



Sustainable Operations Management and Collective Action in Samut Prakan's Tie-Dye Clothing Community Based Enterprises

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Abstract

These are the mix-methods research studies that investigated the sustainability operations of the tie-dye clothing industry in Samut Prakan Province. The primary objectives were to: 1) assess the operational management of tie-dye clothing among local collective groups in Samut Prakan, and 2) formulate capacity-building strategies for community-based enterprises in order to catalyze sustainable revenue, scale existing successes, and cultivate a unique brand identity that drives job creation and thereby reinforces the community's economic foundation. The population and sample comprised 50 natural fiber tie-dyers in Samut Prakan Province, consisting of 45 questionnaire respondents and 5 in-depth interview participants. They were chosen by using stratified random sampling with a 5% margin of error. Interviews and questionnaires were employed as study instruments.

The results of the study showed that the goal of the group formation was to generate monetary income, and that the tie-dye clothing management system, group management, and group products had an overall average opinion level of high. Older and unemployed women with less secondary education made up the bulk of the sample group. By means of group projects, they learned on how to tie dyes. The group members traditional local expertise provided the operating budget for the tie-dyeing activity. Ten production phases took eight to nine days as stated by the production management system. Among the ten production phases by analyzed using the Critical Path Method (CPM), the critical path analysis reveals that node 8 (Activity H: soaking in color – fixative solution) is a non-critical activity, as its total slack = $7.042 - 5.063 = 1.98$, is not equal to zero. Twenty percent of the money was taken out for the group once the tie-dyeing activity was finished, and the remaining amount was divided among the group members.

Keywords: Tie-Dye Clothing, Sustainability Operations Management, Line Balancing, Community-Based Enterprises, Production Management

Introduction

As the cornerstone of self-sufficient economic development, the Community Enterprise Promotion Act B.E. 2005 and its modifications (No. 2) B.E. 2562 (2019) seek to foster community building and promote the community economy. It encourages mutual aid, revenue generating, and local knowledge and expertise. Along with strengthening communities and encouraging self-reliance to a higher degree of integration, this law also aims to develop products, maintain the caliber of technology and marketing research and development, establish consumer safety and business trust, and coordinate funding sources to upgrade and develop them into entrepreneurs or small and medium-sized businesses. Community-level business formation, legally recognized, promotes knowledge and local wisdom, develops management skills, and meets the actual needs of the community. This leads to a strong, self-reliant community economic system that is ready for future commercial competition (The Secretariat to the Community Enterprise Promotion Board, 2011). The formation of community enterprise groups is based on the philosophy of sufficiency economy. A learning process is the key in achieving strong and

sustainable development. This approach prioritizes the production of essential goods to satisfy communal requirements while simultaneously facilitating income generation and cost mitigation. Furthermore, it emphasizes strategic debt management, the cultivation of self-reliance, and the reinforcement of social cohesion through collaborative responsibility, ultimately integrating community enterprise initiatives within a broader developmental master plan (Dhammasaccakarn et al., 2025, p. 148).

In the domain of sustainable operations management, Community-Based Enterprises (CBEs) present a unique organizational model where environmental goals, social ties, and economic activities are intertwined. Sustainable leadership and CSR are not dynamic capabilities themselves; instead, they shape the organizational culture and relationships that strengthen and activate dynamic capabilities. Community-based enterprises can enhance their resilience through four core sustainable leadership competencies, a people-centric approach, long-term sustainable vision, innovation capability, and adherence to ethical standards (Chajae et al., 2026, p. 18). Prior literature underscores that driving circular economy innovations within localized craft sectors heavily relies on collective action and social capital rather than high-tech automation (Duarte Lima et al., 2025), a critical operational bottleneck in community-level supply chains is the persistent vulnerability of labor volatility and unplanned shortages, as rural workers often balance communal craft production with permanent livelihood commitments. Consequently, integrating structured operations management tools, such as process mapping, time standardization, and resource optimization, becomes imperative to elevate internal efficiency and ensure the ultimate operational viability of non-technological, artisanal enterprises.

Samut Prakan Province utilizes a developmental framework centered on community engagement and the augmentation of local potential. By offering expert guidance on the integration of traditional knowledge with community enterprises, the province aims to bolster local occupations and optimize the allocation of communal capital (Strategy and Information for Provincial Development Group, Samut Prakan Provincial Office, 2023). In response to evolving living standards, it is imperative to develop community-level technical and operational proficiencies. By bridging the gap between local production and market competitiveness, these initiatives support the national objective of achieving sophisticated economic, social, and political governance. By employing knowledge management procedures as a tool for community development, this can be extended to the district, provincial, and national levels. The industrial city of Samut Prakan province has a number of amenities that support a contemporary way of living. Nonetheless, a sizable section of the populace continues to work in agriculture, and others stay at home unemployed. That means to say people who are unemployed or looking to complement their normal work may find themselves earning more, this has led to the development of community groups to engage in cooperative activities targeted at generating revenue. Government and private sector agencies, including educational institutions, provide investment support, knowledge, tools for job creation, and production technologies. This results in community-owned products, agricultural produce, and handicrafts that utilize agricultural waste and leftover materials for manufacturing and processing. In fact, some products have a shelf life or expiration date. If more are produced than the market demanded, it will result in losses or spoilage, making the products unsaleable. Therefore, the production method was changed to making handicrafts from paper, weeds, or fabric, etc. Furthermore, Samut Prakan province, as gateway city welcoming tourists, has learned from its experiences in creating products for both personal use and souvenirs. Currently, tie-dyeing and creating products using natural dyes, such as those derived from trees, flowers, and fruits, are becoming popular. This helps to give



value to waste generated from agricultural products (The Secretariat to the Community Enterprise Promotion Board, 2011).

