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Internet of things enabled the control and optimization of supply chain cost for unmanned convenience stores

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Abstract In the context of "new retail", various new retail models have appeared in the market one after another, such as unmanned retail, and unmanned convenience stores, which are based on a model in the unmanned retail industry. At present, unmanned convenience stores still have to deal with the challenges in operations, including difficulty in landing site selection, immature technology, and low public awareness. The most important issue is the supply chain cost control. It seems that operating methods that reduce costs through technical support cannot effectively control their costs. This article not only combines cost analysis methods such as flexible budgeting method to calculate and analyze the supply chain cost of unmanned convenience stores, but also proposes cost control methods from the perspective of supply chain management, and gives suggestions on the future development direction of unmanned convenience stores.

1. Introduction

Unmanned retail, also known as smart retail, is the starting point for the digital transformation of the retail industry. Unmanned retail uses so-called "black technologies" such as the Internet of Things, artificial intelligence, big data, and cloud computing to address the key pain points of the tradi-

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tional retail industry such as cost, efficiency, and consumer experience, and reform the retail format and the entire retail chain. Unmanned convenience stores refer to the intelligent and automated processing of all or part of the business processes in the store through technical approaches to minimize or eliminate manual intervention. Unmanned convenience stores apply cutting-edge technologies such as artificial intelligence, cloud computing, biometrics, mobile payment, electronic tags, 360° non-dead-angle monitoring, and big data collection and analysis of consumer behavior to traditional convenience stores to help consumers accomplish self-service shopping and self-payment in the store.

In terms of its goal setting and development direction, unmanned convenience stores have specific retail scenarios and consumer groups, diversified technology applications, and advanced service concepts which are committed to creating a new shopping model that saves resources. At the same time, it serves society and injects new vitality into the retail market. Through comparative analysis of the development of unmanned convenience stores in recent years, its operating conditions are far worse than expected. There are situations in which many stores are facing bankruptcy, which reflects the lack of operating capacity and cost control problems. In response to this problem, the industry practitioners and scholars have begun to analyze and seek solutions from the perspective of consumer experience, financial management systems, and retail scene selection. However, it is worth noting that the essence of unmanned convenience stores is retail. The focus of fundamentally solving the cost control problem, integrating all resources, and making technical assistance to the fullest effect is supply chain management.

At present, the scenarios where unmanned retail transactions are used mainly include office buildings, transportation sites, and communities, in which the community accounts for the highest proportion 24%. Both office buildings and traffic stations account for 21%. Shopping malls accounts for 15%. Office accounts for 9%. The elevator room accounts for 4%. Others are 6%. Fig. 1 is proportion of unmanned retail transaction scale.

The remainder of the paper is organized as follows. Section 2 reviews the related works. In Section 3, main cost structure of unmanned convenience store supply chain is discussed. The proposed model is presented in Section 4. Supply chain cost control and optimization strategies for unmanned convenience stores are provided in Section 5, and the conclusions are presented in Section 6.

2. Related work

At present, research by various scholars has shown that the business model of unmanned convenience stores requires almost no labor costs, and the rent can be saved comparing with traditional convenience stores. But a variety of technical approaches enhance the shopping experience while also invisibly increase costs. H. Liang pointed out that there are still many problems in unmanned convenience stores, including cargo damage control, supply chain, technology, and location selection. However, it needs to be noted that the continuous demand of consumers is the driving force for the development of enterprises, so the decision of consumers can determine whether the unmanned convenience store can survive [1]. The first mover which introduces the concept of "unmanned convenience store" was Amazon, which launched the first Amazon Go unmanned retail store in Seattle in December 2016 [2]. Later, as the concept of new retail continued to heat up, some domestic entrepreneurs also began to pay attention to this format – convenience stores. Therefore, unmanned convenience stores such as Bingo Box, F5 Future Store, Take Go, Magic House, EAT BOX, etc. have appeared along with the trend [3]. By the end of 2017, the total financing of the unmanned convenience store project had exceeded 1 billion yuan. However, its development at this stage is not smooth. For example, Amazon Go cannot replicate the store on a large scale due to high costs and technical defects. The Bingo Box was suspended due to problems such as temperature control failure and payment disorder [4].

Regarding the supply chain related research in the retail industry, there are some papers in the literature that consider the dual-channel supply of retail services. Chen et al. unfolded a dual-channel supply chain, in which the manufacturer decides the price of the direct channel, the retailer decides its retail price and order quantity, and then the customer chooses the purchase channel based on the given price and service quality [5]. Wu et al. studied dual sales channel management with service competition, in which traditional channel services are measured by production availability, and direct channel services are measured by product delivery lead time [6]. Zheng Liu et al. discussed the role of carbon footprint in the supply chain and how to build a more energy-saving and emission-reducing supply chain [7]. Zhang et al. focus on the decision-making of retail services in the dual-channel market. They show that improving retail services can ease channel competition and channel conflicts, and improve supply chain performance [8]. Wu et al. studied price and lead time determination in a dual-channel supply chain, and lead time can be regarded as a service [9]. Bin Hu et al. compared and analyzed the optimal decision-making problem of the supply chain between the centralized decision-making and decentralized decision-making of producers and retailers under the constraint of carbon tax [10]. Dan et al. studied the pricing policy that considers retail services in the dual-channel supply chain of centralized retail and decentralized retail [11]. Xu et al. studied the impact of price comparison services on pricing strategies in a dual-channel supply chain [12].

