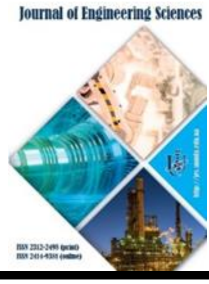
JOURNAL OF ENGINEERING SCIENCES

Volume 10, Issue 2 (2023)



Kittichotsatsawat Y., Rauch E., Woschank M., Tippayawong K. Y. (2023). Development of product supply chain strategy using BMC and axiomatic design. Journal of Engineering Sciences (Ukraine), Vol. 10(2), pp. A43–A58. DOI: 10.21272/jes.2023.10(2).a6

Development of Product Supply Chain Strategy Using BMC and Axiomatic Design

Kittichotsatsawat Y.[1][0000-0002-1819-2843], Rauch E.[2*][0000-0002-2033-4265],
Woschank M.[3][0000-0003-1496-3388], Tippayawong K. Y.[1][0000-0003-4892-0079]

[1] Chiang Mai University, 239, Huay Kaew Rd., Suthep, 50200 Chiang Mai, Thailand;
[2] Free University of Bolzano, 5, Piazza Università St., 39100 Bolzano, Italy;
[3] Montanuniversitaet Leoben, 18, Franz Josef St., 8700 Leoben, Austria

Article info:

Submitted:	June 14, 2023
Received in revised form:	October 7, 2023
Accepted for publication:	October 18, 2023
Available online:	November 2, 2023

***Corresponding email:**
erwin.rauch@unibz.it

Abstract. Product is an essential industrial manufacturing that creates high economic value worldwide. Global entrepreneurs' lack of marketing management led to a severe problem in the manufacturing preparation and control of the supply chain. Therefore, this research aims to develop the product supply chain using axiomatic design and a model canvas to generate a product manufacturing model. A particular case study proved the results. The result showed a suitable model for the product supply chain that can increase entrepreneurs' profitability through the matrix design. As a result, a suitable model was created for Thailand's industry. For this purpose, axiomatic design was applied to create a model that could increase supply chain efficiency. In addition, the implications provide capacity and readiness for manufacturers. The output of the appropriate model allows for developing and improving the supply chain strategy according to the Industry 4.0 strategy. However, this model should be tested in manufacturing enterprises to increase reliability. According to the applied methods and described management tools, entrepreneurs can operate their enterprises sustainably and gain market profitability in the future.

Keywords: Industry 4.0, sustainable manufacturing, small enterprise, medium-sized enterprise, product supply chain management.

1 Introduction

Product manufacturing is a crucial component of the global economy, creating high economic value across various industries and sectors. [1]. Additionally, product manufacturing is a cornerstone of the global economy, contributing to economic growth, technological advancement, and job creation [2]. Its significance extends across various industries and is vital in the modern world's interconnected and dynamic economy [3].

However, product manufacturing has created problems because of errors in the management system and the lack of marketing management in the product supply chain. Entrepreneurs attempt to create opportunities for enterprises by fulfilling manufacturing and branding operations to upgrade competitiveness and succeed in the market. For this reason, the entrepreneur tries to concentrate on an idea for developing the corresponding models for manufacturing and service industries to enable cost reduction and manufacturing improvements and respond to a full range of customers' needs. This research proposes to analyze the marketing activities in the product supply chain to increase the market profitability.

Axiomatic design (AD) can provide a framework for expressing objects consistent with all design problems. In the middle of the 1970s, a method of designing scientific, generalized, modified, and systematic procedures was developed. Meanwhile, design implies a continuous interaction between what we want to achieve and how we want to achieve it [4]. Consequently, the design process commences with an explicit declaration of the goals we want to achieve and a clearly defined methodology for achieving them [5].

AD can improve production and eliminate manufacturing waste (time, cost, and quality) [6]. Meanwhile, AD is used in marketing terms to meet and satisfy customers' needs. Therefore, AD decomposition can be created not only for product design and process design but also for customer services [7–9].

A business model canvas (BMC) is an appropriate visual modeling method to cover a company's model [10]. The BMC method relates to adding sticky notes to each building block; however, the model will be presented by the notes of element involvement. A complete BMC will be emphasized from the key elements in a model through a fixed point in time chosen by its creator [11]. There are, in total, nine building blocks: key partners, activities, resources, value proposition, customer relationships and segments, distribution channels, cost structure, and revenue streams [12].

2 Literature Review

The AD framework is provided for describing all of the design problems [13]. The relationships between the intended functions of an object and how they are achieved are understood by different designers. Therefore, a guideline design approach must begin with an obvious statement of what needs to be achieved and how it can be achieved [14]. However, the organization tries to improve the production process and eliminate waste (such as time, cost, and quality) within the manufacturing process. This research applies the AD, which Suh developed in 1990, for the design framework of the production industry [15].

AD has been applied to many industries; for example, Houshmand and Jamshidnezhad [16] used AD to create the lean production system design model in the manufacturing system of a car body assembly line. Arcidiacono et al. [17] utilized lean management and Six Sigma to optimize patient flows related to activities, structures, and resources developed through the AD decomposition. Vinodh and Aravindraj [18] applied the conceptual model of lean manufacturing and AD to design a manufacturing system. In addition, Baxter et al. [19] implemented AD to evaluate the costs and lead times of the parts of a product by using Acclaro software.

Holzner et al. [20] employed the AD to develop a systematic design for SME requirements in Italy, using a questionnaire survey and Acclaro software to create and analyze the FRs and DPs decomposition design matrix. Girgenti et al. [7] AD is manipulated as a guideline to build a customer development model systemically and to corroborate the agreement between what is offered and the customer's needs. Moreover, Rauch et al. [8] utilized AD and Acclaro DFFS software to generate customer needs and functional requirements and define and translate SMEs' flexible, agile manufacturing and assembly systems through design guidelines. In addition, AD was applied to evaluate the elements of the required services [9]. Nevertheless, from the literature, the AD method is not only created for product design but also for services, for example, entrepreneurial design, assisting new product analysis, customer requirement phase, and the evaluation and implementation phase.

According to the study of AD, it can be applied to designing an appropriate model to develop production processes and services using functional requirements derived from customer needs. It can design a suitable model framework that leads to a higher quality of products and services and increases the organization's profitability.

According to systems theory, AD is one of the most proper techniques for complex system management. The functional criteria for each requirement specify the uncertainty of achieving it. According to a specific probability, considered as a continuous random variable, the complexity can be measured, and AD is controlled through the complex system. Furthermore, the equal-level requirement can be included as a step to the next level, from the design process before the attributed solutions, so that the design can resolve some critical questions: "What do we want to achieve?" and "How do we choose to satisfy the need?" [21].

Interestingly, AD can apply to several different areas and systems since the domains of AD primarily consist of four domains, which depict the foundations of the AD procedure (i.e., customer, functional, physical, and process domains) [22]. However, the customer domain holds what is believed to be the beneficial attributes of the customer. In contrast, the obtained function domain holds the functional demands (FRs - Functional Requirements), and the design domain provides design parameters (DPs) for the consequent implementation of FRs [23].

The AD method is based on the following domains [24]:

– the intentions and customer needs (CAs) can be solved by the customer domain;

– based on customer needs, the functional domain addresses the FRs of the system;

– the design parameters (DPs) assist in meeting the functional requirements and are contained in the physical domain;

– the design parameters are transferred in the direction of actual process variables (PVs) via the process domain.

AD and BMC can be applied to design an appropriate model to develop the process using functional requirements obtained from customer needs. Designing a suitable model framework also leads to higher efficiency in the process and increases profitability.

Thus, following the problems mentioned above, entrepreneurs strive to develop models for the supply chain to solve this problem. Next, a suitable model for a supply chain will be generated using AD and BMC to increase profitability for the entrepreneurs. Following the methods and management expressed above, entrepreneurs can operate sustainably.

The system designer must consider the following two axioms when applying AD [25].

The design principles methods (or design Axioms) guiding the development of a high-quality product or system design are categorized into analysis and decision-making. The two Axioms used in AD are the Independence Axiom (to maintain the independence of the functional requirements (FRs)) and the Information Axiom (to minimize the information content of the design).

Axiom 1, Independence Axiom, coupled with part of the axiomatic design, is utilized to express the lack of independence among the FRs of the system as defined by the DPs. In other words, the results show that the FRs are coupled when the differentiation of DPs is more likely to have a considerable influence on two separate FRs. Furthermore, the AD will present a matrix analysis related to the design matrix to appraise and moderate the coupling outcomes.

Axiom 2, Information Axiom, furnishes a metric of the probability that a specific DPs will carry the functional performance required to satisfy the FRs. After the process, the matrix will be normalized to create the simulation system. Thus, systems with less functional performance risk will be selected and preferred over alternative systems with higher information satisfaction.

In AD, functional requirements are attributed to the design parameters utilizing the design matrix, in which the functional requirements and design parameters are determined and treated as vectors [8], as follows:

$$\{FR\} = [DM]\{DP\}; \quad (1)$$

$$DM_{ij} = \frac{\partial FR_i}{\partial DP_j}. \quad (2)$$

where $[DM]$ – the design matrix; $\{FR\}$, $\{DP\}$ – vectors of functional requirements (FRs) and design parameters (DPs), respectively:

$$[DM] = \begin{bmatrix} a_{11}\ a_{12} \dots a_{1j} \\ a_{21} a_{22} \dots a_{ij} \\ . \\ . \\ . \\ a_{i1} a_{i2}\ \dots a_{ij} \end{bmatrix}; \{FR\} = \begin{Bmatrix} FR_1 \\ FR_2 \\ . \\ . \\ . \\ FR_i \end{Bmatrix}; \{DP\} = \begin{Bmatrix} DP_1 \\ DP_2 \\ . \\ . \\ . \\ DP_j \end{Bmatrix}. \quad (3)$$

The AD system design utilizes matrix methods to analyze customer needs systematically in terms of functional requirements and design parameters [4]. Explicitly, a set of FRs is associated with a set of DPs by a design matrix:

The interaction between a functional requirement (i-element) and a design parameter (j-element) is demonstrated as “X” (a_{ij}). Otherwise, a “0” factor is assigned. Three distinct types of design matrices can be acquired based on the *i-j* element values.

(i) A Diagonal Matrix (“uncouple”) in which each design parameter satisfies the corresponding functional requirement exactly ($a_{ij} = X$ for *i-j*). This kind of matrix can be recognized as “uncoupled” and represents an “ideal design” of the system.

(ii) A Lower or Upper Triangular Matrix (“decouple”) is characterized by the presence of “X” elements that are above or under the diagonal. A “decoupled” matrix refers to how more than one design parameter is satisfied by one functional requirement. Therefore, the Independence Axiom is invalid. A decoupled design matrix presents how an idea sequence for the implementation of DPs exists. FRs can be fulfilled by adjusting the DPs to a particular order to avoid feedback loops between the functional and design domains. Such system design is not conceptual but can be regarded as an “acceptable design.”

(iii) A Full matrix (“Couple”) is furnished by “X-elements” that are placed both above and under the diagonal. In this case, the FRs cannot be satisfied independently of the DPs, and consequently, the system can be considered a “bad design. Interactions generate coordination effort and the need for iterative feedback loops and also induce more complex systems [8].

