

# Use of the AHP Method to Evaluate Key Inventory Control Indicators: Case Study of a Taiwanese Manufacturer in China

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## SUMMARY

*Control of inventory is a crucial management task that can affect a company's success and survival, and good inventory control offers many benefits. In this paper, the Analytic Hierarchy Process (AHP) method is used to investigate key inventory indicators at a manufacturer and obtained an initial set of factors influencing inventory control, including five major assessment dimensions and 15 assessment criteria. "Rolling customer demand forecast accuracy" was a key assessment dimension that can be used to evaluate the case company's inventory. The five most important key inventory control indicators consisted of "forecasting accuracy," "purchases in China," "production, sale, and inventory (PSI) meeting," "skilled worker turnover rate," and "major changes in market demand." In addition, these key indicators are discussed and some practical recommendations are made.*

**KEYWORDS:** *Inventory control; indicator; Taiwanese manufacturer; Analytic Hierarchy Process (AHP).*

## 1. INTRODUCTION

In production management at a factory [1], inventory control may have a decisive impact on managing working capital, customer satisfaction, on-time delivery rate, stable production quality, production efficiency, production scheduling, and maximization of financial utilization. Depending on the content of a company's production management processes [1-3], inventory management is usually a necessary task. Factories should generally have materials on hand before manufacturing products requested by customers, particularly when just-in-time

deliveries have to be made. When there are large market fluctuations, and the sales department cannot accurately forecast customer demand, inventory volume may have to be increased to meet possible unexpectedly large requests, but this may be constrained by storage capacity limits and entails many costs. From a budgetary angle, inventory has an accumulative function toward corporate funds and tightens a company's capital chain, but the excess inventory can be dangerous for a factory as well [4]. Consequently, apart from developing sales and increasing market share, reducing inventory value and increasing inventory turnover rate are also important methods of increasing a company's free cash flow, net profit, and operating profit [5,6].

Many manufacturers understand the importance of inventory reduction and a high inventory turnover rate. Current approaches to inventory reduction include material requirement planning (MRP) inventory system, lean manufacturing, and the Toyota Production System's (TPS) Material Kanban Management System (MKMS) [7-9]. For instance, Toyota's MKMS kanban system integrates multiple types of information before confirming rational inventory levels. The important issues are whether it is possible to use scientific management to reduce inventory further and free up funds when a production system has a basic rational inventory; or if a factory can rely on an advanced 6M (man, machine, materials, management, money, and market) management system to further reduce inventory [10] in order to increase profit.

Production management departments need to obtain information from suppliers and customer service, purchasing, human resources, equipment, and financial accounting departments to perform stock-keeping unit (SKU) management and determine quantities of items needed in inventory [11,12]. Since production management departments have to schedule production processes, confirm production orders, decide when to produce which types of products, perform just-in-time production and shipments, determine inventory quantities, and maintain balanced inventory in preparation for the lack of capacity during the busy season, they need to deal with many factors in numerous categories [2,7]. Since this data may be very complex, it can be difficult to make scientific conclusions about which factors are the most important and the weight each of the various major factors is assigned. In addition, the lack of any single definitive inventory assessment criterion is a common problem afflicting factory management. Finally, if production management departments lack data concerning various important influencing factors that affect inventory reduction, they will find it difficult to make effective production decisions.

Since the dimensions and criteria involved in assessing possible inventory reduction strategies are far-ranging and complex, they are suitable for research employing multi-criteria decision-making (MCDM). In particular, the *Analytic Hierarchy Process* (AHP) [13] offers a systematic decision-making method that can be effectively used to resolve decision-making questions characterized by uncertain situations and multiple attributes [14]. Hence, this study applies the AHP method to evaluate the relative importance of factors affecting a factory's inventory control. These assessment factors enabled us to evaluate the key indicators affecting inventory control at this manufacturer.

In summary, an important research topic is how factory operators should compile and evaluate the assessment criteria to guide inventory control and assess inventory reduction solutions. In light of this, this article takes the manufacturing plant of the S company as a case study. It applies the AHP method to empirically evaluate the key inventory control indicators at the S company.