In other fields related to the supply chain, many scholars have done in-depth research. Genc and De Giovanni modeled two Stackelberg games to study the best collection structure when the rate of return depends on price and quality [13]. Miao et al. developed three closed-loop supply chain models with product discounts: centralized collection (C type), retailer collection (R type) and manufacturer collection (M type). They obtained the best solution for each collection strategy of the three models, and analyzed the advantages and disadvantages from the perspective of economic and environmental performance [14]. Qi Xu et al. studied the O2O supply chain model of online subsidy services, and analyzed the impact of demand interruption on the performance of the O2O supply chain [15]. Ma et al. studied a company's best pricing strategy and determined whether the company should provide both "old for new" and "old for new" thresholds [16]. Zhu et al. studied the optimal pricing and remanufacturing decisions of companies that adopted the trade-in program, and compared the manufacturer-initiated scheme with the retailer-initiated

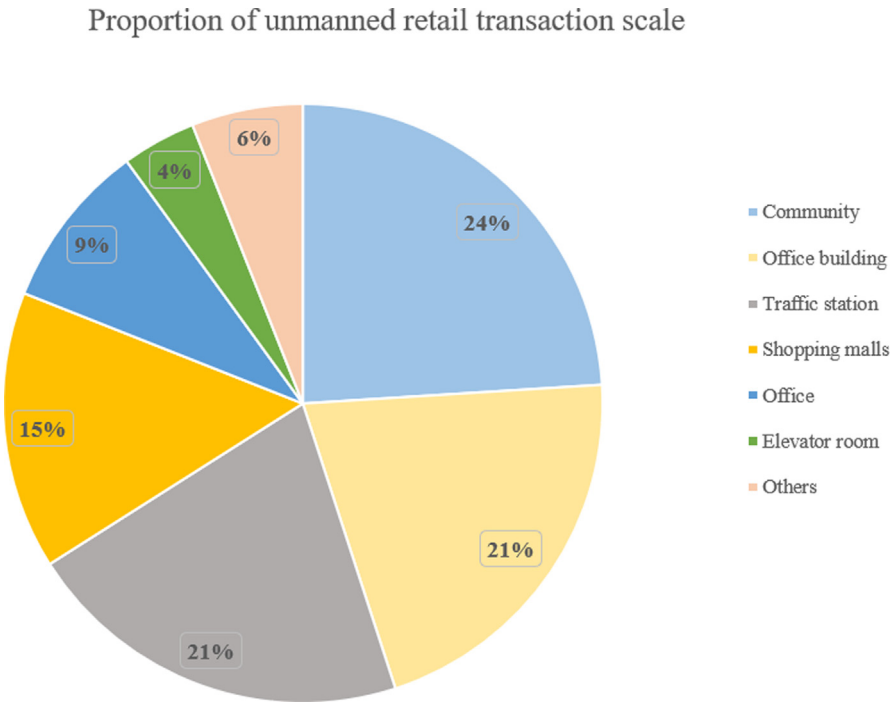

Fig. 1 Proportion of unmanned retail transaction scale.

scheme [17]. Fu et al. proposed a two-stage game model to obtain the optimal price and trade-in discount for offspring products with strategic consumers and limited trade-in periods [18]. Qu et al. Considered a B2C platform with self-operated stores and third-party stores, and studied the best trade-in strategy for the platform, whether to provide rebates to consumers through gift cards or cash coupons [19]. Long et al. studied the best decision for retailers to provide traditional extended warranty or new extended warranty with additional trade-in service, and how to determine the best trade-in price when choosing a new extended warranty with trade-in service [20]. Zhu et al. established a two-period model in which OEMs provide trade-in to recover used products, and can choose to remanufacture these used products and resell them to the second-hand market [21].

3. Main cost structure of unmanned convenience store supply chain

3.1. Labor costs

On the surface, there are no staff on duty in the unmanned convenience store, and the introduction of technical means has replaced many tasks that need to be done by people in traditional convenience stores [22]. However, a large amount of technological assistance also requires manual construction and maintenance [23]. In store operations, electronic tags are usually complementary to mobile payment. The two data provided separately will work together on a unified data system to provide certain feasibility assistance for store inventory statistics and customer sales preference analysis [24]. Certain requirements are put forward for the establishment and operation of the inventory system [25]. In all aspects of the operation of unmanned convenience stores, there is a certain labor cost in procurement, transportation, inventory, etc., manual system maintenance, system optimization, and data mining.