BMC is a visual modeling method used to capture the model of an enterprise. It consists of nine distinct parts, all related to each other at several levels [26]. It can be considered a summary of the activities a company or an organization must perform to supply their value offerings (products, services, or other value offerings) to their customers, partners, and stakeholders [27].

The method involves adding sticky notes to each of these building blocks, which represent the elements involved in the model. Nevertheless, a completed BMC highlights the key elements of a model at a fixed point in time, as selected by its creator [28]. Furthermore, the BMC has achieved widespread adoption; in other words, it is used to model the current state of companies’ models and any future model innovation.

García-Muiña et al. [29] applied BMC to examine the introduction of the corporate value proposition throughout its evolution from an established practice. Sivertsson and Tell [30] employed the BMC to identify and describe the innovation that overcame a few barriers in small Swedish farms and developed new models, while Partalidou [31] utilized BMC to analyze different crop sectors and fulfill farms in Greece.

Hence, this research highlights a suitable model by applying a BMC to describe, design, challenge, and pivot the basis for the following stages, proving that all later steps are feasible and originate from a strong backbone. Moreover, BMC designs a model that considers customer requirements. It assigns a weighting to the customer requirements column in the AD matrix.

3 Research Methodology

3.1 Description of the applied research approach

This research applied AD decomposition to determine DPs for a proper model for a supply chain. The following steps were conducted:

– identification of CAs (literature review, survey interviews, matching process, and definition of a list of CAs);

– definition of Cs, FRs, and FRs (determination of Cs and FRs);

– mapping and decomposition of FRs-DPs (mapping of FRs-DPs; decomposition of FRs-DPs tree to obtain concrete DPs, and check independence axiom in the design matrix);

– demonstrates the model by integrating AD into the BMC building block (key partners, activities, resources, value proposition, customer relationships and segments, distribution channel, cost structure, and revenue streams).

The primary step is to identify the CAs from the literature review and survey to ascertain the customer attributes.

The second step relied on defining the top-level and determining the customer attributes through the feasible functional and non-functional requirements and constraints.

The third step illustrated the mapping and decomposition of the functional requirements and design parameters. The FRs-DPs Tree was proved by mapping and decomposing the functional requirements and design parameters; a zigzagging process was used to identify the design parameters. A high-level design that satisfies Axiom 1 was used by zigzagging between the functional and physical domains iteratively manner. The FRs-DPs Tree resulted from mapping the FRs and DPs using a zigzagging process to identify the design parameters. A high-level design that fulfills Axiom 1 used the zigzagging between the functional and physical domains iteratively to perform a deep functional decomposition before setting up the feasibility. In this study, the next level of detail can continue from the functional decomposition. Likewise, the Acclaro DFSS software evaluated the design matrix before the FRs and DPs were classified into BMC building blocks in the last step.

3.2 Research framework

The research framework focused on a case study of the supply chain. The scope of this study ranged from the harvesting process to delivery to the end of the customer and consisted of four steps (Figure 1).

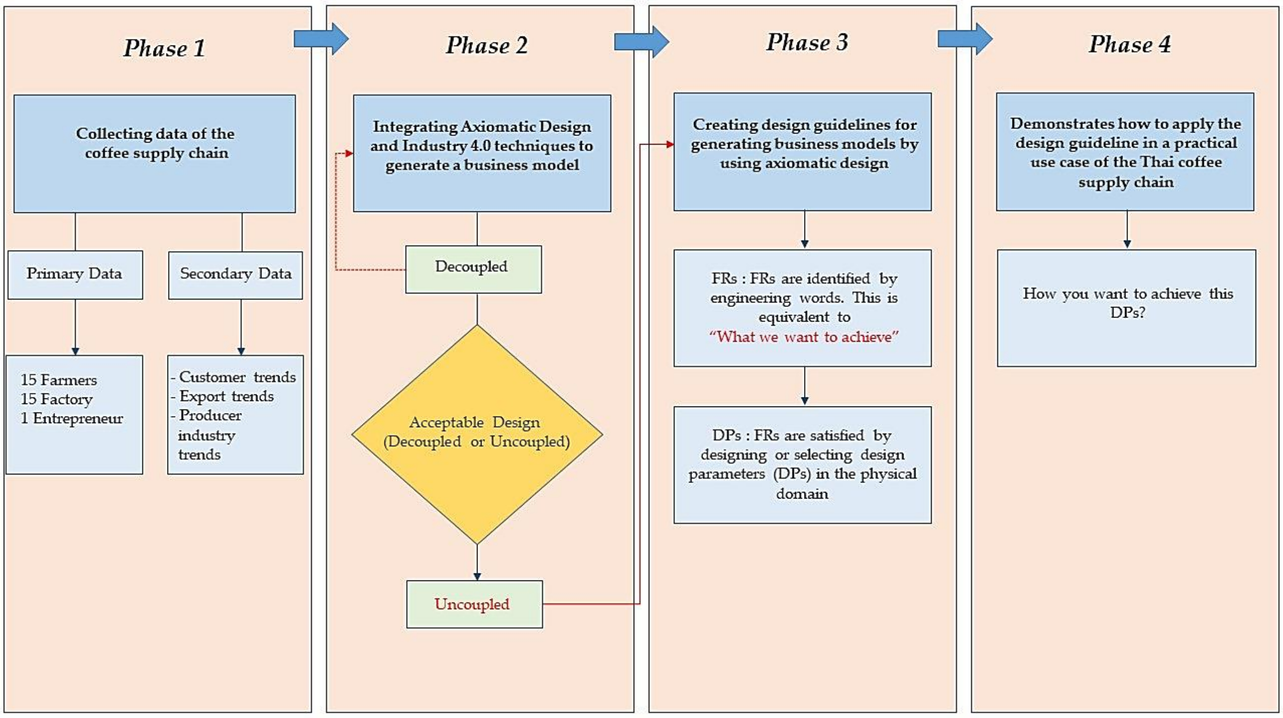


Figure 1 – The research framework methodology of the supply chain

The primary data were collected from diverse sources, such as entrepreneurs. The secondary data was accumulated from external sources, for example, customer trends, export trends, and producer industry trends in the industrial enterprises. The questionnaire used to analyze data in this study was in the form of the Likert 5-point scale. In this measurement scale: level 1 – "strongly disagree" (in the range of 1.00–1.89), level 2 – "disagree" (in the range of 1.90–2.69), level 3 – "neutral" (in the range of 2.70–3.49), level 4 – "agree" (in the range of 3.50–4.29), and level 5 – "strongly agree" (in the range of 4.30–5.00).

AD was applied to design a matrix of the customer requirements (CNs), the functional requirements (FRs), design parameters (DPs), and process variables (PVs). BMC was used to design an enterprise through the nine building blocks: customer value proposition, customer segments, channels, customer relationships, revenue streams, key resources, key partners, key activities, and cost structure [12].

The organization's efficiency is expected to be increased through AD and BMC by designing a suitable model for the supply chain, leading to an increase in the company's profitability. Finally, the suitable matrix design was carried out as nine building blocks of BMC under three contributing advantages (expense, income, and profit). Figure 1 shows the research framework of the supply chain.

The research framework includes the following phases. The first phase is to collect production data: the primary data was collected from interviews, site visits, and questionnaires. Fifteen plants, fifteen entrepreneurs, and one producer were selected as case studies in the industry. Secondary data was investigated from customer, export, and producer industry trends. The questionnaire was created to analyze the problems and data obstacles.

The second phase is to integrate a tool for designing a model using axiomatic design and Industry 4.0 techniques. Integrating the tools to design a model using the matrix design and Industry 4.0 techniques to create a model contained four steps. The CNs' research was acquired from the questionnaire in the first step. Secondly, the FRs were generated by CNs. After the FRs had been generated, the DPs were created to match CNs as the third step. The matrix design components between FRs and DPs were then evaluated and tested in the design matrix by Acclaro DFSS. Eventually, the completed design matrix from DPs was shown to be an acceptable design that uncoupled or decoupled the design through a diagonal matrix form.

The third phase is to create design guidelines for generating models using axiomatic design. The design guidelines were generated by the interaction between "what we want to achieve" and "how we achieve it" by applying the FRs and DPs to match CNs. After that, the FRs were designed from CNs and DPs and created to match the FRs. Meanwhile, DPs were matched with FRs by identifying or choosing from the DPs in the matrix design. Finally, after selecting and introducing FRs and DPs, the design matrix was exhibited between the relation and correspondence of FRs and DPs. DPs defined the PVs in the same manner.

The fourth phase is to demonstrate the axiomatic design to generate a model. The model was generated by integrating the AD into a BMC to generate a suitable model for the supply chain under nine BMC building blocks.

4 Results

4.1 Identification of customer attributes

The study aims to develop the supply chain using AD and BMC to generate a model. It specifically targeted the supply chain to examine and propose improving marketing profitability. AD and BMC were integrated to generate a suitable model under nine building blocks of BMC concepts and to increase the company's profitability.

The representative customer attributes for the model were obtained in two distinct ways. An investigation of the topic defined the first part of the analysis revealed in publications. The second part focused on the users of Industry 4.0 techniques conducted through a survey and interviews.

The examined studies on Industry 4.0, axiomatic design in manufacturing, BMC, and supply chain were used to determine the following nine main customer attributes (CAs) through nine building blocks of BMC: CN_1 – creating value propositions; CN_2 – customer segmentation; CN_3 – customer relationship management; CN_4 – creating data-driven marketing; CN_5 – customer journey; CN_6 – partnership marketing; CN_7 – material requirement planning; CN_8 – cost structure; CN_9: revenue streams.

4.2 Mapping and decomposition of functional requirements and design parameters

The definition of customer domains and constraints of the functional requirements allowed the mapping process to proceed. The causes of the marketing problem were identified through CNs; meanwhile, FRs found a strategy to solve this problem.

The highest level of FRs and DPs was determined and enunciated as follows: FR_0 – to increase long-term sustainable profitability in the supply chain; DP_0 – BMC-based supply chain strategy for increasing profitability.

The highest and lower-level requirements were decomposed through a subsequent step; meanwhile, in the systematic and structural decomposition process, lower-level functional requirements were identified based on the translation of CAs into FRs and linked to feasible solutions. The impartiality of the decomposition process is the most crucial principle that supports the creator operating without the influence of existing solutions. The decomposition explains nine major requirements of a suitable model on the first hierarchy level after this, defined as the "design of functional requirements."

The outcome of the initial workshop defined the FRs for the design; the high level of FRs, which are relative DPs, being as follows: FR_1 – collect and analyze data from customer suggestions and marketing data; FR_2 – categorize and identify the data of the product from customer needs; FR_3 – introduce CRM; FR_4 – improve the efficiency of marketing operations; FR_5 – improve the efficiency of the logistics channel; FR_6 – improve efficiency for collaborating with key partners correctly; FR_7 – implement MRP for lean operations improvement; FR_8 – reduce cost; FR_9 – Improve product and service income.