Extensive prior literature have demonstrated successful collaboration among government agencies, non-profit organizations, and local groups during the establishment phase of community enterprises. However, a significant research gap remains concerning the long-term sustainability of these groups after the initial formation stage. Few studies have investigated how local communities continue to sustain their operations independently, or examined the subsequent operational bottlenecks and resource constraints that surface after the initial collective action has been initiated. Primarily on a part-time basis, prioritizing their permanent employment over communal production. This dynamic leads to severe production unbalancing, unplanned absenteeism, and a distinct lack of operational planning. Consequently, when incoming orders for tie-dye clothing spike, production bottlenecks inevitably occur during stages that demand specialized craft skills. Bottlenecks, Adhering to eco-friendly practices restricts production speed. The slow extraction of natural dyes and reliance on manual dyeing techniques generate strict production bottlenecks that clash with mass-market timelines (Suriyankietkaew et al., 2022).

The integration of modern technology with traditional dye plants not only safeguards traditional dyeing techniques and promotes understanding of traditional knowledge but also creates employment and income opportunities for villagers (Qin et al., 2026, p. 18).

Product development, as well as production process methods, are supported by agencies, organizations, or educational institutions. Community members are educated on tie-dyeing and design, and their existing knowledge is incorporated into the sewing process, creating visually appealing, attractive, and unique products. Modern designs help address past problems of product shortages or surpluses. Based on the importance and origin of the problem mentioned above, the research team was interested in conducting research on “Sustainable Operations Management and Collective Action in Samut Prakan’s Tie-Dye Clothing Community Based Enterprises”.

Research Objectives

1. Assess the operational management of tie-dye clothing among local collective groups in Samut Prakan.
2. Formulate capacity-building strategies for community -based enterprises in order to catalyze sustainable revenue.

Literature Review

Systems Theory (Baimai, 2017, pp. 37-39) is a systematic analysis of the holistic production process comprises three key components: Input, Process, and Output. Each component is interconnected and integrated into a unified whole.

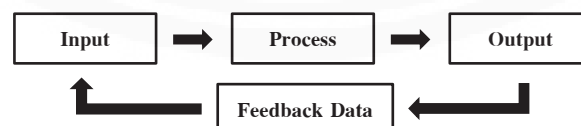


Figure 1 Component system.

Production Management (Heizer & Render, 2013, pp. 3-17) is defined as the creation of goods and services in the form of activities related to value creation, the process of transforming or converting input into output or into goods or services, which includes marketing (sales), finance (accounting), and production (operations).

The operation occurs because there is a need to know how goods or services are produced that is leading to understanding of the roles and responsibilities of each party. If there are good and appropriate production and operational system, it will create more opportunities and higher profits. For line balancing (IEBS, 2021, pp. 16–17), the researchers chose the heuristic approach, which uses a set of reasonable rules to balance the production line. This method is very popular and not complicated. Within is the following framework:

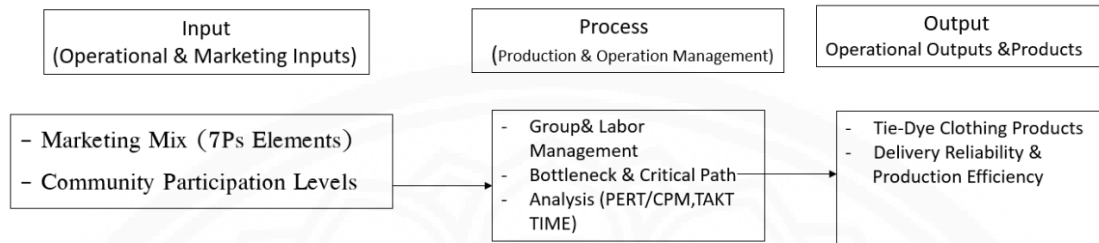


Figure 2 Framework.

Methods and Materials

This study adopts an Exploratory Sequential Mixed Methods Design to comprehensively address the operational and social constraints within the community enterprise. The research architecture is executed in two distinct, sequential phases: Phase 1: Qualitative Exploration – inductive content analysis was employed to systematically interpret the semi-structured interview data. The analysis followed a rigorous four-stage process: data familiarization and verbatim transcription, initial open coding, categorization of codes into distinct sub-themes, and final theme development. Codes such as part-time commitment and unplanned absenteeism were synthesized into the overarching theme of Labor Volatility, while codes regarding restricted government grants were categorized under Resource Constraints. To ensure the trustworthiness and validity of the qualitative findings, peer debriefing and member checking with key informants were performed, successfully establishing a robust qualitative baseline to inform the subsequent PERT/CPM quantitative phase.

Planning deficiencies Phase 2: Quantitative Optimization – Building upon the qualitative insights, a quantitative phase was subsequently deployed to precisely examine the production line. This involved field observations of time durations and employee capacity, which provided empirical data to calculate Takt Time, execute Production Line Balancing, and map the critical path via PERT/CPM to isolate production bottlenecks. By utilizing this sequential mixed-methods framework, the study effectively bridges qualitative community narratives with rigorous, quantitative operations management solutions.