3.2. Technology cost

One of the cores of unmanned retail's cost control is to replace the corresponding manual labor with the support and assistance of technical approaches, i.e. reducing labor costs while optimizing operations [26]. Up to now, the technology used in major unmanned convenience stores has been able to ensure that convenience stores provide unmanned cashiers, that is, consumers enter and exit stores, and complete shopping and payment activities independently [27,28]. However, there are still problems in face recognition for verifying payment and product barcode recognition due to technical problems, which leads to failures in the operation of unmanned convenience stores, and affects the shopping experience of consumers and the operation of the store [29,30].

3.3. Maintenance cost

Regarding RFID, the most used radio frequency technology in the unmanned retail industry, the essence of this technology is to identify products through chips, obtain customer purchase information, and calculate the amount to be paid, to realize the digitalization of the whole process of customer consumption [31,32]. However, according to the feedback from most unmanned convenience store operations at present, this RFID tag is extremely easy to fall off on the product [33]. At the same time, this type of label recognition has higher requirements in working environment. These problems and restrictions have caused certain difficulties and led to the failure in the operation of unmanned convenience stores and . In addition, it is worth noting that under the commonly used RFID solution, each

product tag will increase the cost of about 0.4 yuan [34]. With the increase in sales, the cost of labels attached to products has also introduced more cost to unmanned convenience stores.

3.4. Experience cost

In terms of artificial intelligence, the current unmanned retail and the popularization of artificial intelligence are in a phase of mutual transition [35]. It will take some time for the basic technology theory of perception layer such as vision and speech recognition to get matured for commercialisation [36,37]. If consumers give up this purchase only because they cannot shop normally or because of a poor shopping experience, it will have a certain impact on sales and profits [38,39,40]. The resulted decline in the circulation rate of goods and capital has also virtually increased the operating costs of the store [41].

4. Control model of supply chain cost of unmanned convenience store

According to the characteristics of unmanned convenience stores, this paper selects the flexible budget method to calculate the cost of its supply chain and proposes a corresponding cost model [52].

4.1. Flexible budget method

The flexible budget method is based on a variety of business volume levels that may occur during the budget period. The corresponding cost amounts are determined and compiled, which can adapt to a variety of business volume levels, and thus can reflect the profit level in each business volume. The primary condition for using the flexible budget method to calculate supply chain costs is to divide the costs and expenses according to the classification of fixed costs and variable costs. Fixed cost, that is, its total amount does not change with the increase or decrease of other business volumes. Therefore, when the actual budget is calculated, only variable costs need to be adjusted accordingly.

$$Y = a + bX \tag{1}$$

In which, Y represents the total cost budget, a represents the total fixed costs, b represents the unit variable costs, and X represents the planned business volume.

When calculating the supply chain cost based on the flexible budget method, it is necessary to select a suitable measurement object first, which follows the principle of strong representativeness and strong intuitiveness. Next, we need to determine the range of changes in business volume. In addition, it is necessary to determine the relationship between various expenses and business volume, and calculate the forecast data for costs and expenses under various business levels based on the specific relationship. Finally, we need to choose the expression of flexible budget. The flexible budget method has two expressions: the list method and the formula method [42–44]. Fig. 2 shows flowchart for the preparation of the flexible budget method.

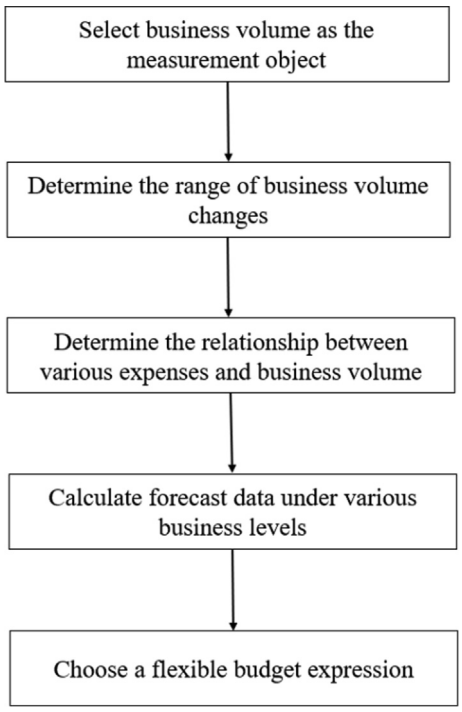

Fig. 2 Flowchart for the preparation of the flexible budget method.

4.2. Supply chain cost accounting based on flexible budget method

4.2.1. Selection of business volume measurement objects

As a retail format, the unmanned retail store's main business is the retail of goods. From the operator's point of view, the most important business changes come from changes in store sales, as the goods sold will bring costs and profits. Inventory changes by sales will also directly affect store inventory management and replenishment behavior.

