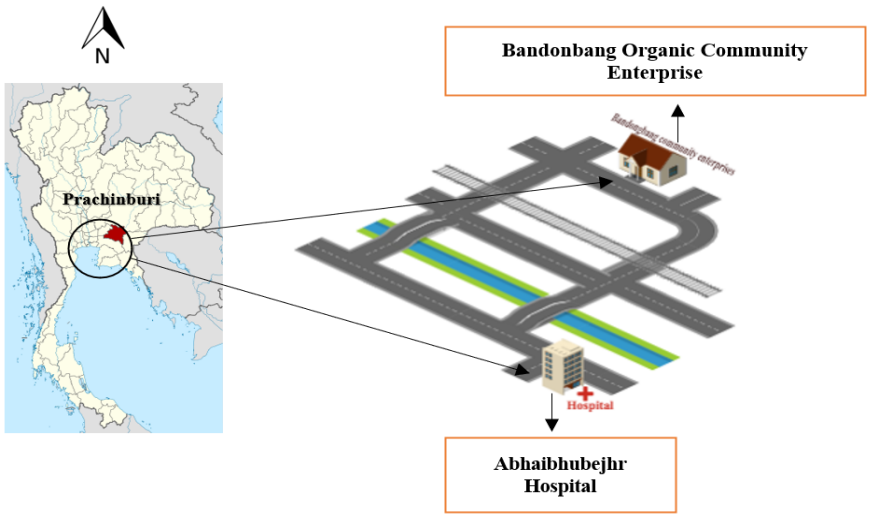

Figure 1. Bandonbang Organic Community Enterprise is located in the Dong Khilek Subdistrict of the Mueang District in Prachinburi Province and Chao Phraya Abhaibhubejhr Hospital—figure adapted from Wikipedia, 2023.

Data collection

Data were systematically collected through participatory questionnaires and in-depth interviews with key informants, each representing a distinct segment of the supply chain for *Andrographis paniculata* within the BOCE in Prachinburi Province. Structured into three primary sections, the questionnaire aligned with the conceptual framework of the SCOR model.

The first section contained general information about the respondents to establish the context and background of their involvement in the supply chain. The second section involved the core operations in the *Andrographis paniculata* supply chain, organized around the five SCOR pillars: Plan, Source, Make, Deliver, and Return. The final section solicited input on additional challenges and recommended improving the existing supply chain. Each question employed a three-level rating scale, with scoring allocated as follows: 'never practice' 1 point, 'sometimes practice' 2 points, and 'always practice' 3 points. This methodological approach allows for nuanced evaluation and interpretation of the collected data, supporting a robust supply chain analysis (Sirisuwan, 2018).

Data analysis

Data analysis is conducted using both quantitative and qualitative methods. For the quantitative aspect, descriptive statistical techniques were

employed to investigate the characteristics of the sample group involved in the *A. paniculata* supply chain, framed within the SCOR concept. The data are presented using tables to display frequency, percentage, mean, and standard deviation. Additionally, a performance grading system is incorporated, categorizing the results into three distinct levels based on a set of criteria established by Best (1977). Specifically, the levels are defined as follows: a 'Low level' corresponds to an average score ranging from 1.00 to 1.66; a 'Moderate level' pertains to an average score between 1.67 and 2.33; and a 'High level' is characterized by an average score ranging from 2.34 to 3.00.

The qualitative aspect employed methodological triangulation as proposed by Denizen (1970) to ensure data reliability. This involved cross-referencing information across different areas such as time, place, and person, as well as from the researcher's perspective and the underlying theory supported by Chanthawanich (2004). Content analysis was utilized to offer a deeper understanding of the qualitative data.

Results

Sociodemographic information

The gender distribution significantly showed the proportion of females, constituting 80% of the sample, whereas males represented 20%, suggesting that female farmers dominated cultivating *A. paniculata* within this community (Table 1). Regarding age distribution, most farmers were in the age range of 41–60 years, with the 41–50 and 51–60 years brackets representing 40%. Additionally, 20% of the farmers were over 60 years old, indicating that a significant portion of the community involved in *A. paniculata* cultivation was experienced and engaged in farming for several decades.

Regarding educational attainment, most farmers held a bachelor's degree at 60%. These individuals were actively involved in farming practices despite their high-level educational background. Twenty percent of the farmers completed primary school, while an equal proportion attained a junior high school education. None of the respondents had an education level below primary school or vocational, diploma, or postgraduate qualifications. A particularly notable finding among all farmers was that 21–25 years old planted *A. paniculata*, suggesting a deeply rooted tradition and experience in cultivating within the community. Lastly, all farmers managed land areas ranging from 1 to 5 rai (approximately 0.4 to 2 acres) for *A. paniculata* cultivation. This highlighted that the farming plots may be relatively small but intensively cultivated, given the uniform expertise in cultivating herbs.