Along with the following details:

1. Population and Sample

The population and sample for this study consisted of 50 individuals involved in natural fiber tie-dye clothing production in Samut Prakan Province. The sample was divided into two groups, 45 questionnaire respondents and 5 in-depth interview participants.

1.1 A total of 51 members of natural fiber tie-dyeing groups in Samut Prakan Province were sampled by using stratified random sampling based on the type of tie-dyeing group (Significant level = .05, Margin of Error = 5% and Proportional Sampling (Yamane, 1967, p. 581), resulting in a sample size of 45 people as follows:



$$n = \frac{N}{1 + Ne^2} = \frac{51}{1 + 51(0.05^2)} = \frac{51}{1 + 51(0.0025)} = \frac{51}{1 + 0.13} \approx 45$$

1.2 A total of 5 personnel with knowledge of natural fiber tie-dyeing from the community. These included the community group leaders, community enterprise group leaders, community experts, teachers, and lecturers with knowledge and experience in tie-dyeing in Samut Prakan province, totaling 5 individuals, who were selected as samples based on the specified criteria.

2. Tools Used in the Research

2.1 The questionnaire for sample group 1 was a Likert scale consisting of general questions, closed-ended questions, and open-ended questions to allow for additional responses or suggestions, in 6 sections. Content validity was determined using an IOC value between 0.67–1.00. This study adopts an Exploratory Sequential Mixed Methods Design: Qualitative Exploration Phase and Quantitative Optimization Phase.

To establish the trustworthiness and rigor of the qualitative findings, methodological and data source Triangulation were systematically applied within the study's design. First, data source triangulation was achieved by cross-examining interview insights across multiple key informants with different operational roles, including the community enterprise leader and core production artisans, ensuring a comprehensive view of labor volatility. Second, methodological triangulation was established by converging qualitative narrative data with quantitative empirical metrics, specifically verifying the reported production bottlenecks against actual time-study measurements used for takt time and PERT/CPM calculations. This dual-layer triangulation successfully mitigated subjective bias and secured the overall validity of the research outcomes.

The questionnaire was then pilot-tested with 30 participants in tie-dye clothing in Chachoengsao and Samut Sakhon provinces, yielding a reliability of 0.974. In summary, the questionnaire consisted of 80 questions.

2.2 Interview questionnaire for the second sample group, focusing on production processes, the group's financial statements (income and expenses), government funding received, and other relevant information. Disclosure of this information was optional for the sample units.

Table 1 Population and sample size

Population and Sample		Population (Person)	Sample (Person)
Group 1 Group Members			
1.1	Luad Lai Bon Phuen Nam Products Group	7	6
1.2	AMOUNT Tie-Dyeing Professional Group	12	11
1.3	The Batik House Community Enterprise Group	15	13
1.4	Suan Kao Saen Agricultural Housewives Community Enterprise Group	17	15
Sum		51	45
Group 2 Leader			
2.1	Leader of Luad Lai Bon Phuen Nam Products Group	1	1
2.2	Leader of AMOUNT Tie- Dyeing Professional Group	1	1
2.3	Leader of The Batik House Community Enterprise Group	1	1
2.4	Leader of Suan Kao San Agricultural Housewives Community Enterprise Group	1	1
2.5	Experts of Tie-Dye Fabric Products	1	1
Sum		5	5
Total		56	50



3. Statistical Data Analysis

3.1 Descriptive Statistics analyzed the data using Frequency, Percentage, Arithmetic Mean and Standard Deviation.

3.2 Plant Layout analyzed the data using Production Line Balancing, Line Efficiency, Work Station Efficiency, Critical Path Method (CPM).

Results

In accordance with Objective 1:

1. Information Obtained from the Questionnaires

Table 2 Personal factor, count, percentage, mean and standard deviation

Gender	Count	Percentage
1. Male	3	6.7
2. Female	42	93.3
Total	45	100.0
Mean of AGE = 50 years and Standard Deviation = 11.32		
Education	Count	Percentage
1. Primary Level	10	22.2
2. Lower Secondary Level	15	33.3
3. Upper Secondary Level / Vocational Certificate Level	10	22.2
4. High Vocational Certificate Level / Diploma	4	8.9
5. Bachelor's Degree	6	13.4
Total	45	100.0
Marital Status	Count	Percentage
1. Single	17	37.7
2. Married	14	31.2
3. Divorced / Separated	4	8.9
4. Others	10	22.2
Total	45	100.0
Occupation	Count	Percentage
1. Making Tie-Dye Clothing	13	28.8
2. Merchant / Trader	2	4.4
3. Personal Business	2	4.4
4. Housewifery	24	53.5
5. General Employee	4	8.9
Total	45	100.0
Average experience in tie-dyeing = 6 years and Standard Deviation = 5.91		

Table 2 showed that the members were women with an average age of 50 years. Most achieved lower secondary education level and have the probability have stayed at home to raise children and grandchildren while also working in tie-dyeing. The members had 6 years of experiences in tie-dyeing.

