Digital Patchwork from the Perspective of the Circular Economy: Cost Accounting based on Activity-based Costing

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Abstract

An activity-based costing (ABC) approach was selected in the context of the circular economy to address the cost accounting challenges of customized geometric patchworks. This was done by comparing the patchwork characteristics with conventional cost accounting methods to improve accuracy. First, an accounting model for costs was created. Five activity centers were created from the classification and consolidation of activities, and each center was given a budget for direct and indirect expenses. Secondly, carry out a cost study. Indirect costs were calculated by multiplying the cost driver quantity by the driver rate, whereas direct costs were the product of material usage and unit price. A case study finally confirmed the viability. The results show that both the actual resource consumption of goods and services and the complexity of the patchwork production process are accurately reflected by the ABC method. Additionally, this method achieves accurate cost accounting by addressing a gap in economic research in patchwork promotion.

Keywords: Geometric Patchwork; Digital Patchwork; Cost Accounting; Circular Economy; Activity-Based Costing

1. Introduction

The circular economy, as a sustainable economic system, adheres to the "3R" principles, emphasizing resource reduction, reuse, and recycle. Its goal is to minimize waste and extend the life cycle of resources. As the key sector in the global economy, the textile industry is faced with severe challenges due to pollution. An estimated 150 million tons of textile waste will probably be deposited or burned by 2050 [1]. The transition to sustainability is an inevitable reaction to environmental challenges [2], and the implementation of a circular economy can advance the sustainable transformation of the textile industry [3]. As an effective method for the reuse of fabric, patchwork is a textile process in which small pieces of fabric are sewn together to form larger, more complex, and complete textiles [4]. Patchwork is both a practical and decorative craft that can be designed and composed using specific geometric patterns according to the creator's aesthetic, possessing unique artistic value [5].

Patchwork, an ancient textile craft, dates back to China, ancient Egypt, and medieval Europe. From the outset, patchwork embodied the principles of economic and resource optimization and is therefore a natural expression of sustainability in everyday life [6]. It is also closely related to the use of fabric scraps. In China, traditional garments such as “Baina Yi” and “Shuitian Yi” are examples of patchwork techniques. These garments combine geometric fabrics with different textures and colors to create diverse visual effects. They reflect the frugality that is valued in traditional Chinese society and also embody cultural symbolism and the unique aesthetics of folk art. Nowadays, patchwork has gradually evolved from a craft focused on utility and frugality to a means of expressing personalized aesthetics in design [7]. Industry 4.0 is the current era, but there is a strong push for Industry 5.0. Digital technologies are acknowledged as the primary force behind economic transformation as well as the essential instruments for bringing about the circular economy [8, 9]. Patchwork designs can now overcome the limitations of traditional techniques and produce increasingly intricate quilting patterns thanks to the development of digital design tools [10]. The market for customized patchwork patterns has grown as a result of the emergence of the isomorphic patchwork intelligent design platform [11]. Against this backdrop, digital patchwork has emerged, which integrates traditional patchwork crafting techniques with digital technologies. From the perspective of the circular economy, digital patchwork is based on fabric reuse and leverages digital tools to achieve an all-around upgrade spanning the entire process from design and production to sales. As a product of sustainable principles, existing research in the digitization of patchwork is mostly focused on the field of design. Existing digital patchwork design platforms both at home and abroad enable users to conduct independent online design, accomplish the splicing design of isomorphic and heterogeneous geometric figures, and provide corresponding layout references. The lack of standardized economic evaluation models in cost accounting and other economic fields is not conducive to achieving a balance between economic feasibility and environmental benefits in the patchwork industry, thereby hindering its sustainable development.

This paper builds the order section of existing patchwork customization platforms and establishes a cost accounting model. Based on the characteristics of the patchwork, it can be compared with traditional cost accounting methods. After comparison, the activity-based costing method was ultimately chosen as the core method for research. Based on the research on customized geometric patchworks, the cost is broken down into two parts: direct cost (DC) and indirect cost (IC) for accounting. The establishment of this model can more accurately reflect the consumption of customized geometric layout resources, providing support for reducing waste. Meanwhile, based on the concept of circular economy, research is conducted on optimizing fabric layout.

2. Methods

The customized geometric patchworks discussed in this paper belong to the category of handcrafted collectibles. In cost accounting, indirect costs account for a significant portion, and the composition of manufacturing expenses is relatively complex. Additionally, the price of these products largely depends on the skill of the quilter and the complexity of the patchwork craftsmanship.