This article selects the sales volume per unit time in the unmanned convenience store as the business volume measurement object, and the daily sales volume varies from 0 to 500. (Unit: Piece)

4.2.2. Determination of the relationship between various expenses and business volume

There are more business costs involved in the investment and operation of unmanned convenience stores. According to the premise of the flexible budget method, its cost is divided into fixed cost and variable cost. In which, fixed costs include the initial construction costs of building unmanned convenience stores (including store construction costs, internal shelf containers, settlement facility costs, cameras, initial stocking, etc.), rent, water costs, electricity costs, network costs, and labor costs. The variable cost includes the cost of the product sold in the store, the cost of the RFID tag consumed on the display product, and the logistics cost caused by replenishment.

The total amount of fixed expenses does not change with the increase or decrease in sales volume. The relationship

between variable cost and sales volume in unmanned convenience stores is:

$$Y_1 = a_1 \times X \quad (2)$$

In which, Y_1 is the purchase price of the product, a1 is the unit price of the product, and X represents the sales volume of the product in the unmanned convenience store per unit time.

$$Y_2 = a_2 \times X \quad (3)$$

In which, Y_2 is the cost of the RFID tag, a_2 is the unit price of the RFID tag, and X represents the sales volume of goods in unmanned convenience stores per unit time.

$$Y_3 = 20 \times n \quad (4)$$

In which, Y_3 is the cost of replenishment flow, and n is the number of replenishment times. However, replenishment is only required when SKU $\leqslant$ 500.

4.2.3. Main data collection

According to the survey and data compilation of most unmanned convenience stores in the current market, the area of a single store is 15 square meters to 30 square meters and the SKU is 800–1000. The construction cost of the unmanned convenience store is about 50,000 yuan, and the service life is 3–5 years. The shop area of unmanned convenience stores is about 15 to 30 square meters. According to Wang Guoping, a member of the New Retail Advisory Group of Linkshop, the operation of unmanned convenience stores uses commercial plots, and the current daily rent in first-tier cities is not less than 7–8 yuan per square meter. In the community scenario, the daily rent for commercial land will not be less than 3–5 yuan per square meter. The price of commercial water is 2.32 yuan per ton, including a sewage treatment fee of 0.8 yuan per ton and a water resource fee of 0.02 yuan per ton. Commercial electricity charges are around 1.2 yuan per kilowatt-hour. Unmanned convenience stores mainly sell convenience goods such as snack foods, beverages, and ordinary daily necessities. The overall average price of the goods is around 8 yuan. The cost price of RFID tags on the market is about 0.4 yuan. The relationship between the cost of the cost item and the sales volume can be obtained in Table 1.

Table 1 Standard compilation of costs for unmanned convenience stores.

Cost item	The relationship between expenses and sales
Commodity purchase price	The cost per unit of sales is 8 yuan
RFID tag cost	The cost per unit of sales is 0.4 yuan
The cost of replenishment logistics	The cost incurred when $SKU \leq 500$ is 20 yuan No cost when $SKU > 500$
The initial construction cost of the convenience store	Irrelevant
Rent cost	Irrelevant
Water fee	Irrelevant
Electricity bill	Irrelevant
Network fee	Irrelevant
Labor costs	Irrelevant

4.2.4. Supply chain cost accounting for unmanned convenience stores

Considering that there are many cost categories involved in the operation of an unmanned convenience store, this article selects the list method to show the supply chain costs of unmanned convenience stores.

Based on the known store construction costs and equipment service life, calculated based on 5 years of depreciation, the average daily fixed cost is 30 yuan. The conventional area and rent data of unmanned convenience stores are calculated based on the rental area of 15 square meters and the rent of 5 yuan per square meter per day, and the daily rent can be 75 yuan. The total water and electricity network fee are calculated at 30 yuan per day. Unmanned convenience stores still require employees to participate in system testing, system maintenance, replenishment, emergency response and other businesses. Therefore, a certain labor cost will be incurred, and the salary standard is 3,000 yuan per month.

(1) Commodity purchase cost

According to formula (2), the purchase price of $Y_1 = 8 \times X$ can be obtained, where X represents the sales volume in the unmanned convenience store that day.

(2) *RFID* tag cost

According to the formula (3), the *RFID* tag cost of the products sold on the day is $Y_2 = 0.4 \times X$, where X represents the sales volume in the unmanned convenience store on the day.

(3) Replenishment cost

The relationship between sales and inventory in unmanned convenience stores is:

$$SKU = \sum SKU - X \quad (5)$$

SKU represents the number of products remaining in unmanned convenience stores, and X represents the sales volume of products in unmanned convenience stores per unit time.

According to the previous data collection, $\sum SKU = 800$ is known, and the replenishment operation will be carried out at $SKU \leqslant 500$. According to formula (4.5), it can be obtained that replenishment is required when $X \geqslant 300$, that is, if more than 300 items are sold, replenishment is required, and each time a replenishment fee is 20 yuan.