**Table 3** Results of the study on their opinions regarding the management system for tie-dye clothing

Questions	$\bar{X}$	S.D.	Meaning
The 7Ps Marketing Mix	4.07	0.63	High
1. Product	4.13	0.63	High
2. Price	4.00	0.73	High
3. Place	3.97	0.63	High
4. Promotion	3.94	0.71	High
5. People	4.48	0.51	High
6. Physical Evidence	4.40	0.47	High
7. Process	4.00	0.67	High
Participation	4.30	0.45	High
1. Objectives and Goals	4.52	0.46	Highest
2. Stakeholder Benefits	4.09	0.84	High
3. Relationships among People in the Group	4.40	0.47	High
4. Group Leader (such as chairman, representative, chief, boss, etc.)	4.41	0.51	High
5. Support from External Agencies	4.14	0.66	High
Total	4.18	0.51	High

Table 3 demonstrated the high average opinion level about the tie-dye clothing management system ($\bar{X} = 4.18$, SD = 0.51). The general average view was at a high level when taking into account the 7Ps marketing mix elements ($\bar{X} = 4.07$, SD = 0.63). At a high level, the sub-factor “people” had the highest average opinion score. The overall average opinion was at a high level ($\bar{X} = 4.30$, S.D.= 0.45) with respect to the involvement element. The average opinion was at the maximum level ($\bar{X} = 4.52$, S.D. = 0.46) when taking into account the sub-factor and objectives/targets.

In accordance with objective 2: Empirical data consisted of operational time averages, while simulation data comprised expenses and production quantities.

1. Information Gathered from Interviews Regarding Tie-Dye Clothing Production

Interviews were conducted with the group leaders regarding the formation of the group that shared the common objective of generating additional income. The group members were people from the community who had no income, uncertain income, or were not employed full-time. Most were older women who stayed at home who prefers to raise children and grandchildren. The majority had an education level of at least lower secondary school. Their Tie-Dye Clothing skills and experience were acquired through on-the-job training, group activities, and training from government and private organizations.

**Figure 3** Interview with the reader who were members of the groups.

In reference to knowledge of using modern technology or tools, digital marketing, and modern sales methods seen on social media are the most members lacked this knowledge. Regarding the operating budget, it was

the group's own fundraising budget that saved for future activities. It was categorized into investment funds, funds for member wages, and funds for group utilities such as water and electricity. The group was managed by using traditional knowledge and assigning tasks according to abilities and suitability to the group's work style. The people received government funding for activities whenever local, district, or provincial events were held. Concerning the activities and capital used in the group's operations, the researchers would summarize based on the information permitted and presented by the sample group, and some parts may be presented using data simulations and symbols.

This research found that operating costs depend on the proportion of work received, with small-scale operations averaging at least 2,000 baht per order, medium-scale operations averaging at least 7,000 baht per order, and large-scale operations averaging at least 10,000 baht per order. With an average of 10 production orders received per month, it could be inferred that there was work to be done almost every month. Once the tie-dyeing activity has been completed, at least 20% of the earnings would be deducted for the group and with the remaining income being shared among the members. A compensation model based on the work was undertaken, assuming a minimum profit of 20% and total monthly expenses equal to Y, for an example:

- If the small-scale activity costs $2,000 \times 10 \text{ times} = 20,000 \text{ Baht}$, the profit will be $20,000 - Y \text{ baht}$ per month, and $(20,000 - Y) \times 20\%$ will be given to the group.
- If the medium-sized activity equals $7,000 \times 10 \text{ times} = 70,000 \text{ Baht}$, the profit will be $70,000 - Y \text{ baht}$, and $(70,000 - Y) \times 20\%$ will be given to the group.
- If the large-scale activity is $10,000 \times 10 \text{ times} = 100,000 \text{ Baht}$, the profit will be $100,000 - Y \text{ baht}$, and $(100,000 - Y) \times 20\%$ will be given into the group.

The remaining 80% will be divided and allocated among each member according to their work performance.

Note: This model is based on minimum operational requirements.

Table 4 Modeling the relationship between node activity and time (Day) throughout the production process

Node	Activity	Time (Days)	Node	Activity	Time (Days)
1	A: Select and purchase	2 days	6	F: Unfold the tie-dyed fabric.	0.021 day
2	B: Soak in plain water	2 days	7	G: Wash and observe for discoloration.	2 days
3	C: Tie-dye	0.021 day	8	H: Soak in anti-color fading solution.	0.021 day
4	D: Dyeing	0.021 day	9	I: Second expose to the sun.	0.021 day
5	E: First sun exposure	1 day	10	J: Tie-dyed fabrics are ready for sale.	1 day

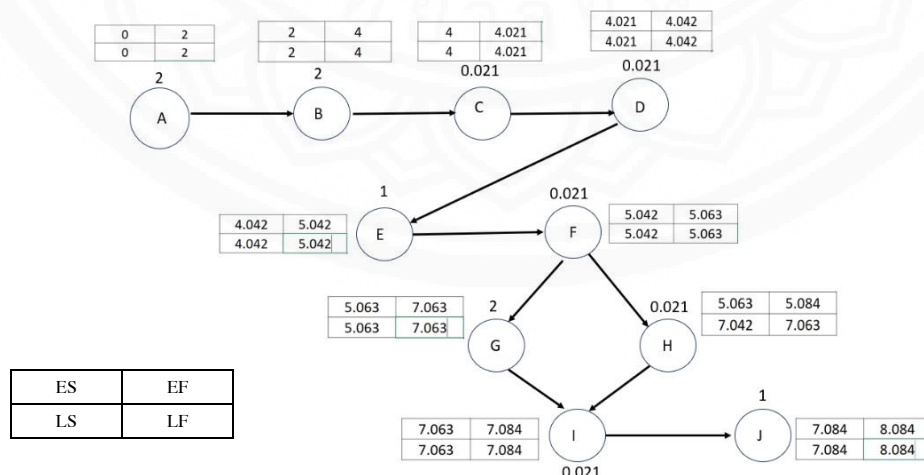


Figure 4 Network diagram showing Early Start (ES) and Early Finish (EF) times as well as the Late Finish (LF) and Late Start (LS) times for each activity.