2.1 Establishment of Cost Accounting Methods

Traditional cost accounting methods focus on direct material and labor costs, with insufficient reflection of IC, making it difficult to accurately and comprehensively present cost information for geometric patchworks. In contrast, Activity-Based Costing (ABC), as an effective tool for ensuring sustainable development, can eliminate ineffective activities and accurately reflect cost consumption [12], thus being more suitable for cost accounting of customized patchworks. ABC allocates resources to activities, establishes activity centers, estimates the unit cost of each activity based on historical data, calculates activity quantities according to cost drivers, and aggregates the data to determine total costs [13, 14]. It categorizes costs into direct costs and indirect costs and enables more precise allocation of manufacturing overhead, which makes it particularly applicable to scenarios where indirect costs account for a significant proportion [15].

2.2 Cost Accounting Modeling Process

"The cost object consumes activities, and activities consume resources" is the guiding principle of ABC [16]. This paper follows the basic framework of ABC to divide the total cost of geometric patchworks into direct costs and indirect costs for accounting purposes. Based on the classification of activity centers, direct costs are straightforward to calculate and can be directly allocated to the geometric patchwork cost accounting when the expense is incurred. The calculation of indirect costs is more complex and should follow the steps outlined below.

1) Based on the classification of activity centers, calculate the cost incurred by each activity. The cost of the *i-th* resource consumed by the *j-th* activity center is equal to the total amount of the *i-th* resource actually consumed by the *j-th* activity center [17]. The expression is as follows:

$$A_{ij} = \sum_{i=1}^{n} X_i \tag{1}$$

Where, X_i represents the *i-th* resource consumed by the *j-th* activity center, A_{ij} represents the cost of the *i-th* activity in the *j-th* activity center.

2) Determine the cost drivers for each activity center and allocate the cost driver rates. Each activity center may have multiple cost drivers. When identifying cost drivers, the one that accounts for the largest proportion and is

easy to measure should be selected as the representative cost driver, in order to calculate resource consumption. Unlike traditional activity-based costing, the allocation of cost driver rates is based not only on cost data from the activity cost pools but also on the importance of each activity center. Finally, based on the above two factors, the cost driver rate for each activity center is determined.

3) The indirect costs within each activity center are calculated by multiplying the quantity of cost drivers by the cost driver rates. After aggregating the data, the total indirect costs for the geometric patchworks are determined.

3. Results

Based on ABC, a cost accounting model for customized geometric patchworks is established. This model creates activity centers based on resource consumption. Complete the cost analysis for direct costs and indirect costs separately.

3.1 Cost Accounting Modeling Process

The patchwork customization platform offers two design options for consumers to choose from. Option one allows consumers to independently design their patchwork online. Option two enables consumers to collaborate with a designer within the platform, where the designer assists in the design process. Using ABC to perform cost accounting for customized geometric patchworks, all the activities involved are classified and aggregated based on the consumed resources. Five activity centers are established, and direct and indirect costs are allocated as shown in Table 1. In the design activity center, the calculation of direct costs is not included. If the consumer selects designer-assisted design, the designer's labor costs must be accounted for and included in the indirect costs.

Table 1. The division of operation center, direct cost and indirect cost

Activity center	Activity	Resource consumption	DC	IC
Design activity center	Design	Designer hiring designer labor hours	-	Designer labor hours
Procurement activity center	Procurement	Supplier evaluation purchasing behavior fabric and auxiliary materials purchasing staff labor hours	DC_1	Buyer's evaluation purchasing activities purchasing staff labor hours
Production activity center	Cutting ironing sewing auxiliary post-finishing	Machine materials energy and power relevant staff labor hours	DC_2	Machine, energy labor hours of relevant staff
Sales activity center	Sales packaging marketing shipping	Logistics packaging materials employee labor hours advertising and promotion	DC_3	Logistics advertising expenses employee working hours
Inspection activity center	Inspection after-sales	Logistics machine materials inspection staff labor hours	DC_4	Logistics machine working hours inspection staff working hours

Calculating the DC of customized geometric patchwork:

$$DC = DC_1 + DC_2 + DC_3 + DC_4 \tag{2}$$

Where, DC represents the direct costs associated with the customized geometric patchwork. DC_1 represents the fabric and auxiliary materials cost in the procurement activity center. DC_2 represents the material costs incurred in the production activity center. DC_3 represents the packaging material costs within the sales activity center. DC_4 represents the material costs within the sales activity center.

Calculate the *IC* of geometric patchworks. Identify cost drivers and allocate cost driver rates.