(4) Cost expression based on tabulation method

According to the relationship between various expenses and sales volume, with the integration of collected data, the flexible budget for daily supply chain costs in unmanned convenience stores can be calculated.

In the fixed cost, the initial construction cost is 30 yuan per day and the rent is 75 yuan per day. Water, electricity, and network costs total 30 yuan. The labor cost is 100 yuan. The total fixed cost is $30 + 75 + 30 + 100 = 235$ yuan.

In the variable cost, when the sales volume on that day is 50 pieces, the purchase price of the goods on that day is 400 yuan. The RFID tag costs 20 yuan. The replenishment cost is 0 yuan. The total variable cost is $400 + 20 + 0 = 420$ yuan.

According to the formula (4.1), the total cost $= 235 + 420 = 655$yuan, that is, when 50 items are sold, the supply chain cost of 655 yuan is incurred on that day.

When the daily sales volume is 100 pieces, the purchase price of the commodity on that day is 800 yuan. The RFID

tag costs 40 yuan. The replenishment cost is 0 yuan. The total variable cost is $800 + 40 + 0 = 840$ yuan.

According to the formula (4.1), the total cost is $235 + 840 = 1075$ yuan, that is, when 100 products are sold, the supply chain cost of 1075 yuan is incurred on that day.

When the daily sales volume is 300 pieces, the purchase price of the commodity on that day is 2400 yuan. The RFID tag fee is 120 yuan. The replenishment cost is 20 yuan. The total variable cost is $2400 + 120 + 20 = 2540$ yuan.

According to the formula (1), the total cost is $235 + 2540 = 2775$ yuan, when 100 products are sold, the supply chain cost of 2775 yuan is incurred on that day.

By analogy, calculate the daily supply chain costs when the sales volume is 0, 50, 100, 150, 200, 250, 300, 400, 500 pieces, and use the tabular method to express them. From this, the following unmanned convenience store supply chain cost elastic budget Table 2 can be obtained.

In the calculation results of supply chain costs at different sales levels of unmanned convenience stores, when the sales volume of the day is 100 pieces, the unmanned convenience stores will incur a supply chain cost of approximately RMB 1,075 on that day. When the daily sales volume is 150 pieces, the unmanned convenience store will incur a supply chain cost of approximately 1475 yuan a day. When the daily sales volume is 200 pieces, the unmanned convenience store will incur a supply chain cost of approximately 1,915 a day. Fig. 3 shows the relationship between sales volume and total cost.

4.3. Calculation of break-even point of unmanned convenience stores

4.3.1. Definition of break-even point

The break-even point refers to the business volume (yield or sales volume) that a company needs to achieve when it is operating in a state of no-win or no-loss. This article selects the daily sales of unmanned convenience stores to represent its break-even point.

4.3.2. Changes in break-even point under different gross margin levels

Gross profit margin is the percentage of gross profit and sales revenue (or operating income), where gross profit is the difference between revenue and the cost of sales corresponding to revenue.

$$\text{Gross profit rate} = \text{gross profit/sales income} \times 100\% \ (\text{sales income} - \text{sales cost})/\text{sales income} \times 100\% \quad (6)$$

Combined with the actual background of this article, the composition of the cost of sales here is

$$\text{Sales cost} = \text{commodity purchase price cost} + \text{RFID tag cost} \quad (7)$$

When the gross profit margin is 0%, according to formula (6), we can get (sales revenue-sales cost)/sales revenue $\times$ 100% $= 0$, that is, sales revenue is equal to sales cost, and sales revenue at this time is also equal to the sales of break-even point. With reference to the supply chain cost data calculated in Table 2, according to formula (7), when the sales volume is 0, the sales at the break-even point is 0 yuan. When the sales volume is 50, the sales at the break-even point is 420 yuan. When the sales volume is 100, the sales at the break-even point is 840 yuan. When the sales volume is 150, the sales at the break-even point is 1,260 yuan.

It is impossible for a company to set its expected gross profit margin at 0%. Here, we first select a situation where the daily sales volume of an unmanned convenience store is 100 pieces, and calculate the sales at the break-even point under different gross margin levels.

Assuming operating income is X yuan.

From Table 2, when the sales volume is 100 pieces, the purchase price of goods is 800 yuan, and the RFID tag cost is 40 yuan. Substituting these data into formula (7), the cost of sales currently is 840 yuan.

When the gross profit margin is 10%, it can be obtained by substituting formula (4.6):$\frac{x-840}{x} \times 100\% = 10\%, x - 840 = 0.1x$, get the solution of the equation $x \approx 933$, at this time, the sales at the break-even point is about 933 yuan.

When the gross profit margin is 20%, it can be obtained by substituting formula (4.6):$\frac{x-840}{x} \times 100\% = 20\%, x - 840 = 0.2x$, get the solution of the equation $x = 1050$,at this time, the sales at the break-even point is about 1050 yuan.