Early Start (ES): The earliest possible time an activity can begin, assuming all predecessor activities have been completed.

Early Finish (EF): The earliest possible time an activity can be completed and calculated by adding its estimated duration to its Early Start time.

Latest Start (LS): The latest possible time an activity can begin without delaying the overall project completion date and calculated by subtracting the activity's duration from its.

Latest Finish (LF): The latest possible time an activity can be completed without pushing back the final project deadline and determined during the backward pass calculation based on succeeding activities.

Total Slack (TS): Calculated as $TS = LS - ES = LF - EF$, If TS is not equal to zero that the activity is classified as a non-critical activity, allowing for operational flexibility.

From Table 4 and Figure 4, construct the critical path network as follows:

$$A \rightarrow B \rightarrow C \rightarrow D \rightarrow E \rightarrow F \rightarrow G \rightarrow I \rightarrow J$$

The activity is a non-critical activity, was node 8: activity H (soaking in anti-color fading solution). Through the critical path analysis, node 8 was identified as a non-critical activity. Its total slack = $7.042 - 5.063 = 1.98$, which is not equal to zero, thereby allowing for operational flexibility. Information about each activity's slack (total, free and interruptive slack) can be useful in making operational decisions for a project. If resources are in scarce supply, management may wish to smoothen the use of resources by delaying the start of some non-critical activities. Activities on the critical path cannot be postponed, but they can be terminated. In managing projects, it is advisable that decisions on the use of free slack be made central. Otherwise, each supervisor may decide to utilize the amount of interruptive slack that is not really available separately (Bagshaw, 2021).

For production planning, the Line Balancing Technique using the Heuristic Approach Method was used. This method prioritized the sub-tasks with the longest work element time. The procedure undertaken was: Assuming a yearly production schedule for tie-dye clothing was approximately 300 days (excluding Sundays and public holidays) and a working day of 6 hours, this research assumed a production efficiency of 90% and assumed monthly production data as shown in Table 5.

Table 5 Simulation of Takt Time (Tk) calculation

Month	Amount	Month	Amount
Jan	X_1	Jul	X_7
Feb	X_2	Aug	X_8
Mar	X_3	Sep	X_9
Apr	X_4	Oct	X_{10}
May	X_5	Nov	X_{11}
Jun	X_6	Dec	X_{12}

$$\text{Takt Time } (T_k) = \text{Line Efficiency} \times \text{time for work}$$

Total of Amount

$$= \frac{0.90 \times 300 \times 6 \times 60}{x_1 + x_2 + x_3 + \dots + x_{12}}$$

$$= \frac{0.90 \times 108,000}{x_1 + x_2 + x_3 + \dots + x_{12}}$$

$$= \frac{97,200}{\sum_{i=1}^{12} x_i}$$

$$= M$$

The minimum number of sub-nodes required is:

$$\frac{\text{Total Flow Time}}{\text{Takt Time}} = \frac{2+2+\dots+1}{A} = B$$

Table 5 showed that knowing the monthly production requirements, tie-dye manufacturers could calculate the Takt Time (Tk) using the standardized formula for tie-dye production in each group. It was also found out that the minimum number of nodes required, i.e., nodes with similar tasks in a specific order, without causing the total time at each node to exceed the Takt Time (A).

Table 6 Results of the study on group management opinions

Questions	$\bar{X}$	S.D.	Meaning
Group Management	4.26	0.55	High
1. in terms of planning	4.20	0.54	High
2. in terms of organization	4.31	0.54	High
3. in terms of coordination	4.22	0.64	High
4. in terms of control	4.30	0.60	High

Table 6 revealed that the overall average opinion on group management was at a high level ($\bar{X} = 4.26$, S.D.= 0.55). When considering the details of organizational structure, the average opinion was highest at a high level ($\bar{X} = 4.31$, S.D.= 0.54).

Table 7 Results of the group's product feedback study

Questions	$\bar{X}$	S.D.	Meaning
Group Output	3.86	0.65	high
1. Community Identity	3.58	1.14	high
2. Receive advice from experts	4.27	0.65	high
3. Help generate more income	3.71	0.84	high
4. Have opportunity to present work	3.69	1.20	high
5. Impact future strategies for creating sustainable income for the unemployed/elderly	4.04	0.88	high

Table 7 indicated that the group's output had an overall high average opinion score ($\bar{X} = 3.86$, S.D.= 0.65), with the issue of receiving advice from experts having the highest average opinion score at a high level ($\bar{X} = 4.27$, S.D.= 0.65).