In the design activity center, the quantity of products quantity, *m*, is adopted as the cost driver, with r_1 as the cost driver rate. In the procurement activity center, given that the cost of each procurement activity is fixed while the number of procurement's varies, the number of pronouncements, *a*, is selected as the cost driver, with r_2 as the cost driver rate. The production activity center, which is affected by factors such as size and craftsmanship, exhibits variations in production time; thus, manual labor hours, t_1, with r_3 as the cost driver rate. As a core value-added link, its cost driver rate carries a relatively high weight in the allocation of indirect costs. In the sales activity center, sales and marketing costs are allocated evenly, and since packaging and shipping costs are related to product quantity, the quantity of products quantity, *m*, is used as the cost driver, with r_4 as the cost driver rate. In the inspection activity center, due to differences in inspection time for each product, inspection time, t_2, is selected as the cost driver, with r_5 as the cost driver rate.

In conclusion, the cost of geometric patchworks can be calculated as follows:

$$C = DC + IC \quad 3)$$

Where, *C* represents the total cost of the customized geometric patchwork, *DC* represents the direct costs associated with the customized geometric patchwork, and *IC* represents the indirect costs associated with the customized geometric patchwork.

3.2 Cost Analysis of Customized Geometric Patchworks

3.2.1 Direct Cost

The calculation of DC_1 should be divided into five parts, as shown in Fig.1. Among them:

$$DC_1 = DC_{11} + DC_{12} + DC_{13} + DC_{14} + DC_{15} \quad 4)$$

Where, DC_{11} represents the top cost, DC_{12} represents the batting cost, DC_{13} represents the backing cost, DC_{14} represents the binding cost, and DC_{15} represents the cost of other auxiliaries.

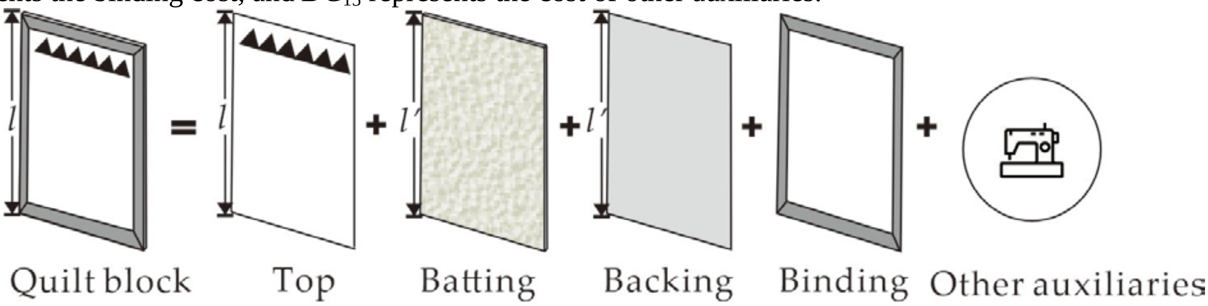

Fig.1 DC_1 calculation model of purchasing operation center

When analyzing DC_{11}, the geometric patchwork design diagram should first be modularized. Modules with the same color and material should be grouped together and denoted as G_n (n=1,2,3......). Next, the modules should be centralized. An appropriate seam allowance is added to each module, with the standard seam allowance size for international patchwork being 0.25 in. Considering fabric wastage and other factors, the actual seam allowance is set at 1 cm. Based on the division of G_n in the first step, the modules within each group are combined. The fabric length consumed by the patchwork top is calculated based on the width of the respective fabric, denoted as S_n. Finally, by multiplying by S_n the unit price of the corresponding fabric and summing the results, DC_{11} is calculated. When analyzing DC_{12} and DC_{13}, it is important to consider that the batting and backing have specific widths when ordered. Therefore, only the longitudinal dimensions of the batting and backing need to be considered. The theoretical length of the batting and backing should be the same as the length of the patchwork product. Taking fabric shrinkage and wastage into account, a 10% allowance is added to the length data, resulting in the actual longitudinal dimension l'. By multiplying l' by the unit price of the batting and backing, DC_{12} and DC_{13} are calculated. When analyzing DC_{14}, the finished binding fabric is selected. Therefore, only the length of the binding needs to be calculated. The theoretical length of the binding should be the same as the perimeter of the patchwork piece. Considering fabric shrinkage, labor loss, and other factors, a 10% allowance is added to the perimeter data to obtain the actual length of the binding, denoted as *el*. By multiplying *el* by the unit price of the binding, DC_{14} is calculated. When analyzing DC_{15}, the unit price of each auxiliary item is multiplied by its quantity to obtain the total cost. For the calculation of DC_2, a wide variety of materials are required during production, and not all of these materials may be reflected in the final patchwork product. Therefore, in this part of the cost calculation, the materials should be represented in the form of a material kit, with the specific materials within the kit being selected by the consumer. The calculation of DC_3 and DC_4 is relatively straightforward, as it involves multiplying the material unit price by the quantity used to obtain the corresponding cost information.