## 2. THE AHP METHOD

AHP [13] is an MCDM method proposed by Prof. Thomas Saaty at the University of Pennsylvania in the 1970s and later developed at the University of Pittsburgh in the 1980s. Researches employing AHP have appeared regularly in academic journals over the past 30-40 years. This method has been used in a very wide range of applications, and it has been put in use in management practice on numerous occasions. For instance, the AHP has been applied to environmental sustainability assessment [15,16], strategic planning assessment [17,18], Internet of Things (IoT) [19,20], e-commerce [21,22], selection of suppliers [23,24], assessment of risk factors [25,26], and inventory management [27,28] etc. The goal of AHP is to systematize complex problems, arrange the assessment dimensions of each problem in a hierarchical framework, and use that framework to distinguish different levels on which pairwise comparison can be performed.

In the AHP method, analytical factors and hierarchical levels possess the following characteristics [29]: reciprocal comparison, homogeneity, independence, and expectations. The structure of an MCDM problem typically consists of goals, criteria/sub-criteria, and alternatives, while the number of levels depends on the nature of the problem and depth of analysis [30]. According to Saaty [13], the number of assessment criteria subjected to pairwise comparison should not exceed 7. When all the levels have been constructed, a pairwise comparison must be performed for the criteria of each level where the criteria or objectives of the level above serve as assessment standards. If there are  $n$  criteria,  $n(n-1)/2$  pairwise comparisons must be performed. Because pairwise comparisons constitute an effective method of making cohesive judgments, AHP is used to determine the relative weights of the assessment criteria in this study.

Since AHP is a well-known decision-making method, many academic journal articles also describe its mathematical operation steps. Therefore, the operation procedure will not be described in this article, to save space. For further reading on the detailed operation steps, Saaty's book [13] is recommended. As already suggested, the empirical process of this article refers to Saaty's book [13] and Ding et al.'s article [31].

## 3. PRELIMINARY FACTORS INFLUENCING INVENTORY CONTROL AT THE S COMPANY

The COVID-19 pandemic has disrupted companies' production orders and slowed shipments in many material supply chains (particularly international shipments). As a result, dependence on supply has become a major concern for manufacturers. To meet demand, many companies have had to increase their material inventories, which may have affected production costs and their bottom line profits. Therefore, how to perform effective materials management, ensuring stable shipments and no shortages of materials during the pandemic, thereby enabling companies to seize opportunities amid crisis, emerges as a vital research topic. This paper, therefore, selected the S company, a conventional manufacturing company founded in Taiwan during the 1970s, for an inventory control case study (the S company is a manufacturer of rubber sealing elements). The production system implemented by S Company is summarized as follows:

- *Machinery and equipment:* When the company was founded, it originally developed steel molds, employed all personnel directly in manufacturing, and used steam to heat rubber to

be shaped into simple products. The S company has long cooperatively developed production equipment with equipment manufacturers. It has shifted from semi-automated production to world-class digitally-controlled equipment able to produce high-quality products. Advanced, stable machinery and equipment are necessary conditions for the survival of production enterprises.

- *Product types:* Originally producing simple O-rings with standard specifications, the company now also produces customized sealing elements with sealing, leak prevention, and dust-prevention functions. These include many elements with irregular shapes used in motor vehicles, chemical engineering, machinery, and various equipment. The product type meets the specification of customers, and listening to the voice of customers is the starting point of business management.
- *Material formulation:* The company originally used conventional pure rubber but now imports special chemical materials from the US to meet environmental demands and the current industrial needs of European and American customers. This provides differentiated, innovative products as a powerful tool for enterprises to increase profits.
- *Production sites:* The company has expanded from its original plant in Taiwan to an international production system with four plants located in Taiwan, China, and northern and southern Vietnam. Different manufacturing plants are chosen according to the complexity of the products so that enterprises can reduce production costs, satisfy customers, and increase profits.
- *Customer and market segments:* Originally supplying Taiwan's O-ring market, the company is now a major Original Equipment Manufacturer (OEM) supplier of irregularly-shaped sealing elements to the European and American automotive aftermarket. This increases product categories from business to market service and expands coverage area.
- *Management system:* Originally a family enterprise with an autocratic decision-making approach, the company has now hired a professional management team and also relies on consultants to guide improvements and increase efficiency. The management mechanism is the cornerstone of the sustainable growth of soft power and the foundation of the enterprise.