Discussion

The first objective of this study was to examine the current situation of these groups and the issues they encounter in their operations, as well as to identify suitable solutions of which could be discussed as follows:

In terms of opinions, the overall management system for tie-dye clothing in the community of Samut Prakan Province was found to be at a high level. In particular, participation had the highest average score, and the sub-factor of the group's objective had the highest average score. This may be because the members came together with a common objective: to earn income or supplemental income. Since most members were elders, using



technology in the workplace and lacking knowledge in sales promotion to help sell the products in the business was a challenge for the group. Consistent with Jompong and Saenphumi (2025, pp. 62–63), the group members mostly deficient of knowledge and understanding of strategic marketing and expertise in using online marketing channels. Although they had a Facebook page, they were unable to attract many customers due to the lack of a clearly developed marketing plan. Therefore, the group needs funding support from an organization to enable them to continue their work and product development. Regarding the marketing mix, the 7Ps framework yielded the second-highest mean score, with the personnel sub-factor emerging as the most significant variable. This suggests that human capital is perceived as the primary driver of organizational efficacy. The existing structural framework integrates multifaceted business operations, including strategic marketing, strength-based task allocation, and the specialized design of artisanal products for tiered distribution at local, provincial, and national levels. Furthermore, stakeholders anticipate that international market penetration will enhance economic viability. Such sustained revenue streams are projected to improve the socio-economic well-being of members and their households, thereby ensuring the long-term sustainability of their livelihoods. In line with Kitiyanan (2025, p. 8), the marketing mix for community products included price as a key factor in consumer purchasing decisions, product development that was aesthetically pleasing and useful, marketing promotion, service provision, and distribution channels. All of these must originate from the personnel in planning and creating strategic approaches for the group's operations.

Interviews with group leaders revealed that the operation of activities depends on varying proportions of work undertaken, available management funds, and production times. Larger groups were able to handle high-volume production orders and possess more capital than smaller groups. The group leader must be able to strategize the allocation of members to suit the tasks. Members could gather in groups, and some activities could be done from home, depending on each person's abilities, skills, and production precision. In addition, the group leader must ensure the quality of the finished products meet standards to minimize errors and meet customer requirements. This aligned with Oungkanussorn and Prasertsang (2021, p. 72), who found that financial planning strategy was crucial in driving group activities, followed by organizational strategy, staff management (staff, style, skill), organizational structure, shared values, and government support, in that order. This also corresponded with Watthanachanobon (2020, p. 226), which stated that group products that showcase a distinctive identity and cultural heritage, incorporating local wisdom including knowledge passed down from generation to generation, knowledge supported and promoted by government agencies, and knowledge inherent in individuals through practice and training, could create added value for products and increase participation in learning and preserving local wisdom.

In the context of this organization, this outcome can be academically explained through the lens of community-based enterprise alignment. The high score in Objectives and Goals dimension reflects members unified, collective vision focused on local community development, enterprise visibility, and access to public resources, such as government travel subsidies for trade exhibitions. Consequently, this shared purpose reinforces the positive assessment of the people dimension as members view their social network and collective capital not merely as production labor, but as the enterprise's core competitive advantage. However, a critical paradox surfaces when these high perceptual scores are contrasted with operational realities. While members exhibit strong emotional alignment with organization goals and deeply value their community network, day-to-day execution remains vulnerable to severe labor volatility caused by primary external employment commitments. This crucial insight

underscores that reliance on shared social values alone is insufficient to guarantee long-term viability. It justifies integrating time-centric engineering frameworks—such as Takt Time and PERT/CPM—to mathematically stabilize the production line and translate high community commitment into predictable delivery performance. To explore efforts in developing the creative economy, particularly in traditional weaving, researchers conducted interviews and observations focusing on marketing strategies related to economic development. Interviews were conducted by the reader and traditional Sasak woven fabric sellers who have sustained and increased their incomes over the years (Netrawati et al., 2024, p. 4).

The second objective was to establish a production management system for tie-dye clothing for community groups in Samut Prakan Province to generate sustainable income of which could be discussed as follows:

The group's performance depends on the proportion of work they are assigned. The group leader must allocate and plan production to ensure timely delivery to meet customer demand. The production of tie-dyed clothing using traditional Thai methods faces obstacles due to weather conditions, particularly during the drying process. The computer-aided design process allows for repeatable variations, ensuring that every batch of tie-dyed clothing produced is consistently beautiful and of the same high standard. If funding is provided to utilize technology to help solve climate-related problems and design challenges, it could lead to increased production volume, greater market appeal, and manufacturers able to communicate with buyers through multiple channels. Furthermore, the tie-dyeing group lacks younger members, resulting in a shortage of people with expertise and skills in technology. This was consistent with Lertpongpiroon's research (2022, pp. 26–27), which discovered that in order for the group's production system to be sustainable and profitable, it was essential to produce goods that satisfy consumer demands, have eye-catching and distinctive designs, and be produced in large enough quantities to sustain group members. In order to improve the products, there must also be avenues for client communication and feedback incorporation. The research results are consistent with the research of Pimpisut (2022, p. 126). It was found that enhancing community management capabilities should include bolstering knowledge in using technology and the group's official social media to build credibility and continuously showcase achievements. However, the group also requests government support in terms of initial operational budget and Sittinoppan (2021, p. 142). It was found that testing the color fastness to washing is essential for tie-dye clothing production, and time must be allocated for testing to ensure confidence in minimizing color changes after washing. This structure will help make the community's products unique and create added value, significantly increasing community income.

Conclusion

The empirical findings derived from Exploratory Sequential Mixed Methods design are presented accordance with the two primary research objectives:

1. Operational Assessment and Quantitative Optimization (Objective 1):

Descriptive statistics revealed that the overall tie-dye clothing management system received a high level of agreement. Within the 7Ps marketing mix, the people dimension obtained the highest mean score. Concurrently, the community participation element demonstrated a high overall assessment, with the objectives and goals sub-factor-achieving the maximum consensus. Quantitative path analysis mapping the 10-phase natural fiber tie-dyeing process via the Critical Path Method (CPM) calculated a total production lead time of 8 to 9 days. Crucially, the bottleneck analysis isolated Activity H (soaking in color-fixative solution) as a non-critical activity,



demonstrating a total slack of 1.98 days ($TS = 7.042 - 5.063 = 1.98$), which does not equal zero and thus provides inherent operational flexibility. Furthermore, group management evaluation was highly rated, led by organizational structure dynamics, while group product output yielded an overall mean of 3.86.