3.2.2 Indirect Cost

The indirect costs are calculated by multiplying the cost driver quantities and cost driver rates within each activity center, as shown in Table 2.

Table 2. Calculation of the indirect cost.

Activity center	Cost driver	Cost driver rate (RMB/unit)	Indirect cost (RMB)
Design activity center	m	r_1	IC_1
Procurement activity center	a	r_2	IC_2
Production activity center	t_1	r_3	IC_3
Sales activity center	m	r_4	IC_4
Inspection activity center	t_2	r_5	IC_5

In conclusion, the total cost of the customized geometric patchwork is calculated as follows:

$$C = DC + IC = DC_1 + DC_2 + DC_3 + DC_4 + IC_1 + IC_2 + IC_3 + IC_4 + IC_5 = DC_{11} + DC_{12} + DC_{13} + DC_{14} + DC_{15} + DC_2 + DC_3 + DC_4 + IC_1 + IC_2 + IC_3 + IC_4 + IC_5 = \sum_{i=1}^{n} tp_n \times S_n + cp \times l' + bp \times l' + ep \times el + DC_{15} + mp + DC_3 + \quad 5)$$

Where, t_{pn} represents the price of the top, *cp* represents the price of the batting, *bp* represents the price of the backing, *ep* represents the price of the binding, and mp represents the price of the material kit.

4. Discussion

To verify the cost accounting method proposed in this paper, an analysis is conducted using the geometric patchwork wall hanging designed by Ms. W on the patchwork customization platform, as shown in Fig.2. This wall hanging product consists of three layers, with dimensions of 57 cm × 56 cm and a binding width of 1 cm. It is made up of several isosceles triangles, each with a height of 6 cm, sewn together and finished with diamond-shaped top-stitching.

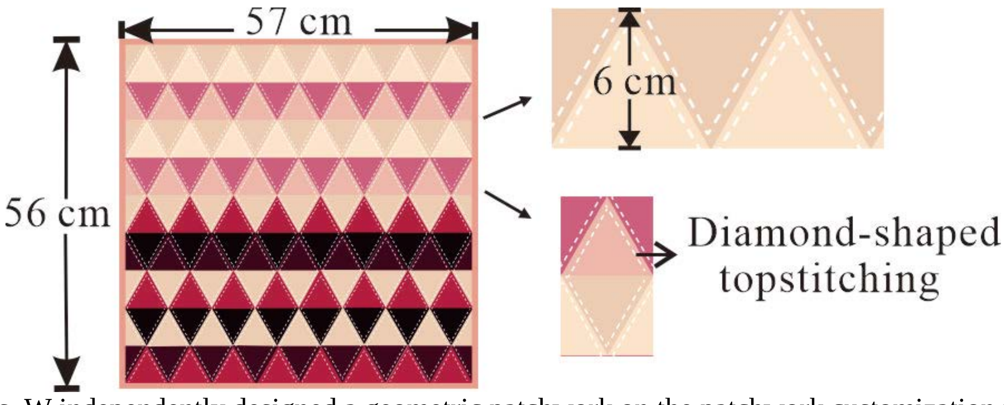

Fig.2 Ms. W independently designed a geometric patchwork on the patchwork customization platform

4.1 Calculation of Direct Costs

The top layer adopts plain-woven pure cotton fabric with a width of 110 cm, and the supplier's quotation is 40 RMB/m. As shown in Fig.3, the wall hanging product is first modularized, and then integrated based on the maximum horizontal and vertical dimensions of each module. For the triangular module, after retaining the necessary seam allowance, its base length is approximately 10.4 cm and height is approximately 9 cm. DC_{11} is calculated, as detailed in Table 3.