The corresponding solutions to meet these functional requirements by designing parameters for solving the problem are as follows: DP_1 – opportunity analysis for customer requirements; DP_2 – design and test data of product from customer needs; DP_3 – customer relationship management system; DP_4 – sales and marketing management; DP_5 – monitoring of logistics channel and decision making; DP_6 – digital connection with key partners; DP_7 – lean and computer-integrated manufacturing; DP_8 – monitoring cost; DP_9 – revenue forecasting and prediction tools.

Figure 2 shows the Tree of the hierarchical levels of FRs-DPs with the identified field.

The top-level FRs-DPs decomposition process proposes transferring the requirements through tangible parameters; however, it can be used in daily industrial practice. The highest hierarchical level of FRs-DPs pairs in Figure 2 is a starting point for the whole process.

After evaluating the matrix design by MATLAB R2019b, an acceptable design showed that the matrix results were uncoupled or decoupled.

If the result shows a decoupled outcome, the developed functional requirements or developed DPs for the FRs must be resolved, and the matrix model re-evaluated (range 1–2).

If the result shows uncoupled outcomes with validity (range 3–5), these results should be used to verify and process the test components of the matrix using the "Acclaro DFSS" software.

If the result of the matrix design shows decoupled results, then the analysis must be conducted and resolved again. On the other hand, if the result shows significant signs of being uncoupled, then this indicates complete design and demonstrates the model in the next step.

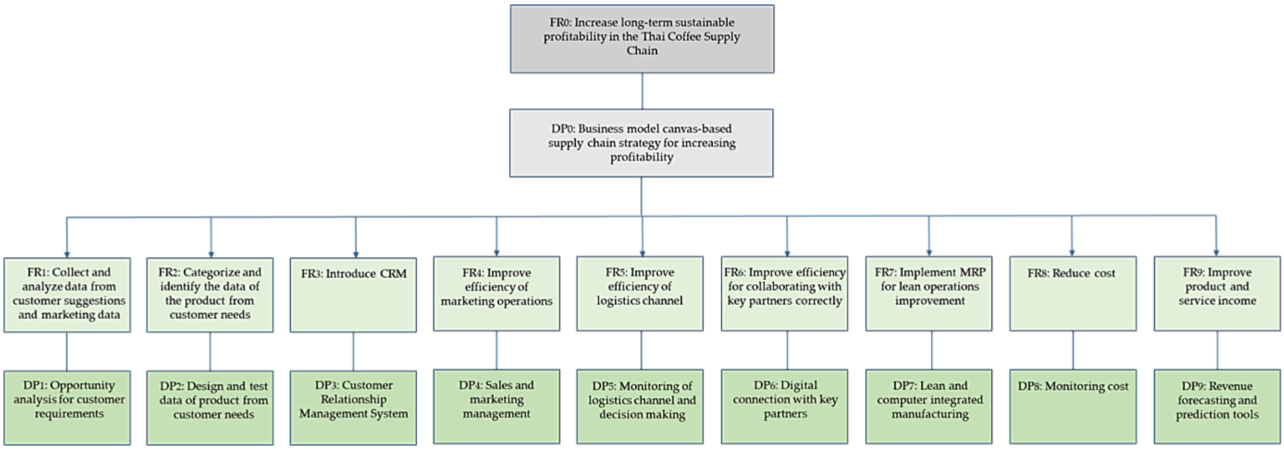


Figure 2 – The highest hierarchical levels of the FRs-DPs tree

4.3 Decomposition and mapping process

The decomposition process started from the top level of FRs and DPs, aiming to transfer the main requirement into tangible parameters close to practical design guidance and related to the collaborative workstation's implementation. The highest hierarchical level of the decomposition process is FRs-DPs pairs, starting from the top to down decomposition and mapping process. The FRs-DPs pairs showed the decomposition performing separately, allowing a better understanding of the process.

FRs and DPs pairs started collecting and analyzing customer suggestions and marketing data (FR_1) to transform the guidelines into opportunities following customer requirements (DP_1). The reports of FR_1 and DP_1 were defined as the successive hierarchical levels in Figure 3.

The design matrix showed the decoupled design ($FR_{1.1, 1.2, 1.3}$ and $DP_{1.1, 1.2, 1.3)}$ due to the FR $_{(1.3)}$ uncorrelation with DP $_{(1.1).}$

The primary and secondary data ($DP_{1.1}$) were agglomerated to hoard the demand and supply trend data on the social network ($FR_{1.1}$). Similarly, $FR_{1.1}$ can be categorized into three partial requirements in each successive level.

The ERP or CRM systems ($DP_{1.1.1}$) were used for collecting internal data ($FR_{1.1.1}$), whereas the benchmarking database from the Thailand industry was derived from the website ($DP_{1.1.2}$), and it was explicitly utilized to accumulate external data ($FR_{1.1.2}$). Meanwhile, individual surveys were conducted in shops ($DP_{1.1.3}$) to gather data by directly interviewing customers ($FR_{1.1.3}$).

Big Data Analytics ($DP_{1.2}$) was implemented to identify and predict customer needs ($FR_{1.2}$) and gather the network's demand and supply trend data.

The requirements comprise two partials: data mining analytics ($DP_{1.2.1}$) was applied to identify data patterns related to customer needs and opportunities ($FR_{1.2.1}$). Machine learning ($DP_{1.2.2}$) was used for evaluating future customer needs and opportunities in trends of products.

Opportunity Analysis ($DP_{1.3}$) is one of the critical parts of analyzing customer needs to improve existing products and services.

FR		DP		Design Matrix
$FR_{1.1}$	Collect data	$DP_{1.1}$	Primary and secondary search of data	Decoupled design $\begin{Bmatrix} FR1.1 \\ FR1.2 \\ FR1.3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ X & 0 & X \end{bmatrix} \begin{Bmatrix} DP1.1 \\ DP1.2 \\ DP1.3 \end{Bmatrix}$
$FR_{1.1.1}$	Collect internal data	$DP_{1.1.1}$	ERP/CRM systems	Decoupled design $\begin{Bmatrix} FR1.1.1 \\ FR1.1.2 \\ FR1.1.3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ X & 0 & X \end{bmatrix} \begin{Bmatrix} DP1.1.1 \\ DP1.1.2 \\ DP1.1.3 \end{Bmatrix}$
$FR_{1.1.2}$	Collect external data	$DP_{1.1.2}$	Benchmarking database from Thailand coffee industry, web	
$FR_{1.1.3}$	Ask directly customers (coffee shops)	$DP_{1.1.3}$	Surveys/interviews in Coffee Shops	
$FR_{1.2}$	Identify and predict customer needs and opportunities in the data	$DP_{1.2}$	Big Data Analytics	
$FR_{1.2.1}$	Identify data patterns related to customer needs and opportunities	$DP_{1.2.1}$	Data mining analytics	Uncoupled design $\begin{Bmatrix} FR1.2.1 \\ FR1.2.2 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{Bmatrix} DP1.2.1 \\ DP1.2.2 \end{Bmatrix}$
$FR_{1.2.2}$	Predict future customer needs and opportunities	$DP_{1.2.2}$	Machine Learning	
$FR_{1.3}$	Satisfy customer needs and take market opportunities	$DP_{1.3}$	Opportunity Analysis	
$FR_{1.3.1}$	Evaluate importance for customer	$DP_{1.3.1}$	Surveys/interviews with customers (Coffee Shop Owners)	Uncoupled design $\begin{Bmatrix} FR1.3.1 \\ FR1.3.2 \\ FR1.3.3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP1.3.1 \\ DP1.3.2 \\ DP1.3.3 \end{Bmatrix}$
$FR_{1.3.2}$	Evaluate own competence in market opportunities	$DP_{1.3.2}$	Benchmarking with other competitors	
$FR_{1.3.3}$	Interpret results of core opportunity analysis	$DP_{1.3.3}$	Definition of new/revised value proposition	

Figure 3 – Decomposition of the CN_1 – creating value propositions

It also satisfies exact customer needs and takes market opportunities ($FR_{1.3}$), including three partial requirements: (i) surveys or interviews (shop owners) ($DP_{1.3.1}$), which are applied to evaluate the customer needs ($FR_{1.3.1}$) by using benchmarking with other competitors ($DP_{1.3.2}$), (ii) evaluation of owning competence in the market opportunities shown in the interpreted results ($FR_{1.3.2}$), and (iii) a new or revised value proposition for the industry ($DP_{1.3.3}$), as shown in Figure 4.

FR		DP		Design Matrix
$FR_{1.1}$	Collect data	$DP_{1.1}$	Primary and secondary search of data	Decoupled design $\begin{Bmatrix} FR1.1 \\ FR1.2 \\ FR1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ X & O & X \end{bmatrix} \begin{Bmatrix} DP1.1 \\ DP1.2 \\ DP1.3 \end{Bmatrix}$
$FR_{1.1.1}$	Collect internal data	$DP_{1.1.1}$	ERP/CRM systems	Decoupled design $\begin{Bmatrix} FR1.1.1 \\ FR1.1.2 \\ FR1.1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ X & O & X \end{bmatrix} \begin{Bmatrix} DP1.1.1 \\ DP1.1.2 \\ DP1.1.3 \end{Bmatrix}$
$FR_{1.1.2}$	Collect external data	$DP_{1.1.2}$	Benchmarking database from Thailand coffee industry, web	
$FR_{1.1.3}$	Ask directly customers (coffee shops)	$DP_{1.1.3}$	Surveys/interviews in Coffee Shops	
$FR_{1.2}$	Identify and predict customer needs and opportunities in the data	$DP_{1.2}$	Big Data Analytics	
$FR_{1.2.1}$	Identify data patterns related to customer needs and opportunities	$DP_{1.2.1}$	Data mining analytics	Uncoupled design $\begin{Bmatrix} FR1.2.1 \\ FR1.2.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP1.2.1 \\ DP1.2.2 \end{Bmatrix}$
$FR_{1.2.2}$	Predict future customer needs and opportunities	$DP_{1.2.2}$	Machine Learning	
$FR_{1.3}$	Satisfy customer needs and take market opportunities	$DP_{1.3}$	Opportunity Analysis	
$FR_{1.3.1}$	Evaluate importance for customer	$DP_{1.3.1}$	Surveys/interviews with customers (Coffee Shop Owners)	Uncoupled design $\begin{Bmatrix} FR1.3.1 \\ FR1.3.2 \\ FR1.3.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP1.3.1 \\ DP1.3.2 \\ DP1.3.3 \end{Bmatrix}$
$FR_{1.3.2}$	Evaluate own competence in market opportunities	$DP_{1.3.2}$	Benchmarking with other competitors	
$FR_{1.3.3}$	Interpret results of core opportunity analysis	$DP_{1.3.3}$	Definition of new/revised value proposition	

Figure 4 – Decomposition of the CN_2 – customer segmentation

Design and test data procedures of products (DP_2) were used to categorize and identify the product data from customer needs (FR_2), as shown in Figure 4. Trend Analysis ($DP_{2.1}$) was applied to understand new and trending products from the customer requirements ($FR_{2.1}$) to forecast the trends of customer needs during each period.