When factory managers draft inventory control plans, the different choices that can be made are largely the result of individual attitudes of decision-makers faced with uncertainty. The focal points of their assessment will depend on how they plan to perform inventory control and what key factors they can assess. Because factors involving uncertainty and different potential choices reflect the decision-maker's subjective assessment of inventory control plans, they cannot readily be estimated using standard dimensions. So, choosing key inventory reduction indicators is a major unresolved issue that this research aims to solve by finding the management standard of lean manufacturing/TPS-MKMS to reduce inventory. Following a review of the literature and discussion with scholars and S company managers, the major factors influencing inventory control at the S company were preliminarily gathered. These factors consisted of 5 assessment dimensions and 15 assessment criteria (their codes are shown in parentheses). The characteristics of these assessment dimensions and assessment criteria are explained in Table 1, as follows:

**Table 1** Preliminary factors influencing inventory control for the S company

<b>Assessment Dimensions</b>	<b>Assessment Criteria</b>	<b>Explanation of assessment criteria</b>	<b>References</b>
Rolling customer demand forecast accuracy (C <sub>1</sub> )	Production, sale, and inventory (PSI) meeting (C <sub>11</sub> )	PSI meetings are joint meetings held at least once each month, and participants include representatives from the production, sales, and materials departments. During the meeting, the production department must report production ability, sales personnel must report the 12-month rolling demand forecast, and the materials department must report inventory and suppliers' situations. The goal of the PSI meeting is to integrate three types of information for interdepartmental sharing and the promotion of transparency.	32-37
	Forecasting accuracy (C <sub>12</sub> )	The sales department must provide a rolling demand forecast for the coming 12 months. Because the sales department is in long-term contact with customers and has to be familiar with production schedules, sales personnel must interact closely with the user end to obtain first-hand market trend information. Accordingly, forecasting accuracy should have the highest priority at a PSI meeting.	33-38
	Assignment of customers to ABC classes (C <sub>13</sub> )	Time is money. The 80/20 principle provides a useful guideline: since class A customers can significantly improve overall performance and inventory reduction, companies should direct most of their attention toward those few class A customers providing 80% of their sales revenue. Companies must consequently monitor increased or decreased demand from class A customers, which will help them adjust materials in inventory and stocks of finished products quickly. B and C customers, which account for a smaller market share, must satisfy the supplier's minimum order quantity requirements.	32, 35, 38
Availability of production equipment (C <sub>2</sub> )	Total productive maintenance (TPM) (C <sub>21</sub> )	The stability of production operations depends on the TPM. Machine uptime percentage (%) is an extremely important production indicator. Maintaining equipment in good condition to start up at any time is an indispensable means of preparing for orders.	5, 7, 33, 38, 39
	New mold development (C <sub>22</sub> )	The mold development process includes the stages of design finalization, first piece trial production, and batch production of finished products. Each stage results in extensive work in process (WIP), and switching between new and old products increases the inventory burden. Consequently, when mold development proceeds slowly, design and shape modification work tends to result in the major accumulation of items in inventory.	5, 7, 32, 33, 40, 41
	Investment in new types of injection molding machines (C <sub>23</sub> )	Investments in new equipment will require changes in production methods, shortening of production processes, and reductions in working procedures; reducing inventory and increasing orders will aid the company's operations. Because effective new equipment can reduce the lead time (LT) and WIP, it can directly achieve the goal of inventory reduction while satisfying customer requirements, which will increase new orders.	7, 32, 33, 40