Table 1. Sociodemographic characteristics of farmers.

Variables	Frequency	Percentage
Gender		
Male	1	20
Female	4	80
Age (year)		
41 – 50	2	40
51 – 60	1	40
> 60	2	20
Education Level		
Lower primary school	0	0
Primary school	1	20
Junior high school	1	20
Senior high school or vocational	0	0
Diploma or high vocational	0	0
Bachelor's Degree	3	60
Postgraduate	0	0
Andrographis paniculata cultivation experience (year)		
21 – 25	5	100
Areas of *Andrographis paniculata* cultivation (rai)		
1 – 5	5	100

Supply chain of the Bandongbang Organic Community Enterprise

Andrographis paniculata supply chain for the BOCE located in Dong Khilek Subdistrict, Mueang District, Prachinburi Province, is a well-structured process involving several stakeholders and various activities. Starting from the upstream, the primary players were the farmers, who were integral members of the BOCE. They were responsible for cultivating *Andrographis paniculata*. Herb is produced within the BOCE and depicted the meticulous care and attention given to the herb's growth, with uniform planting rows in a lush environment (Figure 2).

Once the cultivation process is completed, the herbs were undergone specific activities, with drying being a crucial midstream activity. It provided insights into the drying process, highlighting the use of specialized infrastructure for optimal drying results (Figure 2). Furthermore, it revealed a storage room, indicating the importance of appropriate storage solutions for preserving the herb's quality.

The BOCE played a pivotal role as the midstream entity in this supply chain, acting as the primary liaison between its member groups and the downstream stakeholders, particularly the Chaopraya Abhayabhubesorn Hospital Foundation. Its responsibilities extended beyond communication,

encompassing the collection of dried produce from member groups and ensuring its delivery to the downstream partner in Chao Phraya Abhaibhubejhr Hospital Foundation. The hospital's foundation processed the herb into various products, subsequently distributed to their consumer base. This strategic partnership between the BOCE and the hospital foundation ensured a seamless supply chain, optimizing production and distribution processes.

Figure 2. Production of herbs within the Bandongbang Organic Community Enterprise and production storage room from Siam Kubota, 2016

A comprehensive overview of the BOCE supply chain is presented in Figure 3, detailing the specific activities at each stage—from upstream to downstream. These activities included cultivation adhering to IFOAM standards, drying, communication, training, quality checks, and final distribution, highlighting the intricacies and well-coordinated efforts in the supply chain. The *Andrographis paniculata* supply chain managed by the BOCE is supposed to be a robust and intricate system, ensuring the herb's optimal cultivation, processing, and distribution to meet the industry's demands and standards.

Performance level by the SCOR-based method

The farmers' supply chain management practices in five distinct areas, plan, source, make, delivery, and return, are shown in Table 2. Each of these areas was an essential factor in ensuring the efficient operation of the supply chain for *Andrographis paniculata*. The planning process was an integral aspect of the supply chain, with farmers achieving a mean score of 2.67. This high score indicated that the farmers are accepted at forecasting, assessing resources, and matching production to market demand. Collaborative efforts with the Chao Phraya Abhaibhubejhr Hospital Foundation further enhanced the planning process, ensuring farmers can access necessary production inputs. This meticulous planning ensured that product delivery met market demand. With a

mean score of 2.80, it was evident that the sourcing processes were of high operational significance. A formalized agreement, often through an MOU, ensured clarity and commitment from both parties. The Chao Phraya Abhaibhubejhr Hospital Foundation played a pivotal role in aiding farmers, mainly when seedling shortages occur. Quality control mechanisms, such as inspection before payments, were also in place, ensuring the sourcing process's credibility.