There are three partial requirements. The primary requirement (i) was the digital marketing or surveys ($DP_{2.1.1}$), which were employed to customize the product ($FR_{2.1.1}$), and (ii) Data analytics, artificial intelligence, or machine learning ($DP_{2.1.2}$) were operated in personalized marketing ($FR_{2.1.2}$), while (iii) electronic commerce ($DP_{2.1.3}$) was similarly used to sell trending products ($FR_{2.1.3}$). However, the matrix decomposition between the customized product ($FR_{2.1.1}$) and electronic commerce ($DP_{2.1.3}$) was not correlated and showed the decoupled design on the upper diagonal matrix.

Process design ($DP_{2.2}$) is necessary for designing new products and service offers ($FR_{2.2}$) to get a suitable model for new products and services. The partial requirements include three sub-partials. Firstly, surveys, interviews, or site visits ($DP_{2.2.1}$) were employed to define the product and service design (your product and service) ($FR_{2.2.1}$). Secondly, engineering software ($DP_{2.2.2}$) was used to design and improve product and service development ($FR_{2.2.2}$). Eventually, SWOT analysis ($DP_{2.2.3}$) was utilized to evaluate products and services ($FR_{2.2.3}$). On the other hand, the surveys, interviews, and site visits ($DP_{2.2.1}$) did not match up with evaluating products and services from customers ($FR_{2.2.3}$).

Quality control ($DP_{2.3}$) was also operated for testing new products and helpful service appropriateness ($FR_{2.3}$) to test the model for new products and services. Quality assurance ($DP_{2.3.1}$) was applied for validating the new products ($FR_{2.3.1}$). In the same way, quality improvement ($DP_{2.3.2}$) was used for the products ($FR_{2.3.2}$). Finally, testing and research ideas were committed to ensuring product success ($FR_{2.3.3}$) and to launching the minimum viable products (MVP) ($DP_{2.3.3}$).

A customer relationship management system (DP_3) is categorically essential and necessary in the process design of every industry (FR_3). The accurate product and real-time service ($DP_{3.1}$) are essential for concentrating on the long-term relationship ($FR_{3.1}$) because these can complement the customer's desires in the ultimate supply chain (Global Precipitation Analysis products of the Global Precipitation Climatology Centre). A long-term partnership ($FR_{3.1.1}$) focuses on supporting and training its partners ($DP_{3.1.1}$). Additionally, collaborative partnership ($DP_{3.1.2}$) is promoted to determine and develop the collaborative partnership structure ($FR_{3.1.2}$). Enterprise Resource Planning (ERP) ($DP_{3.1.3}$) plays a significant role in raising data connections by directing connections with customers ($FR_{3.1.3}$).

An auto-response message ($DP_{3.2}$) immediately responds to customers (FR3.2) using an autonomous system to reply to customer inquiries and demands promptly. Automated (AI-based) response messages ($DP_{3.2.1}$) are employed to support and quickly respond to standard customer issues ($FR_{3.2.1}$). A quick response is integral to a sales operator ($DP_{3.2.2}$) to increase customer satisfaction for complex cases ($FR_{3.2.2}$).

However, the decomposition of increased customer satisfaction for complex cases ($FR_{3.2.2}$) does not correlate with automated (AI-based) response messages ($DP_{3.2.1}$). Nevertheless, the online survey software ($DP_{3.2.3}$) was included to evaluate customer satisfaction in the industry ($FR_{3.2.3}$), as shown in Figure 5.

Sales and marketing management (DP_4) in Figure 6 are considered to improve marketing operations (FR4) efficiency.

Digital sales management ($DP_{4.1}$) is required to increase the effectiveness of sales employees ($FR_{4.1}$), aiming to achieve the planned market operating objectives. Furthermore, intelligence software ($DP_{4.1.1}$) assesses the current sales volume per agent ($FR_{4.1.1}$).

SWOT analysis based on BI data ($DP_{4.1.2}$) was used for evaluating the sales territory ($FR_{4.1.2}$). However, sales management should be controlled by digital sales management software ($DP_{4.1.3}$) when the entrepreneur needs to optimize sales administration processes ($FR_{4.1.3}$).

Moreover, quality improvement in marketing data ($DP_{4.2}$) is applied to reduce the risk of employee errors in creating marketing data ($FR_{4.2}$) and to increase organizational performance efficiency.

FR		DP		Design Matrix
$FR_{3.1}$	Concentrate on the long-term relationship	$DP_{3.1}$	Accurate product and real-time service	Uncoupled design $\begin{Bmatrix} FR3.1 \\ FR3.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP3.1 \\ DP3.2 \end{Bmatrix}$
$FR_{3.1.1}$	Focus long term partnership	$DP_{3.1.1}$	Support and training for own partner	Uncoupled design $\begin{Bmatrix} FR3.1.1 \\ FR3.1.2 \\ FR3.1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP3.1.1 \\ DP3.1.2 \\ DP3.1.3 \end{Bmatrix}$
$FR_{3.1.2}$	Determine and develop the structure of the collaborative partnership	$DP_{3.1.2}$	Collaborative Partnership	
$FR_{3.1.3}$	Create a direct data connection with customers	$DP_{3.1.3}$	Direct connection of own and customer Enterprise Resource Planning (ERP)	
$FR_{3.2}$	Respond immediately to customer	$DP_{3.2}$	Auto-response messages	
$FR_{3.2.1}$	Support and quick response to standard customer issues	$DP_{3.2.1}$	Automated (AI-based) response messages	Decoupled design $\begin{Bmatrix} FR3.2.1 \\ FR3.2.2 \\ FR3.2.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ X & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP3.2.1 \\ DP3.2.2 \\ DP3.2.3 \end{Bmatrix}$
$FR_{3.2.2}$	Increase customer satisfaction for complex cases	$DP_{3.2.2}$	Quick response by a sales operator	
$FR_{3.2.3}$	Evaluate the satisfaction of the customers	$DP_{3.2.3}$	Online Survey Software	

Figure 5 – Decomposition of the CN_3 – customer relationship management

FR		DP		Design Matrix
$FR_{4.1}$	Increase effectiveness of sales employees	$DP_{4.1}$	Digital sales management	Decoupled design $\begin{Bmatrix} FR4.1 \\ FR4.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ X & X \end{bmatrix} \begin{Bmatrix} DP4.1 \\ DP4.2 \end{Bmatrix}$
$FR_{4.1.1}$	Assess current sales volume per sales agent	$DP_{4.1.1}$	Business Intelligence software	Uncoupled design $\begin{Bmatrix} FR4.1.1 \\ FR4.1.2 \\ FR4.1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP4.1.1 \\ DP4.1.2 \\ DP4.1.3 \end{Bmatrix}$
$FR_{4.1.2}$	Evaluate sales territory	$DP_{4.1.2}$	SWOT Analysis based on BI data	
$FR_{4.1.3}$	Optimize sales administration processes	$DP_{4.1.3}$	Sales Management/Controlling Software	
$FR_{4.2}$	Reduce the risk of employee errors for creating marketing data	$DP_{4.2}$	Quality improvement of marketing data	
$FR_{4.2.1}$	Focus on prevention	$DP_{4.2.1}$	Risk assessment and risk management	Uncoupled design $\begin{Bmatrix} FR4.2.1 \\ FR4.2.2 \\ FR4.2.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP4.2.1 \\ DP4.2.2 \\ DP4.2.3 \end{Bmatrix}$
$FR_{4.2.2}$	Train employees thoroughly	$DP_{4.2.2}$	Human resource management (HRM)	
$FR_{4.2.3}$	Evaluate employee performance	$DP_{4.2.3}$	Performance assessment	

Figure 6 – Decomposition of the CN_4 – creating data-driven marketing

In contrast, reducing the risk of employee errors when creating marketing data ($FR_{4.2}$) does not interact with digital sales management ($DP_{4.1}$), while risk assessment and risk management ($DP_{4.2.1}$) are, therefore, included to prevent and reduce waste in the supply chain ($FR_{4.2.1}$). Likewise, human resource management (HRM) ($DP_{4.2.2}$) is used to train employees thoroughly within the company ($FR_{4.2.2}$); however, the employee performance assessment ($DP_{4.2.3}$) was evaluated ($FR_{4.2.3}$) to control the KPI standard level of employee in the company.

Monitoring of the logistics channels and decision-making (DP_5) is applied to design the transportation channel, which becomes conducive to improving the logistics channel's efficiency (FR_5). Supply chain simulation software ($DP_{5.1}$) was utilized to design the transportation channel ($FR_{5.1}$), focusing on making decisions on delivering goods on time. Meanwhile, multi-criteria decision analysis (MCDA) ($DP_{5.1.1}$) is one of the suitable techniques for defining the physical flows between the various links in the supply chain and distribution flows ($FR_{5.1.1}$). Similarly, logistics network modeling ($DP_{5.1.2}$) is applied for developing the logistics network ($FR_{5.1.2}$), and the distribution channel was evaluated ($FR_{5.1.3}$) by AHP or Fuzzy logic ($DP_{5.1.3}$).

The selection procedure for the means of transport ($DP_{5.2}$) is a critical step for selecting an appropriate transportation ($FR_{5.2}$) to facilitate and reduce transportation time. The Decision Support System (DSS) ($DP_{5.2.1}$) is used to identify the suitable mode of transport ($FR_{5.2.1}$); conversely, it does not correlate with the identified transport for the correct mode ($FR_{5.2.1}$). Product liability insurance ($DP_{5.2.2}$) manages the reliability and regularity of the service ($FR_{5.2.2}$) but does not relate to a minimized cost of transportation ($DP_{5.2.3}$). However, transportation was used to minimize the cost of production ($FR_{5.2.3}$) through a scenario technique and decision-making ($DP_{5.2.3}$), as shown in Figure 7.

FR		DP		Design Matrix
$FR_{5.1}$	Design the transportation channel	$DP_{5.1}$	Supply chain simulation software	Uncoupled design $\begin{Bmatrix} FR5.1 \\ FR5.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP5.1 \\ DP5.2 \end{Bmatrix}$
$FR_{5.1.1}$	Defining the physical flows between the various links in the supply chain and distribution flows	$DP_{5.1.1}$	Multi-criteria decision analysis (MCDA)	Uncoupled design $\begin{Bmatrix} FR5.1.1 \\ FR5.1.2 \\ FR5.1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP5.1.1 \\ DP5.1.2 \\ DP5.1.3 \end{Bmatrix}$
$FR_{5.1.2}$	Developing the logistics network	$DP_{5.1.2}$	Logistics network modeling	
$FR_{5.1.3}$	Evaluate the distribution channel	$DP_{5.1.3}$	AHP/Fuzzy logic	
$FR_{5.2}$	Select an appropriate mean of transportation	$DP_{5.2}$	Selection procedure for mean of transport	
$FR_{5.2.1}$	Identify the right mode of transport	$DP_{5.2.1}$	Decision Support System (DSS)	Decoupled design $\begin{Bmatrix} FR5.2.1 \\ FR5.2.2 \\ FR5.2.3 \end{Bmatrix} = \begin{bmatrix} X & X & O \\ O & X & O \\ O & X & X \end{bmatrix} \begin{Bmatrix} DP5.2.1 \\ DP5.2.2 \\ DP5.2.3 \end{Bmatrix}$
$FR_{5.2.2}$	Manage reliability and regularity of service	$DP_{5.2.2}$	Product liability insurance	
$FR_{5.2.3}$	Minimize cost of transportation	$DP_{5.2.3}$	Scenario technique and decision making	

Figure 7 – Decomposition of the CN_5 – customer journey

Digital connection with key partners (DP_6) was appropriated to improve collaboration efficiency (FR_6). Enterprise analysis planning and monitoring ($DP_{6.1}$) are applied to build a collaborative partnership ($FR_{6.1}$) by focusing on creating reliability for the key partner. Blockchain ($DP_{6.1.1}$) was employed to share information among key partners ($FR_{6.1.1}$). In the same way, data quality assurance ($DP_{6.1.2}$) was used to increase the quality of shared information ($FR_{6.1.2}$), and IoT or cloud computing

($DP_{6.1.3}$) was utilized to increase the efficiency of collaboration in the industry ($FR_{6.1.3}$).