<b>Assessment Dimensions</b>	<b>Assessment Criteria</b>	<b>Explanation of assessment criteria</b>	<b>References</b>
<i>On-time materials supply rate (C<sub>3</sub>)</i>	<i>Purchases in China (C<sub>31</sub>)</i>	<i>The factory investigated in this study is located in China. This company takes Taiwan as its home base; apart from its plant in Taiwan, it also has plants in China and Vietnam. Most ordinary raw materials can be procured from suppliers in China, and their specifications and characteristics can fully meet customers' requirements, especially with a very short lead time. However, due to technological issues or confidential raw material formulations, etc., some special materials must be obtained from suppliers in Taiwan or Vietnam.</i>	<i>42-46</i>
	<i>Imports from Vietnam (C<sub>32</sub>)</i>	<i>The Vietnam factory is the largest of the three production facilities and obtains special raw materials from the United States. Because the US has the lowest limit on order size (minimum order quantity), and lead time is three months, the three factories all purchase materials from Vietnam after estimating demand. The Chinese factory imports materials from Vietnam in two batches each month following its demand. The China factory generally requests the Vietnam factory to ship two cargo containers worth of materials by sea monthly, and these shipments account for roughly 20% of all demand for materials.</i>	<i>42, 43, 46</i>
	<i>Imports from Taiwan (C<sub>33</sub>)</i>	<i>The factory in Taiwan currently serves as an R&amp;D center and provides new formulations, new materials, and special materials. Output is limited, and shipments are made by sea in bulk quantities. As a rule, two shipments are made each month. However, because type A customers often request special items and materials, although quantities may be extremely small, they are highly important; orders of this type account for roughly 10% of demand.</i>	<i>42, 43, 46</i>
<i>Skilled worker/conforming product rate (C<sub>4</sub>)</i>	<i>Skilled worker turnover rate (C<sub>41</sub>)</i>	<i>In semi-automated production facilities, quality is determined by skilled workers' techniques. When there are no "mistake-proof" fixtures in use, skilled workers must make a major contribution to quality. It generally takes a year to train a skilled worker to work quickly and achieve consistent quality. Because it is often difficult to distinguish between conforming and non-conforming products using instruments, defective products must be identified through final inspection employing human vision, impressions, and comparisons.</i>	<i>7, 38, 47-50</i>
	<i>New employee training (C<sub>42</sub>)</i>	<i>The training of new employees is an extremely important topic. Although the company has an incentive system to train new employees with more senior skilled workers, the training process will still lead to reduced capacity and unstable quality. In addition, new employees sometimes resign before completing their three-month probation period. Consequently, the company must have a set of new employee training methods.</i>	<i>7, 47-51</i>
<i>Skilled worker/conforming product rate (C<sub>4</sub>)</i>	<i>Employee education and experience (C<sub>43</sub>)</i>	<i>Employee education and experience provide a rough indicator of their general understanding and learning speed. If a company has no promotion system, it will find it difficult to retain personnel with high levels of education. Generally speaking, while factories may obtain well-educated workers quickly, there is also the risk of rapid turnover. In the case of less-well-educated workers, although they can be recruited quickly, they will tend to remain longer at their positions and be more stable.</i>	<i>7, 32, 38, 47-50</i>

<b>Assessment Dimensions</b>	<b>Assessment Criteria</b>	<b>Explanation of assessment criteria</b>	<b>References</b>
Customer service/ production management/ scheduling/ reworking rate (C <sub>5</sub> )	Major changes in market demand (C <sub>51</sub> )	A manufacturer must be ready to constantly adjust its products, production quantities, and production schedule following changes in market demand. To minimize inventory at a factory, the production management unit must adjust the factory's production schedule. If production management is insufficiently responsive, the products produced by the factory or parts and components purchased from suppliers may not be wanted by the market. These goods may result in an inventory backlog, which will keep inventory persistently high.	7, 32-36, 52, 53
	Customer order transfer (C <sub>52</sub> )	Customer order transfer is an extremely dangerous phenomenon. Suppose the sales department has already confirmed that it cannot retain an old customer but can obtain information concerning the expected time at which supply will be cut off. In that case, it will be possible to notify suppliers to stop deliveries of relevant materials. This will allow production line scheduling personnel to manage already-confirmed orders and ensure that excess materials and finished products do not accumulate in inventory after the supply stop and do not become an unsalable inventory backlog.	32-36, 53
	Readiness of internal personnel and materials (C <sub>53</sub> )	Toyota's MKMS seeks to achieve a high-profitability win-win outcome through a zero-inventory concept. In this system, an enterprise must let customers obtain finished products as inexpensively as possible while also helping suppliers keep materials on hand for the enterprise with the minimum inventory and greatest economic efficiency. This must ensure that the enterprise's production line will not stop due to a lack of materials and that operations can proceed smoothly. Consequently, having competent personnel in place will have a very important linking function in efforts to reduce inventory.	32, 35, 36, 38, 52