When the gross profit margin is 25%, it can be obtained by substituting formula (4.6):$\frac{x-840}{x} \times 100\% = 25\%, x - 840 = 0.25x$,get the solution of the equation $x = 1120$,at this time, the sales at the break-even point is about 1120 yuan.

Table 2 Unmanned Convenience Store Supply Chain Cost Flexible Budget Table (Unit: Yuan).

Expense item		Unit variable cost	Sales volume (pieces)								
			0	50	100	150	200	250	300	400	500
Varia-ble costs	Purchase price	8 yuan/piece	0	400	800	1200	1600	2000	2400	3200	4000
	RFID tags	0.4 yuan/piece	0	20	40	60	80	100	120	160	200
	Replenishment	20 days	0	0	0	0	0	0	20	20	20
	Subtotal	–	0	420	840	1260	1680	2100	2540	3380	4220
Fixed cost	Initial construction	30	30	30	30	30	30	30	30	30	30
	rent	75	75	75	75	75	75	75	75	75	75
	Water and electricity and internet costs	30	30	30	30	30	30	30	30	30	30
	Labor costs	100	100	100	100	100	100	100	100	100	100
	Subtotal	235	235	235	235	235	235	235	235	235	235
Total			235	655	1075	1495	1915	2335	2775	3615	4455

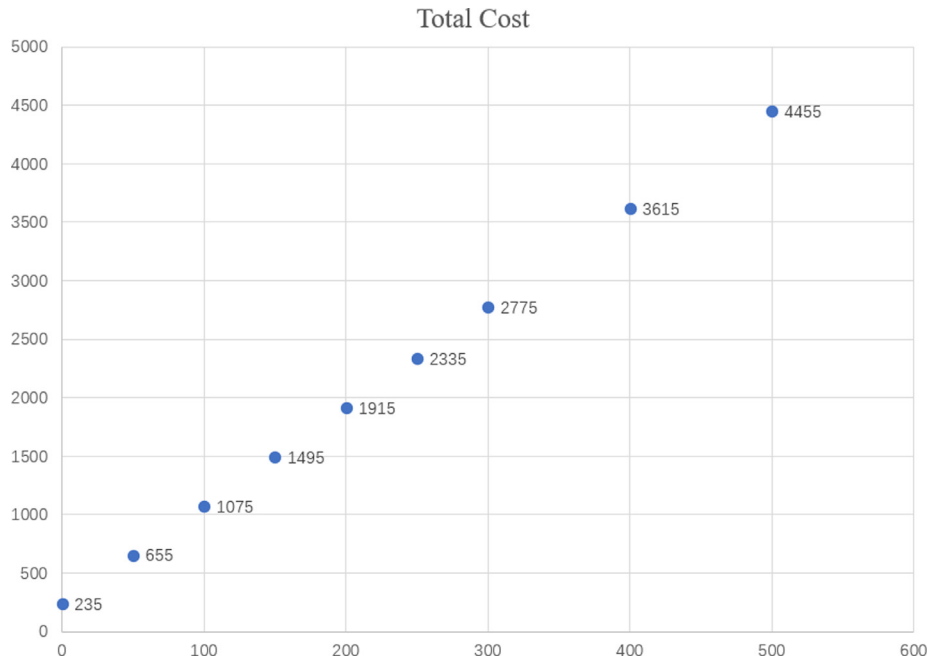

Fig. 3 Relationship between sales volume and total cost.

When the gross profit margin is 30%, it can be obtained by substituting formula (4.6):$\frac{x-840}{x} \times 100\% = 30\%$,$x - 840 = 0.3x$, get the solution of the equation $x = 1200$,at this time, the sales at the break-even point is about 1200 yuan.

Secondly, it is also possible to calculate the sales at the break-even point for different operating costs under the same gross margin level.

Suppose the sales amount is x yuan, and the gross profit margin level is 25%.

When the cost of sales is 1260 yuan, it can be obtained by substituting formula (6): $\frac{x-1260}{x} \times 100\% = 25\%$,$x - 1260 = 0.25x$, get the solution of the equation $x = 1680$, at this time, the sales at the break-even point is about 1680 yuan.

When the cost of sales is 1680 yuan, it can be obtained by substituting formula (6):$\frac{x-1680}{x} \times 100\% = 25\%$,$x - 1680 = 0.25x$,get the solution of the equation $x = 2240$, at this time, the sales at the break-even point is about 2240 yuan.

By analogy, calculate the sales at the break-even point generated under different sales volume and different gross profit margin levels brought about by different inventory levels. The calculation results are shown in Table 3.