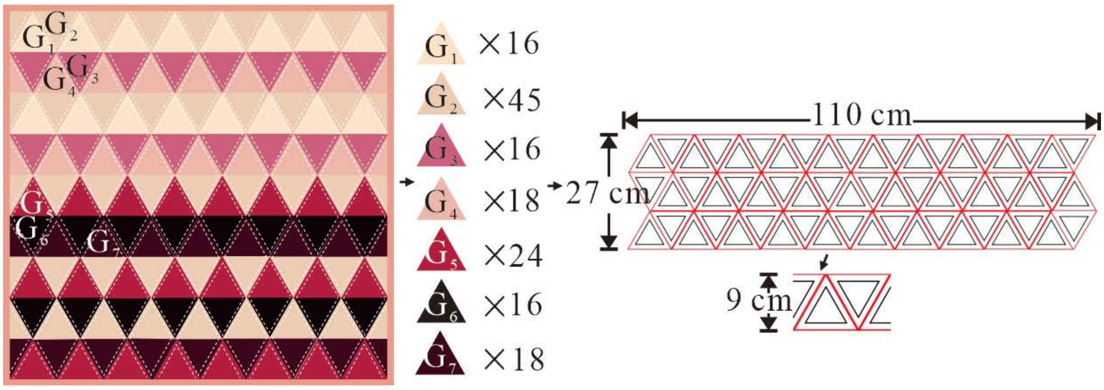

Fig.3 Modular decomposition and modular centralization of the geometric patchwork

Table 3. Calculation model of DC_{11}

Module	Quantity (unit)	Required length of top (cm)	DC_{11} (RMB)
G_1	16	9	3.6
G_2	45	27	10.8
G_3	16	9	3.6
G_4	18	9	3.6
G_5	24	18	7.2
G_6	16	9	3.6
G_7	18	9	3.6
			Total: 36

Table 4. Calculation of the direct cost of geometric patchwork

Activity center	Name	Unit price	Amount	*DC* (RMB)
Design activity center	-	-	-	-
Procurement activity center	Top	40 RMB/m	0.9 m	DC_{11}=36
	Batting	32 RMB/m	0.616 m	DC_{12}=19.8
	Backing	40 RMB/m	0.616 m	DC_{13}=24.7
	Binding	2.5 RMB/m	1.243 m	DC_{14}=3.2
	Other auxiliaries	-	-	DC_{15}=0
Production activity center	Material kit	57 RMB/unit	1	DC_2=57
Sales activity center	Packaging transportation	11 RMB/unit	1	DC_3=11
Inspection activity center	Inspection tools	-	-	DC_4=5
				Total: *DC*=156.7

The batting selected with a width of 150 cm and a thickness of 4 mm; the backing is plain-woven pure cotton with a width of 110 cm; the binding is made of pre-washed cotton fabric with a width of 40 mm. The material kit selected by Ms. W includes a set of needles, pins, and a disappearing ink pen. Since the wall hanging is relatively simple to make and does not involve other auxiliary materials, the cost for auxiliary items DC_{15}=0 RMB. The direct cost accounting for the geometric patchwork customized by Ms. W is shown in Table 4. *DC* is calculated and rounded to one decimal place.

4.2 Calculation of Indirect Costs

Ms. W has customized a single product on the patchwork platform. To complete the production of this product, it is expected that four procurement sessions will be needed. Based on the actual area of the patchwork and historical data, the estimated times are as follows: cutting, ironing, drawing seam allowances, and assembling the top fabric take approximately t_{11}=8 h; cutting, ironing, basting, assembling, top-stitching, and making the binding take approximately t_{12}=1.9 h; post-processing takes approximately t_{13}= 0.5 h. Therefore, the total time t_1=10.4 h and the time for inspection t_2=0.1 h is calculated.

The cost driver rates are allocated as follows: r_1=50 RMB/unit, r_2=10 RMB/unit, r_3=15 RMB/h, r_4=25 RMB /unit, r_5=10 RMB/h. Based on these rates, the total indirect cost, *IC*=272 RMB.In summary, the total cost accounting result for Ms. W's customized geometric patchwork is 428.7 RMB.

5. Conclusion

This study employs ABC as the core methodology, contrasting it with traditional approaches to establish a theoretical foundation for cost accounting in customized geometric patchworks. A model was developed, categorizing costs into direct and indirect components across five activity centers. Direct costs are straightforward, while indirect costs are determined by the cost driver rate and quantity for each center. A case study using a patchwork product from a customization platform validated the feasibility and applicability of the ABC method in geometric patchwork cost accounting. However, the research sample is relatively singular, failing to fully validate its applicability. In the future, the scope of research should be expanded to enhance the universality of the model. Additionally, since labor hour estimation is relatively important in the calculation of *IC*, special research should be conducted on it to further deepen the feasibility and accuracy of the study.

6. Acknowledgment

This paper is funded by the Philosophy and Social Sciences Planning Project of Shanxi Province (Project No. 2023 YY051); Postgraduate Teaching Reform Project of the Education Department of Shanxi Province (Project No. 2024JG042); Special Project for Science and Technology Strategy Research of Shanxi Province (Project No. 202404030401110).

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