Source: Compiled by this study

#### 4. EMPIRICAL STUDY

In this section, a case study for evaluating key inventory control indicators of global settings of the manufacturing logistics flow is surveyed, as follows.

##### 4.1 QUESTIONNAIRE DESIGN AND RECOVERY

The questionnaire survey was used to assess the relative importance of factors influencing inventory control at the S factory and to rank the key inventory indicators. This study used five assessment dimensions and 15 assessment criteria to construct a hierarchical structure, as shown in Figure 1. Furthermore, data from Figure 1 were used to design a questionnaire to obtain the relative weights of all assessment dimensions and criteria.

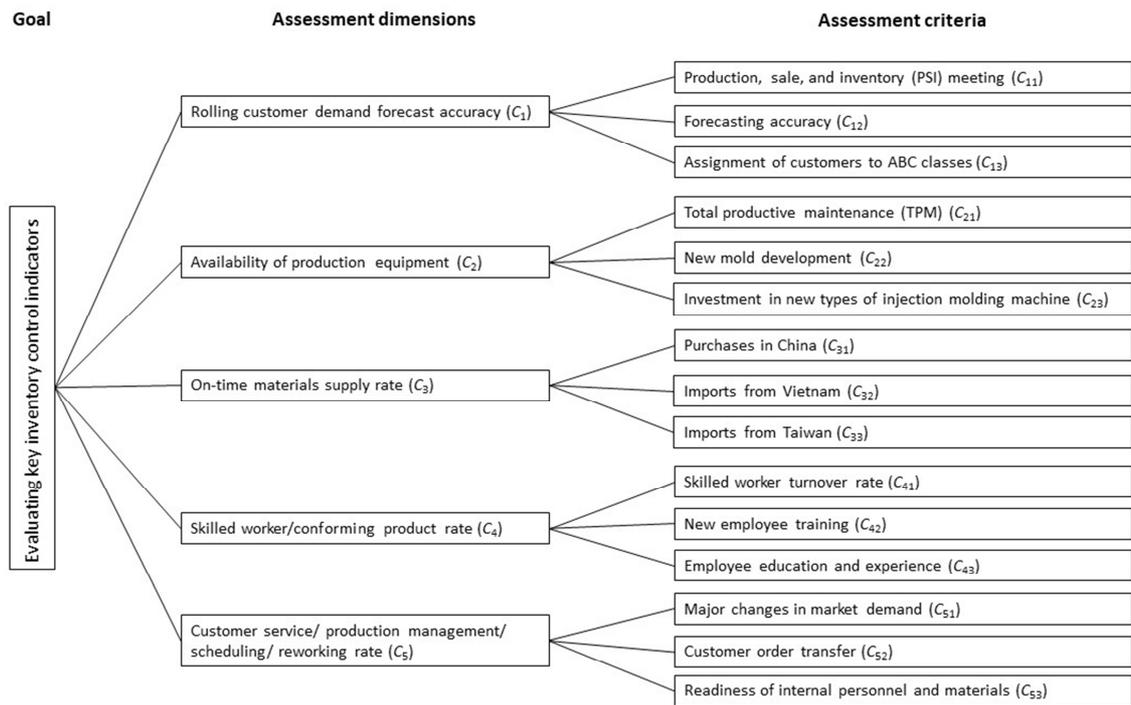


Fig. 1 Hierarchical structure diagram

The S factory's manager, operations experts consisting of deputy general manager-level personnel at other international-class production facilities, and production management scholars consisting of university professors were asked to complete the AHP expert questionnaire. The questionnaire survey period was three months in length. Of the 34 questionnaires distributed, five were not returned during the survey period, and 3 of the remaining 29 questionnaires failed to pass consistency testing. Twenty-six valid questionnaires remained (for an effective recovery rate of 76.47%). The operation steps of the AHP method were applied and the obtained results for 26 valid questionnaires were consistent with the pairwise comparison judgment. The consistency index (CI) and consistency ratio (CR) values are less than or equal to 0.1. The recommendation of Robinson [54] is that 5-7 individuals are the optimal number of experts participating in group decision-making. This indicates that this study's number of valid questionnaires gives the results certain representativeness. In addition, this paper provides the results of eigenvalues, CI values, and CR values of 26 valid questionnaires, as shown in Table 2.