Real-time resources such as planning, process monitoring, and production control ($DP_{6.2}$) focus on the key partners' confidence ($FR_{6.2}$) in successful partnerships. A strong partnership was implemented ($FR_{6.2.1}$) in the data connection among partners for production planning and control (PPC) ($DP_{6.2.1}$), and yet it is not correlated with 4P of the marketing mix ($DP_{6.2.2}$). In part of the design, the partnership ($FR_{6.2.2}$) and 4P (price, place, promotion, product) ($DP_{6.2.2}$) were utilized for analyzing a new product. Eventually, to ensure shared values and goals ($FR_{6.2.3}$), the partnership agreement was measured ($DP_{6.2.3}$) by the index indicator of the organization, as shown in Figure 8.

FR		DP		Design Matrix
$FR_{6.1}$	Build a collaborative partnership	$DP_{6.1}$	Business analysis planning and monitoring	Uncoupled design $\begin{Bmatrix} FR6.1 \\ FR6.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP6.1 \\ DP6.2 \end{Bmatrix}$
$FR_{6.1.1}$	Share information among key partners	$DP_{6.1.1}$	Block chain	Uncoupled design $\begin{Bmatrix} FR6.1.1 \\ FR6.1.2 \\ FR6.1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP6.1.1 \\ DP6.1.2 \\ DP6.1.3 \end{Bmatrix}$
$FR_{6.1.2}$	Increase quality of shared information	$DP_{6.1.2}$	Data quality assurance	
$FR_{6.1.3}$	Increase efficiency of collaboration	$DP_{6.1.3}$	IoT/Cloud computing	
$FR_{6.2}$	Focus on the confidence with key partners	$DP_{6.2}$	Real-time resource planning, process monitoring, and production control	
$FR_{6.2.1}$	Implement a strong partnership	$DP_{6.2.1}$	Data connection among partners for Production planning and control (PPC)	Decoupled design $\begin{Bmatrix} FR6.2.1 \\ FR6.2.2 \\ FR6.2.3 \end{Bmatrix} = \begin{bmatrix} X & X & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP6.2.1 \\ DP6.2.2 \\ DP6.2.3 \end{Bmatrix}$
$FR_{6.2.2}$	Design the partnership	$DP_{6.2.2}$	4P (Price, Place, Promotion, Product)	
$FR_{6.2.3}$	Ensure shared values and goals	$DP_{6.2.3}$	Partner agreement on values and goals	

Figure 8 – Decomposition of the CN_6 – partnership marketing

Lean and computer-integrated manufacturing (CIM) (DP_7) were prepared for implementing the material requirement planning (MRP) in operation improvement (FR_7). This method focuses on process improvement ($FR_{7.1}$) by applying CIM ($DP_{7.1}$) to improve efficiency and effectiveness across the whole of the manufacturing supply chain.

CRM software ($DP_{7.1.1}$) was utilized to forecast sales and production plans ($FR_{7.1.1}$), and MRP software ($DP_{7.1.2}$) simultaneously identified the master production schedule ($FR_{7.1.2}$). Enterprise Resource Planning (ERP) ($DP_{7.1.3}$) was similarly included to calculate the capacity requirement planning ($FR_{7.1.3}$).

Lean techniques ($DP_{7.2}$) were used to design a suitable and efficient manufacturing process ($FR_{7.2}$) to solve ineffective management problems in the organization. However, they are not correlated when intersecting with computer-integrated manufacturing (CIM) ($DP_{7.1}$). Value Stream Mapping (VSM) ($DP_{7.2.1}$) was also used to analyze the production process from a lean point of view ($FR_{7.2.1}$). The production process was evaluated through the performance index ($FR_{7.2.2}$) by the logistics performance index (LPI) ($DP_{7.2.2}$). Eventually, the ECRS techniques ($DP_{7.2.3}$) were used to improve the production process ($FR_{7.2.3}$) to gain efficiency and effectiveness in the supply chain, as shown in Figure 9.

FR		DP		Design Matrix
$FR_{7.1}$	Focus on the process improvement	$DP_{7.1}$	Computer Integrated Manufacturing (CIM)	Uncoupled design $\begin{Bmatrix} FR7.1 \\ FR7.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ X & X \end{bmatrix} \begin{Bmatrix} DP7.1 \\ DP7.2 \end{Bmatrix}$
$FR_{7.1.1}$	Forecasting sales and production plan	$DP_{7.1.1}$	CRM software	Decoupled design $\begin{Bmatrix} FR7.1.1 \\ FR7.1.2 \\ FR7.1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ X & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP7.1.1 \\ DP7.1.2 \\ DP7.1.3 \end{Bmatrix}$
$FR_{7.1.2}$	Identify the master production schedule	$DP_{7.1.2}$	MRP software	
$FR_{7.1.3}$	Calculate the capacity requirement planning	$DP_{7.1.3}$	Enterprise Resource Planning (ERP)	
$FR_{7.2}$	Design a suitable and efficient business process	$DP_{7.2}$	Lean techniques	
$FR_{7.2.1}$	Analyze the production process from a lean point of view	$DP_{7.2.1}$	Value Stream Mapping (VSM)	Decoupled design $\begin{Bmatrix} FR7.2.1 \\ FR7.2.2 \\ FR7.2.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & X & X \end{bmatrix} \begin{Bmatrix} DP7.2.1 \\ DP7.2.2 \\ DP7.2.3 \end{Bmatrix}$
$FR_{7.2.2}$	Evaluate the performance index in the production process	$DP_{7.2.2}$	Logistics performance index (LPI)	
$FR_{7.2.3}$	Improve the production process	$DP_{7.2.3}$	Eliminate, Combine, Rearrange, Simplify (ECRS techniques)	

Figure 9 – Decomposition of the CN_7 – material requirement planning

The cost structure was traditionally considered essential in every industry, especially monitoring costs during the process (DP_8), which shares the primary objective of obtaining the minimum cost in the operation process ($FR_{8.1}$). Lean and Six Sigma improvement tools ($DP_{8.1}$) were adjusted to reduce cost and waste in the production process ($FR_{8.1}$). The integration definition for function modeling (IDEF0) ($DP_{8.1.1}$) was utilized as one of the engineering tools that are suitable for analyzing the problems in the production process ($FR_{8.1.1}$). Similarly, Six Sigma ($DP_{8.1.2}$) was included to improve the cost in the production process ($FR_{8.1.2}$) but only when interacting with a sustainable value analysis tool (SVAT) ($DP_{8.1.3}$). In addition, a sustainable value analysis tool (SVAT) ($DP_{8.1.3}$) was applied to increase the long-term value ($FR_{8.1.3}$).

Advanced manufacturing technologies ($DP_{8.2}$) were considered the best alternative to automating the manufacturing process to reduce time and cost, but it is not math with Lean and Six Sigma tools ($DP_{8.1}$). However, entrepreneurs should research suitable technology for the manufacturing process ($FR_{8.2.1}$) by searching the internet or automation technologies ($DP_{8.2.1}$) with care. In other words, they can use computer-aided drafting design (CAD) or simulation ($DP_{8.2.2}$) to simulate the appropriate technology for the specific product $FR_{8.2.2}$ (Figure 10).

Revenue forecasting and prediction tools (DP_9) were utilized for product and service income in the supply chain from upstream to downstream (FR_9). This method focused on marketing efforts in the industry ($FR_{9.1}$) to gain data from big data analytics ($DP_{9.1}$). Product trends were inspected ($FR_{9.1.1}$) by searching data from ($DP_{9.1.1}$) and exploring new segments ($FR_{9.1.2}$) derived from machine learning ($DP_{9.1.2}$). No correlation was found when interacting with the matrix between FR9.1.1 and DP9.1.2.

FR		DP		Design Matrix
$FR_{8.1}$	Reduce cost in production	$DP_{8.1}$	Lean and Six Sigma improvement tools	Decoupled design $\begin{Bmatrix} FR8.1 \\ FR8.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ X & X \end{bmatrix} \begin{Bmatrix} DP8.1 \\ DP8.2 \end{Bmatrix}$
$FR_{8.1.1}$	Analyze the problems in the production process	$DP_{8.1.1}$	Integration Definition for Function Modeling (IDEF0)	Decoupled design $\begin{Bmatrix} FR8.1.1 \\ FR8.1.2 \\ FR8.1.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & X \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP8.1.1 \\ DP8.1.2 \\ DP8.1.3 \end{Bmatrix}$
$FR_{8.1.2}$	Improve the cost in the production process	$DP_{8.1.2}$	Six Sigma	
$FR_{8.1.3}$	Increase long term value	$DP_{8.1.3}$	Sustainable value analysis tool (SVAT)	
$FR_{8.2}$	Automate the manufacturing process	$DP_{8.2}$	Advanced Manufacturing Technologies	
$FR_{8.2.1}$	Review and research the suitable technology for the manufacturing process	$DP_{8.2.1}$	Internet/research on automation technologies	Uncoupled design $\begin{Bmatrix} FR8.2.1 \\ FR8.2.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP8.2.1 \\ DP8.2.2 \end{Bmatrix}$
$FR_{8.2.2}$	Simulate the appropriate technology for the specific product	$DP_{8.2.2}$	Computer Aided Drafting/Design (CAD) or simulation	

Figure 10 – Decomposition of the CN_8 – cost structure

FR		DP		Design Matrix
$FR_{9.1}$	Focus on marketing and sales efforts	$DP_{9.1}$	Big data analytics	Uncoupled design $\begin{Bmatrix} FR9.1 \\ FR9.2 \end{Bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{Bmatrix} DP9.1 \\ DP9.2 \end{Bmatrix}$
$FR_{9.1.1}$	Investigate and explore trends of product	$DP_{9.1.1}$	Internet/Web site	Decoupled design $\begin{Bmatrix} FR9.1.1 \\ FR9.1.2 \end{Bmatrix} = \begin{bmatrix} X & X \\ O & X \end{bmatrix} \begin{Bmatrix} DP9.1.1 \\ DP9.1.2 \end{Bmatrix}$
$FR_{9.1.2}$	Explore new customer and market segments	$DP_{9.1.2}$	Machine Learning for market segmentation	
$FR_{9.2}$	Re-design and improve product and service after evaluation	$DP_{9.2}$	Data based market evaluation	
$FR_{9.2.1}$	Conduct market research	$DP_{9.2.1}$	Data analytics	Uncoupled design $\begin{Bmatrix} FR9.2.1 \\ FR9.2.2 \\ FR9.2.3 \end{Bmatrix} = \begin{bmatrix} X & O & O \\ O & X & O \\ O & O & X \end{bmatrix} \begin{Bmatrix} DP9.2.1 \\ DP9.2.2 \\ DP9.2.3 \end{Bmatrix}$
$FR_{9.2.2}$	Identify unique selling proposition (USP)	$DP_{9.2.2}$	Survey data and machine learning	
$FR_{9.2.3}$	Develop business brand	$DP_{9.2.3}$	Digital marketing	

Figure 11 – Decomposition of the CN_9 – revenue streams

Furthermore, after evaluation, the data-based market (DP9.2) was redesigned and improved to develop a brand ($FR_{9.2}$) from the simulation software model. The market research ($FR_{9.2.1}$) was conducted by data analytics ($DP_{9.2.1}$). The unique selling proposition (USP) ($FR_{9.2.2}$) will also be identified by survey data and machine learning ($DP_{9.2.2}$). According to the market improvement, if the entrepreneurs need to develop the brand ($FR_{9.2.3}$), they should adopt digital marketing ($DP_{9.2.3}$) in their company to gain as many lucrative benefits as they can, as well as better competitiveness (Figure 11).