2. Capacity-Building and Economic Sustainability Strategies (Objective 2)

Qualitative interviews with community leaders highlighted severe financial vulnerabilities, technological deficits in digital marketing, and acute labor volatility due to the part-time status of elderly female artisans. To secure sustainable revenue streams, the takt time calculation was integrated with a simulated monthly demand model to balance workstation workloads. Furthermore, the empirical data validated a self-sustaining financial model based on minimum operational requirements (ranging from THB 2,000 to THB 10,000 Baht per order across 10 monthly cycles). Under this model, a standardized 20% allocation is directed to the communal group fund to utility overheads and future investments, while the remaining 80% is distributed to individual artisans based on performance.

The integration of takt time, line balancing, and the PERT/CPM framework directly fosters three dimensions of operational sustainability: cost reduction, delivery reliability, and revenue enhancement. First, regarding cost reduction, standardizing process durations and eliminating non-value-added bottlenecks prevents labor waste, thereby minimizing operational overheads under severe capital constraints. Second, concerning delivery reliability, identifying zero-slack critical activities allows the community enterprise to manage part-time labor volatility effectively, protecting the manual production line from compounded delays and ensuring on-time delivery to commercial buyers. Finally, for revenue enhancement, achieving a streamlined and predictable production capacity empowers artisans to scale up production, expand their market reach, and satisfy eco-conscious consumers who demand sustainable, high-quality handmade apparel, thereby securing long-term financial performance. Consequently, operational optimization transforms local community enterprises from subsidy-dependent entities into economically self-reliant, sustainable organizations. They support the production of eco-friendly dyes, boost the local economy, preserve ethnic culture (Qin et al., 2026).

3. Formulated Capacity-Building Strategic Framework for Community Based Enterprises (CBEs)

To fully satisfy Research Objective 2, empirical quantitative metrics and qualitative insights were synthesized to construct a concrete, actionable capacity-building strategic framework. This framework translates operations management theory into a four-item operational roadmap designed to catalyze sustainable revenue and reinforce the economic foundation of Samut Prakan's tie-dye community enterprises.

3.1 Operational Buffering Strategy (Leveraging CPM Slacks)

To mitigate critical labor volatility caused by part-time, elderly, and unemployed female artisans, the enterprise must institutionalize an Operational buffering blueprint. Group leaders must dynamically schedule production by utilizing the 1.98-day total slack identified in Activity H (soaking in color-fixative solution). Instead of forcing rigid daily quotas that lead to unplanned absenteeism, tasks at this non-critical node can be legally paused or delayed to absorb labor shortages, maintaining a stable 8-to-9-day total flow time without triggering compounded delivery delays to commercial buyers.

3.2 Mathematical Workforce Capacity Strategy (Takt Time-Driven Line Balancing)

The enterprise must transition away from traditional, unsystematic task allocation to a Takt Time-Driven Production Control. Using the standardized formula calibrated in this study ($T_k = 97,200 / \sum X_i$), manufacturers must calculate the seasonal takt time based on fluctuating monthly order volumes (small, medium,

and large scales). Artisans must be cross-trained and grouped into specialized work stations where the collective processing times do not exceed the designated Takt Time (A), systematically smoothing production line balancing and cutting down non-value-added idle times.

3.3 Cultural Identity & Digital Branding Strategy

To scale existing successes and drive local job creation, the community enterprise must integrate expert-approved modern design inputs with local traditional wisdom. This involves deploying accessible digital technologies, such as establishing official social media sales channels and engaging content marketing, to showcase the unique cultural identity of Samut Prakan's natural-fiber tie-dye apparel. By targeting the high-value, eco-conscious consumer segment, this strategy expands the enterprise's market footprint and transforms its products from standard souvenirs into a distinct boutique brand.

3.4 Sustained Financial Self-Reliance Strategy (20/80 Revenue-Sharing Model)

To overcome capital constraints and severe dependencies on volatile external government subsidies, the enterprise must formalize the verified performance-based financial model. A strict mandate must be enforced where a minimum of 20% of net profits from every batch order (scaling from THB 2,000 to THB 100,000) is automatically deducted into a communal group fund to secure capital reserves for utility overheads (water and electricity) and technological maintenance (e.g., climate-resilient drying systems). The remaining 80% is distributed transparently among members based on individual performance, creating immediate financial sustainability, structural accountability and direct income generation for vulnerable households.

Contributions to Knowledge: The Formulated Sustainable Operations Model for CBEs.

As the core theoretical and empirical contribution of this research, this model bridges human-centric social values (Collective Action) with rigorous engineering optimization frameworks (PERT/CPM and Takt Time). Prior literature often treated manual community labor strictly as a volatile liability; however, this model conceptualizes local human networks and shared goals as operational Labor Flexibility and Operational Discipline. By mapping active constraints and isolating non-critical phases—such as the 1.98-day total slack in chemical soaking—the model mathematically proves that cooperatives can stabilize an 8-to-9-day total flow time without capital-intensive automation. When this operational streamlining is interlocked with a performance-based 20/80 revenue-sharing mechanism, it establishes a self-sustaining cycle where process efficiency directly funds communal infrastructure and safeguards the enterprise against funding dependency, serving as a standardized operational blueprint for artisanal collectives globally.