According to the survey data of "Linkshop", the gross profit margin of most convenience stores in China is about 20%. For example, the gross profit margin of international brand convenience stores such as Family Mart and 7–11 is around 25%-30%. From the calculation results in Table 3, it can be found that if an unmanned convenience store intends to achieve a gross profit margin of 20%, it needs to achieve at least about 1,050 yuan in sales a day to reach breakeven. If the store aims to achieve a gross profit margin of 25%, it needs to achieve at least 1120 yuan a day in sales to reach breakeven. If the store aims to achieve a 30% gross profit margin, it needs to achieve at least 1,300 yuan a day in sales to reach breakeven. At present, the average price of goods sold in most unmanned convenience stores is between 8 and 10 yuan, it is necessary to maintain a daily flow of about 100–160 people to enter the store to meet the breakeven. Fig. 4 is the relationship between the break-even point of unmanned convenience stores and gross profit margin when inventory quantity equaling to 600. Fig. 5 is the relationship between the break-even point of unmanned convenience stores and gross profit margin when gross profit margin equaling to 25%.

4.4. Calculation of net interest rate of unmanned convenience stores

4.4.1. Definition of net interest rate

Net interest rate, or net profit rate, refers to the percentage of net profit from operations to net sales or the percentage of invested capital.

$$\begin{aligned}\text{Net interest rate} &= \text{net profit}/\text{sales revenue} \times 100\% \\ &= (\text{sales revenue} - \text{sales cost} - \text{operating cost})/ \\ &\quad \text{sales revenue} \times 100\% \end{aligned} \tag{8}$$

In which, the operating cost is the fixed cost amortization calculated in the previous period, and the net interest rate formula can be calculated as:

$$\begin{aligned}\text{Net profit margin} &= (\text{sales revenue} - \text{supply chain cost})/ \\ &\quad \text{sales revenue} \times 100\% \end{aligned} \tag{9}$$

4.4.2. Net profit margin under different daily sales levels

Due to the existence of variable costs, here is a case where the daily sales volume of an unmanned convenience store is 100 pieces, and the net interest rate under different daily sales levels is calculated.

Table 3 Calculation of break-even point of unmanned convenience stores (with gross profit margin and inventory level as variables) (unit: yuan).

Inventory quantity (pieces/day)/Gross profit margin (%)	0%	10%	20%	25%	30%	40%
700	840	933	1050	1120	1200	1400
650	1260	1400	1575	1680	1800	2100
600	1680	1867	2100	2240	2400	2800
550	2100	2333	2625	2800	3000	3500
500	2520	2800	3150	3360	3600	4200
400	3360	3733	4200	4480	4800	5600

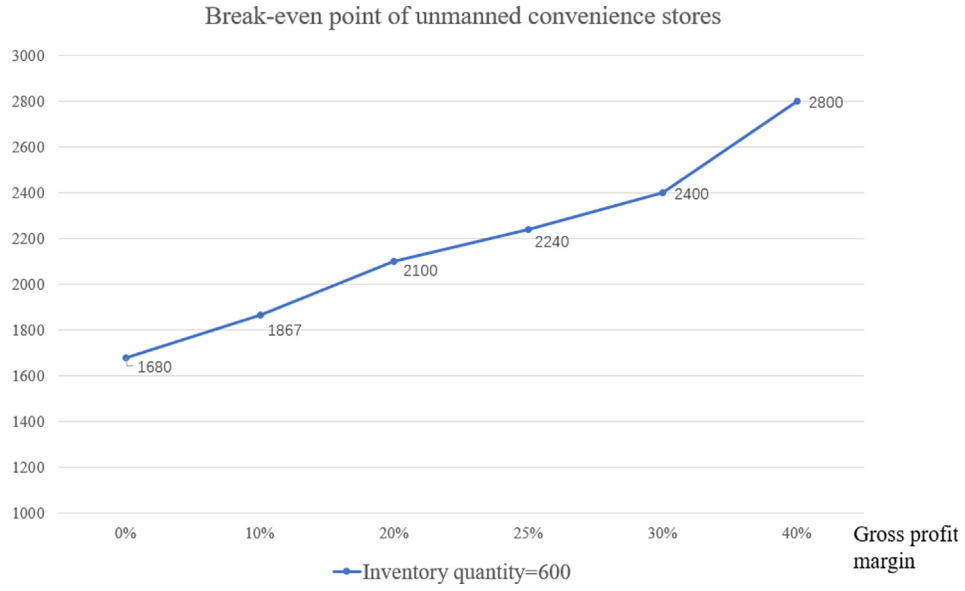

Fig. 4 The relationship between the break-even point of unmanned convenience stores and gross profit margin when inventory quantity equaling to 600.