4.4 Integrated axiomatic design to design a model for the supply chain based on the canvas model

The interaction between "what we want to achieve" and "how we achieve it" was created by choosing each of the completed design parameters related to the block of each BMC group. Then, a suitable model for a case study of the Pang Khon Hill Tribe, Chiang Rai Province, Thailand, is shown in Figure 12.

Highlights a suitable model by applying FRs and DPs through nine elements of BMC. The building block shows the relation between BMC components throughout AD decomposition, which is related through three parts of the income statements, including revenue, expense, and profit.

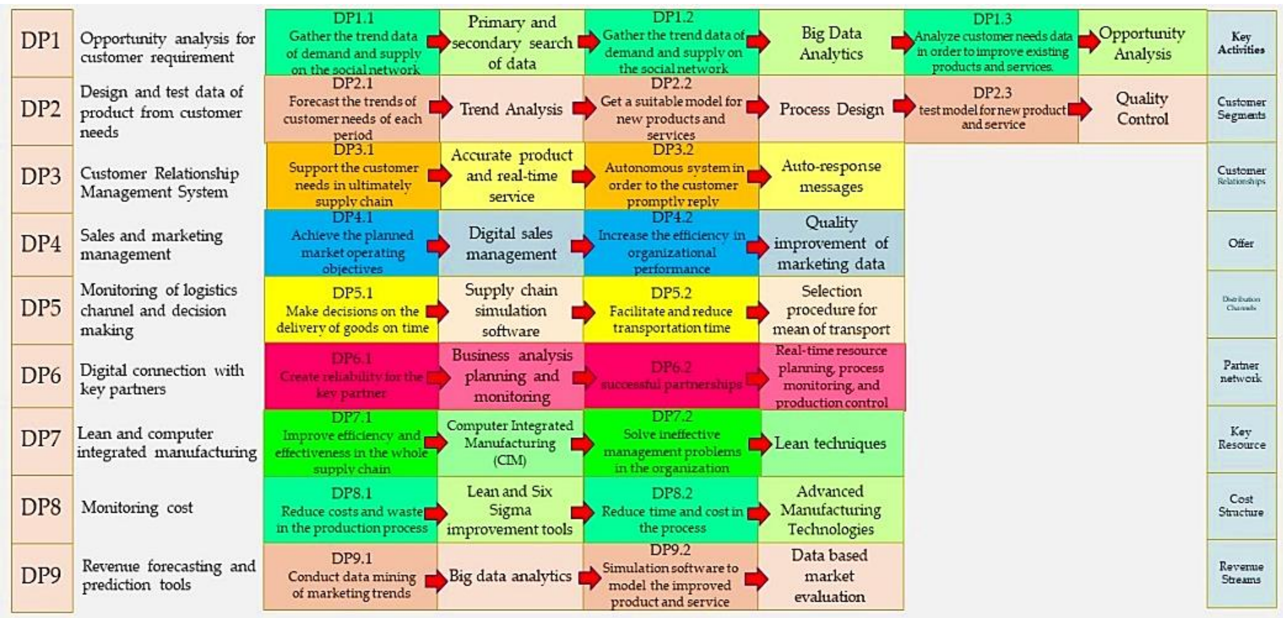


Figure 12 – A model of axiomatic design based on a canvas model

The revenue group includes key activities that show the collaboration of creating value propositions through FR1 and DP1, distribution channels that participate with FR5 and DP5, and revenue streams that interact with FR_9 and DP_9. The expense group consists of customer relationships related to Fs_3 and DP_3, key resources connected with FR_7

and DP_7, and cost structure, which is the association between FR_8 and DP_8. The profit group comprises customer segments related to FR_2 and DP_2, the offer correlates with FR_4 and DP_4, and the partner network relates to FR_6 and DP_6. Moreover, this model can also predict the concerns of customer requirements and establish customer voices. Finally, the integrated AD and canvas supply chain model is shown in Figure 13.

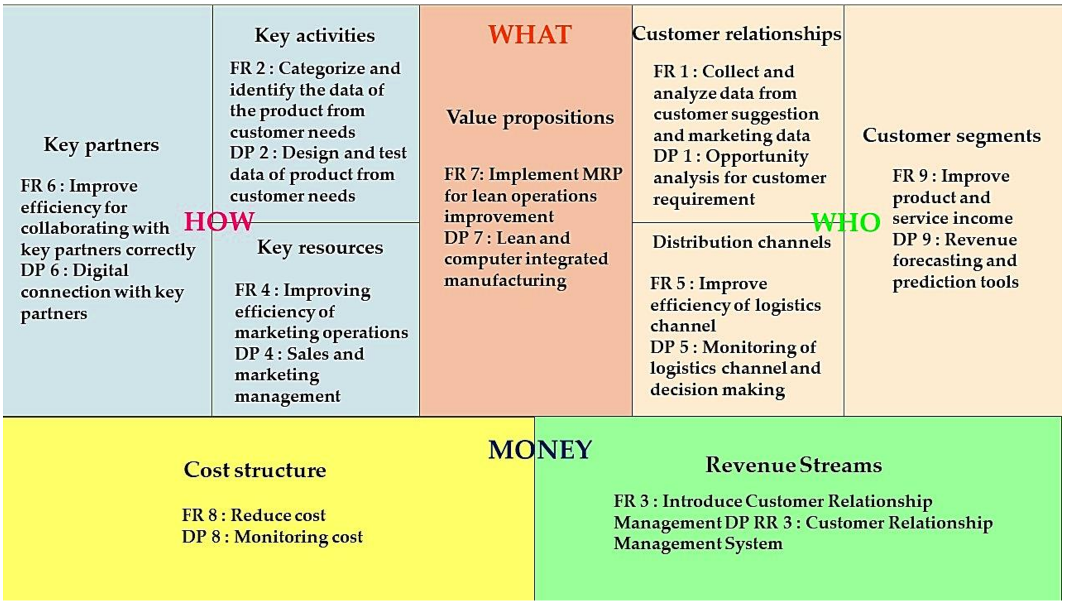


Figure 13 – Canvas model of the supply chain

4.5 A case study: Pang Khon Hill Tribe

After integrating the design into the supply chain – a case study: Pang Khon Hill Tribe. A suitable model for the supply chain can gain income from this model as follows.

Firstly, the entrepreneurs can know the output using deep learning and data analytics. Entrepreneurs can collect and analyze data on their crops to gain insights into factors such as yield, quality, and sustainability. It can help them make more informed decisions about their farming practices and optimize their output.

Secondly, entrepreneurs can control the quality of goods following global standards by using technology to monitor and manage their crops. They can ensure their product meets the quality standards required for global markets, such as the final product's color and moisture content in raw material standards (not exceeding 12 %).

Also, the entrepreneur can develop new products to get a new opportunity in the industry for a particular case study.

Finally, entrepreneurs can improve existing offerings through technology and continually refine their existing products to meet changing consumer preferences and market demands; for example, they can apply artificial intelligence (AI) to improve the database of products through blockchain technology.

Entrepreneurs can pursue new models via technology, enabling entrepreneurs to explore new models, such as e-commerce or e-marketplace, instead of the market. Firstly, deep learning can help entrepreneurs manage their inventory and production to avoid overstocking and reduce waste. For example, data analytics can forecast demand and adjust planting schedules according to customer demand.

AI can help entrepreneurs optimize their supply chain and distribution routes to reduce costs and improve efficiency. For example, route optimization software can identify the most efficient delivery routes and reduce transportation time and costs.

Also, a QR code is used instead of a barcode, helping entrepreneurs track their shipments in real-time and provide customers with accurate delivery estimates. Moreover, it can improve customer satisfaction and reduce the risk of lost or delayed shipments.

Finally, Green packaging or inventory management systems can reduce waste in the supply chain and production processes. For example, green packaging can decompose or implement a just-in-time inventory system to reduce excess inventory and waste.

The quality of product standards can help entrepreneurs understand the fair market value of their and negotiate better prices with customers. It can help entrepreneurs earn a fair income and improve their livelihoods.

A dryer machine can help entrepreneurs measure the moisture content of raw materials and ensure that they meet the customer's standard. Moreover, it can reduce the need for re-drying and improve the product quality.

Deep learning can help manufacturers forecast their income and productivity in advance, reducing the risk of missed trade opportunities and improving their planning. Machine learning can help entrepreneurs identify new trends and opportunities in the industry and develop innovative products that meet the changing needs of consumers. Machine learning and deep learning can help entrepreneurs optimize their pricing strategies and adjust prices in real-time based on market demand and competitor pricing. Machine learning (color sorter and dryer machine) can help entrepreneurs streamline their production processes and improve efficiency.

Deep learning software can help customers plan and manage their orders for raw materials. It can help them optimize their inventory and production schedules and reduce the risk of stockouts or excess inventory. QR codes can help establish clear and transparent product standards, providing customers with confidence and credibility in the quality of the product. For example, a QR code could track the entire supply chain, from the farm to the consumer, providing a tamper-proof record of the product's origin and quality. Customer relationship management (CRM) software can help entrepreneurs manage customer interactions and collect data on the customer lifecycle. It can help them improve customer relationships and loyalty by providing personalized recommendations, targeted marketing, and improved customer service.

Color sorters and dryers can help entrepreneurs monitor and control the quality of products in every lot. It can help them identify and address quality issues before the product is delivered, ensuring consistent quality and customer satisfaction. Deep learning algorithms can help entrepreneurs forecast the yield of products from their farms. It can help them plan their production and delivery schedules, ensuring they have enough products to meet customer demand without overproducing and wasting resources. Machine learning can help entrepreneurs reduce the cost of labor and increase efficiency by using machines instead of labor.