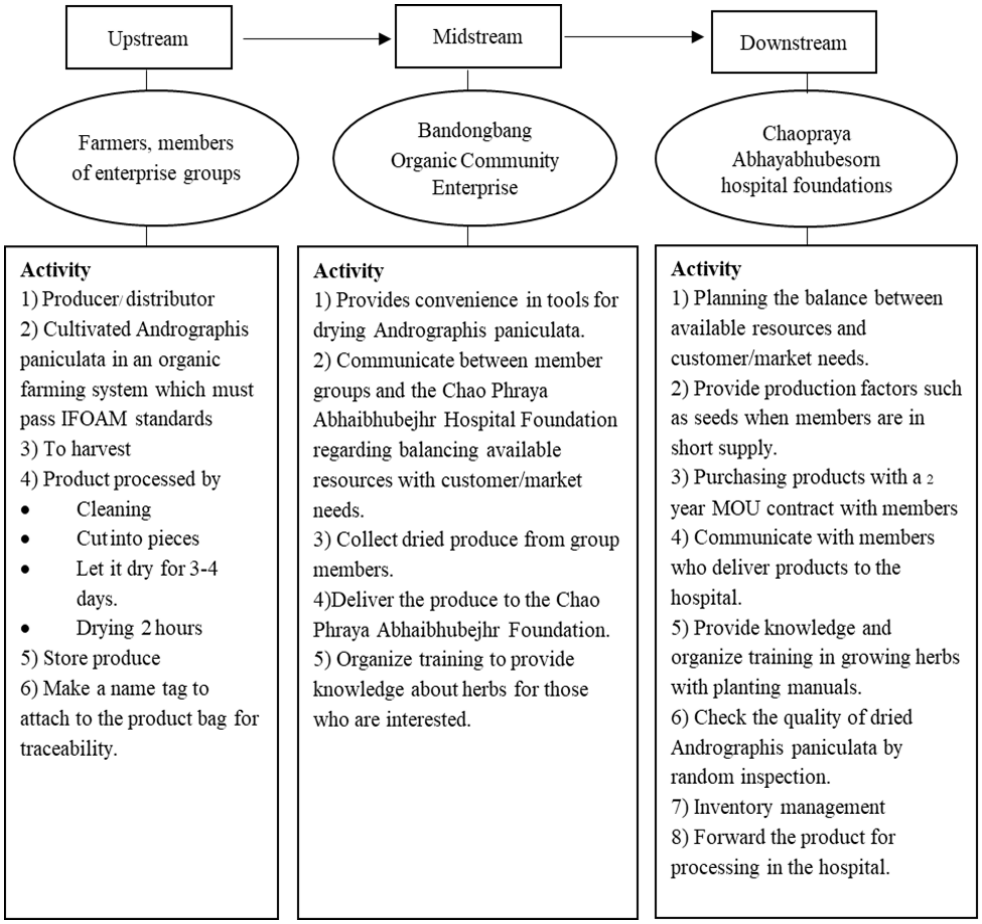

Figure 3. Supply chain of the Bandongbang Organic Community Enterprise

Table 2. Farmer level of performance results by SCOR-based concept

Topic	Mean	Standard deviation	Operational level
1. Plan	2.67	0.45	High
1.1. Planning for procuring production factors, such as seeds, seedlings, and planting materials.	3.00	0.00	High
1.2. Planning production according to demand quantity.	2.60	0.45	High
1.3. Planning transportation methods for product delivery.	3.00	0.00	High
1.4. Planning product returns in the event of damage.	2.80	0.45	High
1.5. Planning complete and timely product deliveries.	2.20	0.45	Moderate
1.6. Balancing resources with customer/market demands in planning.	2.20	0.45	Moderate
2. Source	2.80	0.25	High
2.1. There is a process for receiving and verifying customer orders.	3.00	0.00	High
2.2. Prior to payment, there is an inspection of production factors (seeds, seedlings, cuttings).	2.40	0.55	High
2.3. Careful selection of production factors is done to ensure quality and appropriate pricing.	2.80	0.45	High
2.4. Agreements are established in accordance with purchase orders or sales contracts (MOU).	3.00	0.00	High
3. Make	2.70	0.25	High
3.1. There is a production activity schedule in place.	3.00	0.00	High
3.2. Production results are of high quality in accordance with customer requirements.	2.60	0.55	High
3.3. Production matches the quantity demanded by customers.	2.20	0.45	Moderate
3.4. The production output meets safety standards (e.g., GAP, PGS, IFAOM).	3.00	0.00	High
4. Delivery	2.75	0.22	High
4.1. Gathering production yields in large quantities before delivery.	3.00	0.00	High
4.2. Transporting the production to meet the quantity demanded by customers.	2.20	0.45	Moderate
4.3. Transporting the production to meet the quality standards desired by customers.	2.80	0.45	High
4.4. Delivering products punctually according to the agreed-upon schedule.	3.00	0.00	High
5. Return	2.70	0.22	High
5.1. There are conditions for product returns in case of damage.	3.00	0.00	High
5.2. Timeframes and procedures for product returns in case of damage are specified.	3.00	0.00	High
5.3. Actions are taken to rectify defects or damaged products.	3.00	0.00	High
5.4. Production factors (seeds, seedlings, cuttings) are returned if they do not meet the agreed-upon quality standards.	1.40	0.89	Low