**Table 2** The eigenvalues, CI, and CR values of all assessment dimensions and all assessment criteria for the valid questionnaires

Respondents	Five dimensions (C <sub>1</sub> -C <sub>5</sub> )			Three criteria (C <sub>11</sub> -C <sub>13</sub> ) under dimension C <sub>1</sub>			Three criteria (C <sub>21</sub> -C <sub>23</sub> ) under dimension C <sub>2</sub>			Three criteria (C <sub>31</sub> -C <sub>33</sub> ) under dimension C <sub>3</sub>			Three criteria (C <sub>41</sub> -C <sub>43</sub> ) under dimension C <sub>4</sub>			Three criteria (C <sub>51</sub> -C <sub>53</sub> ) under dimension C <sub>5</sub>		
	Eigen-value	CI	CR	Eigen-value	CI	CR	Eigen-value	CI	CR	Eigen-value	CI	CR	Eigen-value	CI	CR	Eigen-value	CI	CR
Ques-1	5.0131	0.0033	0.0029	3.0012	0.0006	0.0011	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000
Ques-2	5.3946	0.0986	0.0881	3.0959	0.0480	0.0827	3.0958	0.0479	0.0826	3.1023	0.0512	0.0882	3.1013	0.0507	0.0873	3.0775	0.0387	0.0668
Ques-3	5.3717	0.0929	0.0830	3.0540	0.0270	0.0466	3.0749	0.0374	0.0646	3.0293	0.0146	0.0252	3.0325	0.0163	0.0280	3.0724	0.0362	0.0625
Ques-4	5.3294	0.0824	0.0735	3.0724	0.0362	0.0625	3.1059	0.0530	0.0913	3.1107	0.0554	0.0955	3.1107	0.0554	0.0955	3.1059	0.0530	0.0913
Ques-5	5.3956	0.0989	0.0883	3.0724	0.0362	0.0625	3.0869	0.0435	0.0750	3.0540	0.0270	0.0466	3.0958	0.0479	0.0826	3.0741	0.0371	0.0639
Ques-6	5.3972	0.0993	0.0887	3.0000	0.0000	0.0000	3.1023	0.0512	0.0882	3.0000	0.0000	0.0000	3.0026	0.0013	0.0023	3.0000	0.0000	0.0000
Ques-7	5.3018	0.0754	0.0674	3.0537	0.0269	0.0463	3.0537	0.0269	0.0463	3.0539	0.0270	0.0465	3.0092	0.0046	0.0079	3.0092	0.0046	0.0079
Ques-8	5.3602	0.0900	0.0804	3.0869	0.0435	0.0750	3.0000	0.0000	0.0000	3.0867	0.0433	0.0747	3.0546	0.0273	0.0471	3.1107	0.0554	0.0955
Ques-9	5.0268	0.0067	0.0060	3.0012	0.0006	0.0011	3.0000	0.0000	0.0000	3.0012	0.0006	0.0011	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000
Ques-10	5.0524	0.0131	0.0117	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.1110	0.0555	0.0957	3.0000	0.0000	0.0000