Entrepreneurs can receive income by providing sorting and drying services to other manufacturers by sorting and drying the raw material. Moreover, producers can provide a valuable service to other manufacturers and generate revenue. Deep learning can help entrepreneurs control and predict production more accurately through the variable of data and analytics to monitor and manage their farms. Therefore, entrepreneurs can make informed decisions about planting, harvesting, and production, which can help them optimize their yield and quality.

Enterprise resource planning (ERP) software can help entrepreneurs manage and control their production costs, marketing management, and overhead costs by using an integrated system to manage their manufacturing processes. For example, an ERP system could help entrepreneurs track their inventory levels, manage their supply chain, and optimize their production processes to reduce costs and improve profitability.

Color sorter and dryer machines can help entrepreneurs monitor and control the quality of their products in every lot of production. Machine learning, such as data analytics or media monitoring, can help entrepreneurs better understand their customers' needs and preferences. Such as customer behavior, feedback, and demographics, entrepreneurs can identify opportunities to develop products and services that meet their customer's needs and preferences. It can help them improve customer satisfaction and loyalty and gain a competitive edge in the market.

Manufacturers can control the production cost and avoid unexpected price fluctuations that could impact their profitability. It can also help them set a median product price, improving their market competitiveness. Manufacturers can also build credibility and establish long-term, sustainable trading relationships by providing high-quality products, meeting customer needs, and maintaining consistent pricing and quality standards.

Marketing analysis (SWOT, TOWs Matrix, 5 Forces Analysis) can identify ways to streamline their marketing processes, reduce waste, and improve the overall performance of their marketing function. It can help them optimize their marketing campaigns, improve their targeting, and reduce costs, ultimately improving the effectiveness of their marketing efforts. Moreover, marketing analysis (SWOT, TOWs Matrix, 5 Forces Analysis) is applied to effectively manage sales and marketing teams. Moreover, it can help entrepreneurs improve the performance of their teams, increase revenue, and drive production growth.

Entrepreneurs can differentiate their products from competitors and create more value for their customers, such as high-quality product specifications, specialty, and value-added products. It can help them negotiate better prices and improve their profitability. Partner networks can improve the efficiency and effectiveness of their collaboration efforts through web pages. It can help them reduce costs, improve communication, and accelerate project timelines, ultimately improving their overall performance and driving production growth.

To conclude, this study developed a conceptual model for production using the axiomatic design and BMC. The AD decompositions were created to provide a suitable method for designing processes and services. BMC was used to identify and classify the FRs and DPs in each BMC building block. AD and BMC are valuable tools for analyzing and improving the operations of a community enterprise. AD provides a systematic and structured approach to product design and development, while the BMC visually represents a company's value proposition, customer segments, revenue streams, cost structure, and other key components.

The conclusions of using AD and BMC in the community enterprise may vary depending on the specific goals and objectives of the enterprise. However, these tools can help the enterprise identify areas for improvement, optimize processes, and enhance customer satisfaction.

4.6 Verification of the model

A suitable model with an integrated axiomatic design into a canvas model was applied for the supply chain in Pang Khon Hill Tribe to boost product output and income through marketing strategy. To begin with, investigate analysis through SWOT analysis by interviewing and site-visiting entrepreneurs and entrepreneurs to evaluate an industry's or organization's potential and environment. Then, use the Five Forces Model to examine an industry's competitive environment. After that, make a production plan for three periods: one year, three to five years, and more than ten years. Next, execute product marketing for the Pang Khon community enterprise and use the 4Ps to create a target audience. However, based on the information from the researcher's model already on hand, they can suggest guidelines to improve production and advise the guidelines to improve the profit to entrepreneurs and entrepreneurs. Additionally, it was found that there was a consistency between the questions from the researcher and the needs of entrepreneurs. Therefore, this model could be used for data verification (Figure 14).

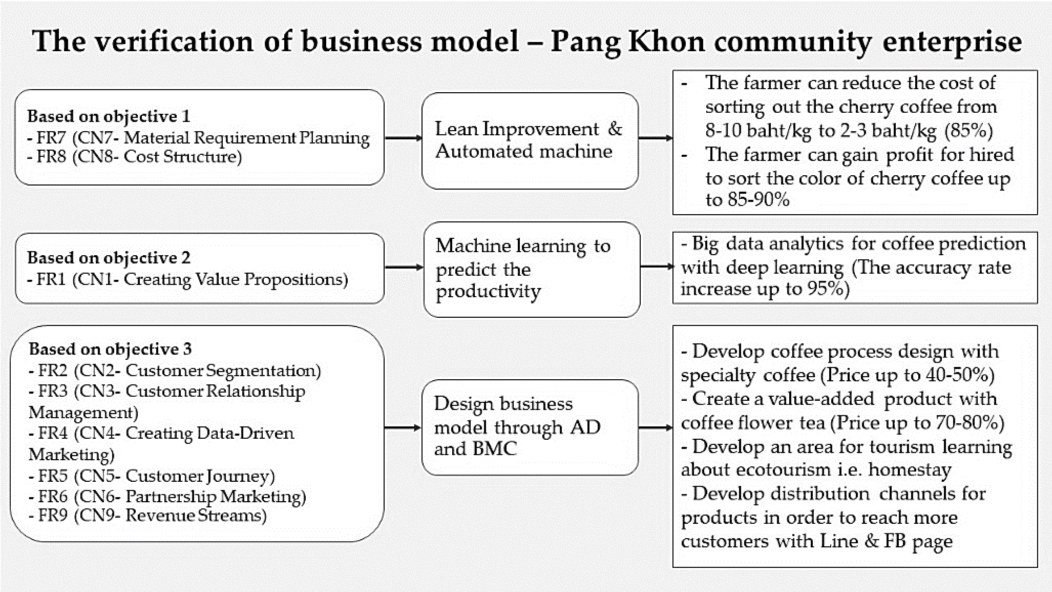


Figure 14 – The verification of the model

The model was verified with a case study based on the FR_7 (CN_7 – material requirement planning), and FR_8 (CN_8 – cost structure) with the Lean technique, and automated machine improvement was used to improve the production process.

This study applied the color sorter machine with the LABSORT color sorter using 500 kg of final product. Besides, the specifications of the color sorter machine are as follows: capacity is 100-300 kg/hour, LED and CCD camera, 1.8 kW (220V/50Hz), air pressure (0.6–0.8 MPa), accuracy of 99 % through the scenario experiment.

The production was sorted out by labor: the labor cost was 8–10 per kg, and the person-hour was 200–300 kg per 8-hour working day. However, when using the color sorter machine instead of the labor, the labor cost decreased to 77–85 % per kilogram, and the sorter's capacity increased by 83–93 % per kilogram.

The capacity of community enterprises is 720,000 THB per year. In addition, if the other suppliers use the color sorter to sort out the product, it can calculate 1,000,000 THB. Furthermore, if the entrepreneur invests in their plant, they will gain the payback within 1.16 years. Additionally, the dryer machine was utilized to control the standard quality of raw material during the dryer process. As a result, it shows the duration time for the dryer was decreased by up to 97%. Moreover, it can help control the dryer and moisture duration.

To summarize, the lean technique and automated machine improved the production process. The total cycle time could be reduced by more than 15 %. The profit of sorted products could be increased by 80 %. The processing time of raw materials could be reduced by almost 97 %. Similarly, based on the FR_1 (CN_1 – creating value propositions) with a deep learning model to predict productivity was utilized to predict the productivity each year, and it can also predict the next year's productivity.

5 Discussion

A prediction model based on deep learning can undoubtedly be applied to production planning in agriculture fields. Deep learning models have shown great potential in various domains, including agriculture, where they can analyze large datasets and extract patterns to make accurate predictions.

Furthermore, by leveraging a deep learning model, entrepreneurs can effectively manage the productivity of production planning. The model can analyze historical data such as weather patterns, soil conditions, cultivation practices, and other relevant factors to generate predictions of the productivity of a product.

In addition, the prediction model can also assist in forecasting the demand for the product. The model can provide insights into the expected demand for the product in the upcoming year by analyzing historical sales data, market trends, and other relevant variables. This information can be invaluable for entrepreneurs to adjust their production levels, pricing strategies, and marketing efforts to meet anticipated customer needs.

Additionally, a prediction model based on deep learning can be applied to other agriculture fields. Deep learning models are versatile and can be adapted to analyze various types of agricultural data and make predictions. The principles behind developing a prediction model for the product can be extended to other crops or agricultural products. By collecting relevant data specific to different crops, such as weather conditions, soil composition, pest infestation levels, and cultivation practices, a deep learning model can be trained to understand the relationships between these factors and crop productivity. Accordingly, with the trained model, entrepreneurs and agricultural planners can obtain predictions and insights for different crops, enabling them to optimize production planning. The model determines optimal planting times based on historical data and real-time inputs.

However, expanding deep learning models to multiple agriculture fields allows for more comprehensive production planning and management. Entrepreneurs can leverage data-driven approaches to increase productivity, minimize risks, and make informed decisions across various crops or agricultural products. Similarly, a deep learning prediction model can empower entrepreneurs and entrepreneurs in the related industry to make data-driven decisions, optimize their production planning, and align their strategies with market demands.

By the way, entrepreneurs can use the prediction model to predict the output of the final product based on historical data, which is the accuracy rate for predicting the increase up to 95 %. Based on the FR_2 (CN_2 – customer segmentation), FR_3 (CN_3 – customer relationship management), FR_4 (CN_4 – creating data-driven marketing), FR_5 (CN_5 – customer journey), FR_6 (CN_6 – partnership marketing), and FR_9 (CN_9 – revenue streams) with design model through AD and BMC, it was employed to design the model by integrating the AD and canvas models so the entrepreneurs could improve the profit in their own companies. Likewise, they use this model to develop production process design with specialty (price of product up to 40–50 %). Moreover, they can create a value-added product, and the price can be up to 70–80 %. In addition, they can utilize the model to develop an area for tourism learning about ecotourism, i.e., homestay. Furthermore, they can use this model to develop distribution channels for products in order to reach more customers with web pages.

Additionally, in marketing strategy and analysis, SWOT Analysis, the Five Forces model, and the 4Ps are strategic frameworks that can provide valuable insights and guidance when developing a plan.

According to the supply chain of Pang Khon Hill Tribe, Community Enterprise was completed from the Canvas model and marketing strategy. A suitable model was created through value creation, value proposition, value capture, and value delivery, as shown in Figure 15.