On the other hand, achieving a mean score of 2.70, the making process was another area where farmers had demonstrated proficiency. Organic farming practices and strict adherence are emphasized to cultivate the guidelines, and mandatory compliance with international organic standards highlights their commitment to producing quality produce. Collaboration between stakeholders ensured that production met the quality and quantity specifications. With a mean score of 2.75, farmers master the operational delivery processes. This phase was crucial since it directly impacted the customer's perception of the supply chain's efficiency. By consolidating produce at community enterprises, farmers can achieve economies of scale, leading to better management of delivery timelines. The impact of external challenges, like the COVID-19 outbreak, underlined the delivery process's resilience and adaptability. The return process, with a mean score of 2.70, was paramounted especially when dealing with perishable goods like *Andrographis paniculata*. The return policies clearly ensured that any discrepancies in product quality can be properly addressed. Although the return of production factors exhibited lower compliance, it was noteworthy that such instances were rare, speaking to the system's overall efficacy.

However, despite these high operational levels, farmers faced inherent challenges that threatened the sustainability of their practices. Labour shortages were pressed due to the ageing agricultural workforce and the disinclination of younger generations towards farming. This issue, coupled with unpredictable weather patterns, exacerbated the challenges that were faced by these farmers. The robustness of farmers' supply chain practices in producing *A. paniculata* attended to external factors that could jeopardize these operations. Addressing such challenges would ensure the long-term viability and sustainability of these practices.

Discussion

The SCOR-based model encompassed five important dimensions: planning, sourcing, making, delivery, and return, which was meticulously evaluated in this study. The assessment showed complex operational processes, illustrating a holistic overview of the entire supply chain. In the upstream supply chain, the findings highlighted that farmers did not merely rely on traditional practices. Instead, they had adopted systematic cultivation strategies for *A. paniculata*. A two-year MOU has underpinned their partnership with the Chao Phraya Abhaibhubejhr Hospital Foundation. This strategic alliance is not only fostered the trust but also brought to a certainty element to the cultivation process.

The midstream supply chain focused on bridging the gap between production and demand. Production planning is meticulously crafted to ensure that the output matched customer demand. This harmonization ensured the timely availability of top-tier products at competitive rates. A robustly structured scheduling mechanism had been put in place to cater to unforeseen challenges, laying the framework for initiating corrective actions (Llones *et al*., 2021). Protocols for returning subpar produce had been established, further fortifying the chain's integrity. The downstream supply chain was the Chao Phraya Abhaibhubejhr Hospital Foundation, which emerged as a cornerstone of the entity. Its role was not merely transactional. Its strategy resource distribution ensured to be perfectly matches market and customer expectations. Whether rooted in a purchase order or a sales contract, every procurement is stringently scrutinized for quality. This meticulous approach is complemented by comprehensive return policies, ensuring the unwavering quality of *A. paniculata* throughout its journey.

The research served as a foundational guide, a blueprint that reveals the intricate interplay spanning the upstream, midstream, and downstream supply chain stages. It delineated the path for producing, processing, and delivering *A. paniculata*. The beacon of hope was concerned with governmental backing. With its support and unwavering commitment to the SCOR-based approach, the future of *A. paniculata* production within the BOCE, Prachinburi Province, is poised for sustainability and efficiency. This optimism is also mirrored in the works of Chutidet (2012) and Monruedee and Wiwat (2019), who championed the SCOR model for revolutionizing supply chain dynamics.

Farmers need comprehensive training in effective planning encompassing the nuances of *A. paniculata* cultivation and plot management. They can be done in the vanguards of modern cultivation techniques with the proper training. In the realm of sourcing, unity was strength. Farmers can be faced a bulk-purchase raw materials by forming a collective, wielding greater negotiation power. When it comes to making, the emphasis should be related to soil conservation. Each post-harvest phase should concern the soil rejuvenated, ensuring it is brimming with essential minerals. Given the unpredictable climate, strategies for having an artesian well for drought and elevated plots for heavy rain can be related to changers (Llones and Suwanmaneepong, 2021). Delivery meets the farmers at their best, and adeptly synchronizes collection and delivery. Lastly, the return mechanism can be optimized. An intra-group reviewed mechanism, pooling collective wisdom, can drastically reduce product returns for the Chao Phraya Abhaibhubejhr Hospital Foundation.

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