Ques-11	5.0060	0.0015	0.0013	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000
Ques-12	5.0060	0.0015	0.0013	3.0012	0.0006	0.0011	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000
Ques-13	5.0166	0.0041	0.0037	3.0000	0.0000	0.0000	3.0092	0.0046	0.0079	3.0000	0.0000	0.0000	3.0037	0.0018	0.0032	3.0000	0.0000	0.0000
Ques-14	5.0060	0.0015	0.0013	3.0000	0.0000	0.0000	3.0012	0.0006	0.0011	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000
Ques-15	5.1069	0.0267	0.0239	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000
Ques-16	5.3980	0.0995	0.0888	3.0723	0.0361	0.0623	3.0869	0.0435	0.0750	3.0544	0.0272	0.0469	3.0543	0.0272	0.0468	3.0869	0.0435	0.0750
Ques-17	5.2949	0.0737	0.0658	3.0000	0.0000	0.0000	3.0952	0.0476	0.0821	3.0539	0.0270	0.0465	3.0539	0.0270	0.0465	3.1098	0.0549	0.0946
Ques-18	5.0268	0.0067	0.0060	3.0012	0.0006	0.0011	3.0000	0.0000	0.0000	3.0012	0.0006	0.0011	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000
Ques-19	5.3693	0.0923	0.0824	3.0741	0.0371	0.0639	3.0948	0.0474	0.0817	3.0542	0.0271	0.0467	3.0539	0.0270	0.0465	3.1098	0.0549	0.0946
Ques-20	5.3977	0.0994	0.0888	3.0000	0.0000	0.0000	3.1073	0.0537	0.0925	3.0951	0.0475	0.0820	3.0952	0.0476	0.0821	3.0092	0.0046	0.0079
Ques-21	5.3576	0.0894	0.0798	3.0000	0.0000	0.0000	3.0537	0.0269	0.0463	3.0655	0.0328	0.0565	3.0000	0.0000	0.0000	3.0959	0.0480	0.0827
Ques-22	5.3580	0.0895	0.0799	3.0092	0.0046	0.0079	3.0538	0.0269	0.0464	3.0000	0.0000	0.0000	3.0000	0.0000	0.0000	3.0867	0.0433	0.0747
Ques-23	5.0922	0.0230	0.0206	3.0092	0.0046	0.0079	3.0387	0.0194	0.0334	3.1093	0.0546	0.0942	3.0540	0.0270	0.0466	3.0092	0.0046	0.0079
Ques-24	5.3268	0.0817	0.0729	3.1098	0.0549	0.0946	3.1023	0.0512	0.0882	3.0952	0.0476	0.0821	3.0874	0.0437	0.0753	3.0958	0.0479	0.0826
Ques-25	5.3976	0.0994	0.0887	3.0952	0.0476	0.0821	3.0958	0.0479	0.0826	3.0775	0.0387	0.0668	3.0820	0.0410	0.0707	3.0867	0.0433	0.0747
Ques-26	5.3739	0.0935	0.0834	3.0183	0.0092	0.0158	3.0538	0.0269	0.0464	3.0092	0.0046	0.0079	3.0092	0.0046	0.0079	3.0538	0.0269	0.0464