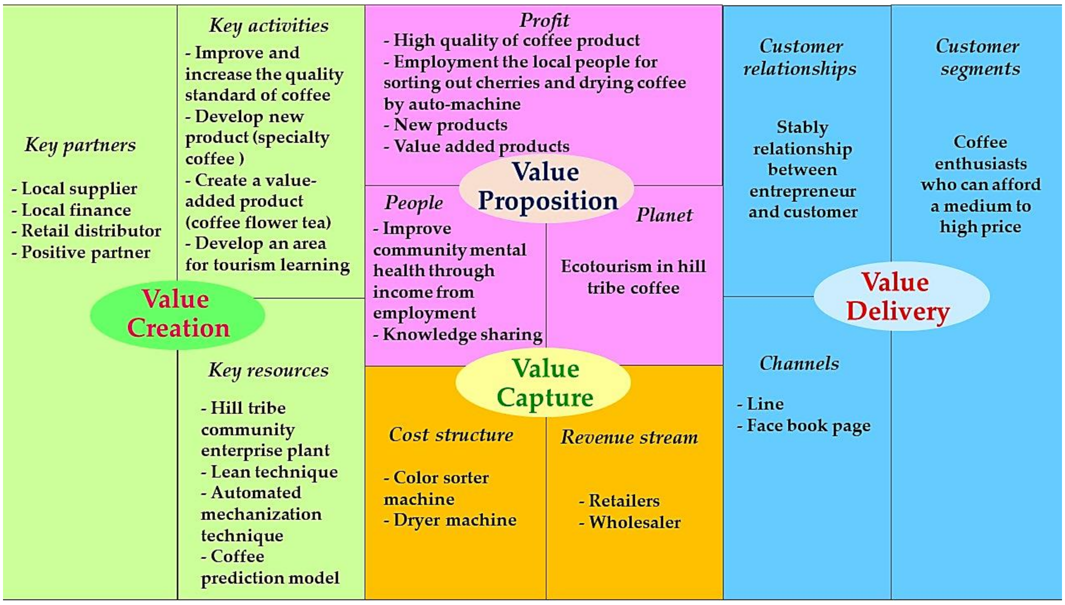


Figure 15 – A suitable model of the Pang Khon Hill Tribe

A suitable case study model was revealed through the canvas model based on value creation, proposition, capture, and delivery. Accordingly, a hill tribe suitable supply chain based on value creation, value proposition, value capture, and value delivery can lead toward a sustainable production model. Creating a sustainable model is essential to integrate these elements and continuously evaluate and improve each stage of the supply chain.

Moreover, collaboration and partnerships with producers, certification bodies, sustainability initiatives, and other stakeholders can also contribute to the overall sustainability and success of the model. Additionally, by aligning value creation, value proposition, value capture, and value delivery with sustainability principles, a product can build a robust and resilient model that benefits the broader community.

6 Conclusions

A suitable model may be created for the Thai industry. AD and BMC were utilized to create a model that could increase the supply chain's income and profitability. Furthermore, the implications provide potential and readiness for manufacturers. However, the output of a suitable model will develop and improve the supply chain to gain profitability. Nonetheless, this model should be verified with owners to increase model reliability.

According to a suitable supply chain model, entrepreneurs can benefit from this model because they can know its suitability. For example, the local industry, market demand, available resources, and the goals of the entrepreneurs, conducting market research, understanding consumer preferences, and considering the unique characteristics of the agrarian region are essential for choosing the most suitable model. Therefore, a suitable product model can help entrepreneurs better understand customer requirements and increase profits.

Acknowledgments

The research was partially realized within the project “A strategic roadmap toward the next level of intelligent, sustainable, and human-centered SME: SME 5.0” from the European Union’s HORIZON 2021 research and innovation program under Marie Skłodowska-Curie grant No. 101086487. The authors acknowledge the Department of Industrial Engineering, Supply Chain and Engineering Management Research Unit (SCEM) of Chiang Mai University for providing research facilities and CMU Graduate School for partial financial support.

References

1. Hegab, H., Khanna, N., Monib, N., Salem, A. (2023). Design for sustainable additive manufacturing: A review. *Sustainable Materials and Technologies*, Vol. 35, e00576. https://doi.org/10.1016/j.susmat.2023.e00576
2. Valaskova, K., Nagy, M., Zabojnik, S., Lăzăroiu, G. (2022). Industry 4.0 wireless networks and cyber-physical smart manufacturing systems as accelerators of value-added growth in Slovak exports. *Mathematics*, Vol. 10(14), 2452. https://doi.org/10.3390/math10142452
3. Awan, U., Sroufe, R., Bozan, K. (2022). Designing value chains for industry 4.0 and a circular economy: A review of the literature. *Sustainability*, Vol. 14(12), 7084. https://doi.org/10.3390/su14127084
4. Suh, N. P., Suh, P. N. (1990). *The Principles of Design*. Oxford Series of Advanced Manufacturing, Oxford, UK.
5. Matt, D. T., Rauch, E. (2011). Continuous improvement of manufacturing systems with the concept of functional periodicity. *Key Engineering Materials*, Vol. 473, pp. 783–790. https://doi.org/10.4028/www.scientific.net/kem.473.783
6. Rauch, E., Dallasega, P., Matt, D. T. (2015). Axiomatic design-based guidelines for the design of a lean product development process. *Procedia CIRP*, Vol. 34, pp. 112–118. https://doi.org/10.1016/j.procir.2015.07.005
7. Girgenti, A., Pacifici, B., Ciappi, A., Giorgetti, A. (2016). An axiomatic design approach for customer satisfaction through a lean start-up framework. *Procedia CIRP*, Vol. 53, pp. 151–157. https://doi.org/10.1016/j.procir.2016.06.101
8. Rauch, E., Spena, P. R., Matt, D. T. (2019). Axiomatic design guidelines for the design of flexible and agile manufacturing and assembly systems for SMEs. *International Journal on Interactive Design and Manufacturing*, Vol. 13, pp. 1–22. https://doi.org/10.1007/s12008-018-0460-1
9. Pecoraro, F., Pourabbas, E., Rolli, F., Parretti, C. (2022). Digitally sustainable information systems in axiomatic design. *Sustainability*, Vol. 14(5), 2598. https://doi.org/10.3390/su14052598
10. Das, P., Perera, S., Senaratne, S., Osei-Kyei, R. J. E. (2020). Developing a construction business model transformation canvas. *Engineering, Construction and Architectural Management*, Vol. 8, pp. 1423–1439. https://doi.org/10.1108/ecam-09-2020-0712
11. Toro-Jarrín, M. A., Ponce-Jaramillo, I. E., Güemes-Castorena, D. J. T. F., Change, S. (2016). Methodology for the of building process integration of business model canvas and technological roadmap. *Technological Forecasting and Social Change*, Vol. 110, pp. 213–225. https://doi.org/10.1016/j.techfore.2016.01.009
12. Brunner, M., Wolfartsberger, J. (2020). Virtual reality enriched business model canvas building blocks for enhancing customer retention. *Procedia Manufacturing*, Vol. 42, pp. 154–157. https://doi.org/10.1016/j.promfg.2020.02.062
13. Harutunian, V., Nordlund, M., Tate, D., Suh, N. P. (1996). Decision making and software tools for product development based on axiomatic design theory. *CIRP Annals*, Vol. 45, pp. 135–139. https://doi.org/10.1016/s0007-8506(07)63032-7
14. Brown, C. A. (2020). Axiomatic design for products, processes, and systems. *In: Matt, D., Modrák, V., Zsifkovits, H. (eds) Industry 4.0 for SMEs*, pp. 383–401. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-25425-4_13
15. Cochran, D. S., Arinez, J. F., Duda, J. W., Linck, J. J. (2001). A decomposition approach for manufacturing system design. *Journal of Manufacturing Systems*, Vol. 20, pp. 371–389. https://doi.org/10.1016/s0278-6125(02)80119-4
16. Houshmand, M., Jamshidnezhad, B. (2002). Conceptual design of lean production systems through an axiomatic approach. *In: Proceedings of Second International Conference on Axiomatic Design*. Available online: https://www.semanticscholar.org/paper/CONCEPTUAL-DESIGN-OF-LEAN-PRODUCTION-SYSTEMS-AN-Houshmand-Jamshidnezhad/237cecfb5d21d63707a948a8c779ae51a3df2165
17. Arcidiacono, G., Matt, D. T., Rauch, E. (2017). Axiomatic design of a framework for the comprehensive optimization of patient flows in hospitals. *Journal of Healthcare Engineering*, Vol. 2017, 2309265. https://doi.org/10.1155/2017/2309265
18. Vinodh, S., Aravindraj, S. J. J (2012). Axiomatic modeling of lean manufacturing system. *Journal of Engineering, Design and Technology*, Vol. 10, pp. 199–216. https://doi.org/10.1108/17260531211241185

19. Baxter, J. E., McKay, A., Agouridas, V., De Pennington, A. (2002). Supply chain design: an application of axiomatic design. *In: Proceeding of the Second International Conference on Axiomatic Design (ICAD 2002)*, 1-7.
20. Holzner, P., Rauch, E., Spena, P. R., Matt, D. T. (2015). Systematic design of SME manufacturing and assembly systems based on axiomatic design. *Procedia CIRP*, Vol. 34, pp. 81–86. https://doi.org/10.1016/j.procir.2015.07.010
21. Suh, N. P. (1998). Axiomatic design theory for systems. *Research in Engineering Design*, Vol. 10, pp. 189–209. https://doi.org/10.1007/s001639870001
22. Rauch, E., Matt, D. T., Dallasega, P. (2016). Application of axiomatic design in manufacturing system design: a literature review. *Procedia CIRP*, Vol. 53, pp. 1–7. https://doi.org/10.1016/j.procir.2016.04.207
23. Matt, D., Rauch, E. (2013). Design of a network of scalable modular manufacturing systems to support geographically distributed production of mass customized goods. *Procedia CIRP*, Vol. 12, pp. 438-443. https://doi.org/10.1016/j.procir.2013.09.075
24. Suh, N. P. (2001). *Axiomatic Design: Advances and Applications*. Oxford University Press, Oxford, UK.
25. Kulak, O., Cebi, S., Kahraman, C. J. E. (2010). Applications of axiomatic design principles: A literature reviews. *Expert Systems with Applications*, Vol. 37, pp. 6705–6717. https://doi.org/10.1016/j.eswa.2010.03.061
26. Keane, S. F., Cormican, K. T., Sheahan, J. N. (2018). Comparing how entrepreneurs and managers represent the elements of the business model canvas. *Journal of Business Venturing Insights*, Vol. 9, pp. 65–74. https://doi.org/https://doi.org/10.1016/j.jbvi.2018.02.004
27. Fritscher, B., Pigneur, Y. (2015). Extending the business model canvas: A dynamic perspective. *In: Proceedings of the Fifth International Symposium on Business Modeling and Software Design*, pp. 86–95. https://doi.org/10.5220/0005885800860095
28. Fritscher, B., Pigneur, Y. (2014). Visualizing business model evolution with the business model canvas: Concept and tool. *In: IEEE 16th Conference on Business Informatics*, pp. 151–158. https://doi.org/10.1109/cbi.2014.9
29. García-Muiña, F. E., Medina-Salgado, M. S., Ferrari, A. M., Cucchi, M. J. S. (2020). Sustainability transition in Industry 4.0 and smart manufacturing with the triple-layered business model canvas. *Sustainability*, Vol. 12(6), 2364. https://doi.org/10.3390/su12062364
30. Sivertsson, O., Tell, J. (2015). Barriers to business model innovation in Swedish agriculture. *Sustainability*, Vol. 7(2), pp. 1957–1969. https://doi.org/10.3390/su7021957
31. Partalidou, M., Paltaki, A., Lazaridou, D., Vieri, M., Lombardo, S., Michailidis, A. J. (2018). Business model canvas analysis on Greek farms implementing precision agriculture. *Agricultural Economics Review*, Vol. 19(2), pp. 28–45. https://doi.org/10.22004/ag.econ.317774