In conclusion, this study demonstrates that within the realm of production management, contemporary Community-Based Enterprises (CBEs) in Samut Prakan's tie-dye clothing sector can successfully reconcile handcraft-based manufacturing timelines with rigorous ecological boundaries. In alignment with the sustainable operations philosophy of Suriyankietkaew et al. (2022), the research reveals that implementing a systemic understanding of production workflows is vital. Specifically, because natural dyeing relies heavily on weather-dependent drying times and precise botanical extraction periods, the application of PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) is concluded to be an essential operational tool for mitigating uncertainties and stabilizing collective manufacturing efficiency. Furthermore, the deterministic nature of CPM presents a notable constraint because it assumes static activity durations, ignoring the weather-dependent realities of natural drying and raw botanical maceration cycles. By integrating a probabilistic PERT approach—which incorporates optimistic, most likely, and pessimistic scenarios into the critical path analysis—Samut Prakan's tie-



dye CBEs can systematically account for environmental disruptions. This empirical synchronization reinforces the findings of Duarte Lima et al. (2025) that despite inherent limitations in handling data complexity, when properly adapted, PERT/CPM frameworks successfully optimize resource deployment and significantly mitigate production waste. Consequently, collective community action transforms these historically rigid industrial tools into flexible, accessible mechanisms that secure independent supply chain continuity and long term viability.

Recommendations

Based on the empirical insights and operational bottlenecks identified in this study, the following recommendations are proposed to enhance the long term viability of community- based enterprises:

1. Operational and Scheduling Adjustments

Group leaders must strategically exploit the 1.98-day total slack identified in Activity H (soaking in anti-color fading solution) to absorb labor shocks. Given that the workforce comprises part-time elderly artisans facing high labor volatility, this non-critical buffer should be utilized to pause or delay production without disrupting the final delivery schedule, effectively stabilizing the 8-to-9-day total flow time.

2. Technological and Financial Integration

Relevant government agencies and educational institutions should provide targeted funding and knowledge-transfer workshops focusing on digital marketing, social media sales channels, and climate-resilient technologies (such as computer-aided design tools and solar-drying systems). This will overcome the community's current technological deficits and mitigate weather-dependency barriers during the fabric-drying phases.

3. Standardized Production and Data Logging

Tie-dye clothing enterprises must mandate systematic quantitative data recording, particularly regarding raw material tracking, unplanned absenteeism rates, precise process durations, and logistical overheads. This empirical logging is vital for manufacturers to accurately execute production line balancing and dynamically recalculate Takt Time against fluctuating monthly order volumes.

4. Financial Self-Reliance Modeling

Grassroots collectives should strictly institutionalize the performance-based 20/80 revenue-sharing mechanism validated in this study. Retaining the minimum 20% for communal infrastructure protection safeguards the enterprise against volatile external subsidies, effectively transforming the local community from a grant-dependent collective into an economically self-reliant, sustainable business organization.

Policy Recommendations

Based on the validated model, government bodies specifically the Department of Agricultural Extension, the Ministry of Industry, and provincial development groups—should reformulate their grassroots economic policies from subsidy-driven support to capacity-driven operational empowerment.

1. Technical Literacy Mandates: Public agencies should condition future community- based enterprise grants on the adoption of basic technical operations management practices, such as standardized process data logging and line balancing training, rather than focusing solely on traditional product-design workshops.

2. Localized Infrastructure Subsidies: Instead of cash grants which are volatile and restricted, industrial and environmental policymakers should provide specialized physical infrastructure, such as solar-powered drying systems and standardized non-toxic wastewater treatment facilities, to eliminate weather-dependent bottlenecks and preserve local ecosystems in industrial gateways like Samut Prakan.



3. Micro-Financial Frameworks for CBEs: Formal financial regulators should recognize performance-based revenue-sharing models (such as the 20/80 model) as viable structural collateral, allowing community enterprises with established communal funds to access low-interest micro-credit markets for technology upgrading.

Directions for Future Research

While this study successfully establishes an operational optimization model for natural-fiber tie-dye clothing enterprises, several avenues remain open for future academic investigation:

1. Dynamic Digital Supply Chains: Future research should investigate how the integration of digital marketing and real-time social media sales channels alters the calculated Takt Time and supply chain agility under sudden, viral market demand spikes.

2. Cross-Sector Validation: Scholars should replicate and test the validity of this Sustainable Operations Model across other manual, labor-intensive craft sectors—such as traditional pottery, hand-loom weaving, or community-based food processing—to assess its universal generalizability.

3. Long-Term Longitudinal Impact: A longitudinal study is highly recommended to track the 5-to-10-year survival rate and capital growth of community-based enterprises that strictly implement the 20/80 revenue-sharing fund, empirically verifying its long-term efficacy in transitioning groups from government-dependency to complete economic self-reliance.

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Conflict of Interests

All authors declare that they have no conflicts of interest. (Amend this declaration statement in case authors have any potential conflict of interest).

Author Contributions

Roumporn Thongrassamee Aarnes: Project administration, Conceptualization, Methodology, Formal Analysis, Investigation and Writing-original draft.

Nannaphat Sawangkan: Funding acquisition.

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Declaration of Generative AI and AI-assisted Technologies

In this article, the AI named Perplexity was used to translate specific terms, phrases, reference form, and information that are not currently available on the internet, as well as to rephrase sentences according to grammatical rules.

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