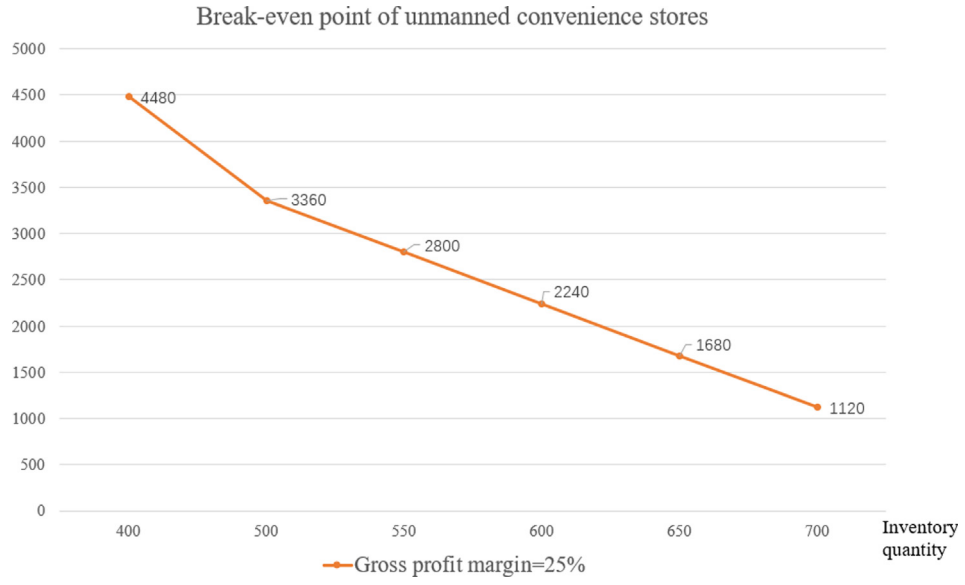

Fig. 5 The relationship between the break-even point of unmanned convenience stores and gross profit margin when gross profit margin equaling to 25%.

In Table 2, when the sales volume is 50 pieces, the supply chain cost is 655 yuan.

When the daily sales are 600 yuan, it can be obtained by substituting formula (9): Net profit rate $= \frac{600 - 655}{600} \times 100\% \approx -9.17\%$

When the daily sales are 700 yuan, it can be obtained by substituting formula (9): Net profit rate $= \frac{700 - 655}{700} \times 100\% \approx 6.43\%$ 。

5. Supply chain cost control and optimization strategies

5.1. Supply chain cost control in the procurement process

The purchaser can continuously optimize and adjust the variety and quantity of purchased goods through the sales in preference data fed back by the sales terminal system, which would increase the purchase quantity of popular goods, and reduce or even cancel the purchase of unpopular goods. When the data collection is sufficient, in-depth analysis of sales data such as seasons and time periods can also be carried out. In this way, individualized purchases of goods in different seasons and different time periods in each store can be used to improve efficiency while avoiding unnecessary waste of procurement costs. At the same time, in terms of supplier selection, convenience stores can also develop collaborative relationships or strategic supply partnerships with suppliers to disclose and share information in a timely manner, such as the processing progress of supplier orders, logistics tracking, and payment progress. Therefore, the supplier can quickly respond to the order, and the purchaser can shorten the procurement process.

5.2. Supply chain cost control in the distribution link

The development of unmanned convenience stores is still in its infancy. There are many brands and a small number of stores, which is not enough to form a scale effect, and there is no unified distribution system. In addition, many stores are outsourced to other operators for management in the form of franchising, which has further led to the decentralization of the distribution activities of various unmanned convenience stores without a unified planning and coordination mechanism. Therefore, it is possible to coordinate and manage the delivery of unmanned convenience stores that have appeared in the existing market. This can be achieved by integrating delivery resources through self-built or third-party platforms, and summarizing the delivery orders and delivery capacity data of each unmanned convenience store a day. Through the unified planning of the system, a reasonable and efficient distribution plan is calculated to reduce the number of distributions and improve the efficiency of distribution, thereby reducing unnecessary transportation costs.

5.3. Supply chain cost control in warehousing

The area of unmanned convenience stores is generally small, and their stores themselves are warehouses. Each store has a fixed maximum SKU inventory, so there is no inventory outside the shelf. That is, its inventory must be controlled within the maximum inventory. If the single supply of a product is too large, it will not be able to be placed on the shelves, and the remaining items will cause cost waste. If the single supply is insufficient or the replenishment cannot reach the store in time, it will also cause operational difficulties and cause out-of-stock costs. With the support of terminal sales data feedback, unmanned convenience stores can also perform more functions that are different from ordinary chain convenience stores, which performs better in minimizing cost.

6. Conclusion

In this paper, the concept definition, background, development status, supply chain cost and supply chain cost control of unmanned convenience store have been explored. The article uses a combination of qualitative analysis and quantitative analysis: a qualitative analysis on the current cost control of unmanned convenience stores, and a quantitative analysis on the supply chain costs incurred in the operation of unmanned convenience stores using flexible budgeting. Finally, some suggestions and predictions for the future development of unmanned convenience stores are proposed. In the future, many new technologies, including cloud (big data, cloud computing), terminal (PC terminal, mobile terminal, smart wearable, sensor, etc.), network (Internet of Things, Internet), are constantly emerging and developing. The construction of its supply chain cost control system and information platform provides corresponding technical support. With the assistance of unified coordination and information systems, costs can be more precisely controlled throughout the entire supply chain.

7. Availability of data and materials*a

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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