Source: Compiled by the authors

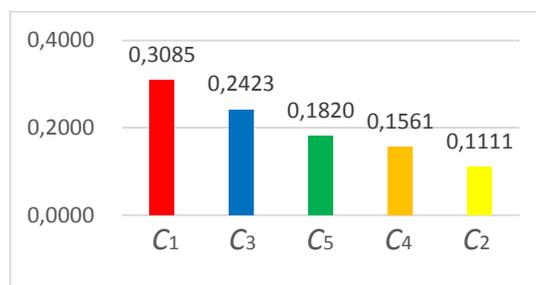
## 4.2 RESULTS

After encoding the valid questionnaires and tabulating the experts' opinions, the operation steps of the AHP method were performed and the weights of the assessment criteria on each level were ultimately obtained. These results explained the relative importance of the assessment dimensions and criteria (see the results organized in Table 3). The bar charts of evaluation dimensions and criteria weights are provided in order of hierarchical evaluation, as shown in Figures 2 and 3. In addition, a Pareto chart is provided in Figure 4, showing the descending order of aggregate weights to facilitate a visual understanding of the differences between priority criteria.

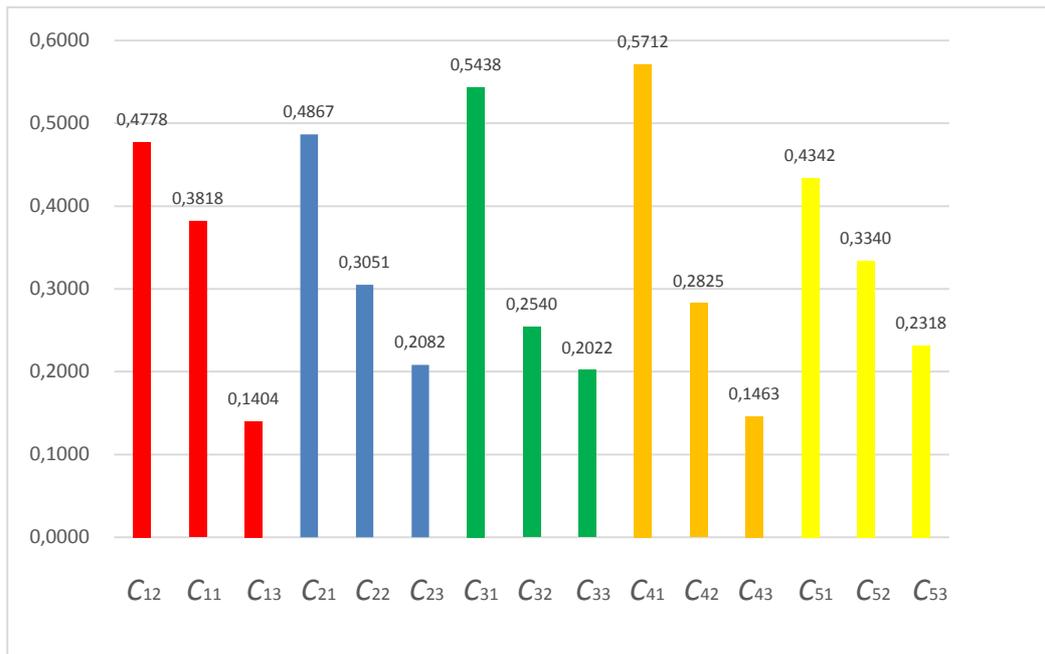
**Table 3** Weights of assessment dimensions and criteria, and aggregate weights

Assessment dimensions	Weights (A)	Assessment criteria	Weight (B)	Aggregate weights (C) = (A) * (B)
Rolling customer demand forecast accuracy (C <sub>1</sub> )	0.3085 (1)	PSI meeting (C <sub>11</sub> )	0.3818 (2)	0.1178 (3)
		Forecasting accuracy (C <sub>12</sub> )	0.4778 (1)	0.1474 (1)
		Assignment of customers to ABC classes (C <sub>13</sub> )	0.1404 (3)	0.0433 (11)
Availability of production equipment (C <sub>2</sub> )	0.1111 (5)	Total productive maintenance (TPM) (C <sub>21</sub> )	0.4867 (1)	0.0541 (8)
		New mold development (C <sub>22</sub> )	0.3051 (2)	0.0339 (13)
		Investment in new types of injection molding machine (C <sub>23</sub> )	0.2082 (3)	0.0231 (14)
On-time materials supply rate (C <sub>3</sub> )	0.2423 (2)	Purchases in China (C <sub>31</sub> )	0.5438 (1)	0.1318 (2)
		Imports from Vietnam (C <sub>32</sub> )	0.2540 (2)	0.0615 (6)
		Imports from Taiwan (C <sub>33</sub> )	0.2022 (3)	0.0490 (9)
Skilled worker/conforming product rate (C <sub>4</sub> )	0.1561 (4)	Skilled worker turnover rate (C <sub>41</sub> )	0.5712 (1)	0.0892 (4)
		New employee training (C <sub>42</sub> )	0.2825 (2)	0.0441 (10)
		Employee education and experience (C <sub>43</sub> )	0.1463 (3)	0.0228 (15)
Customer service/production management/scheduling/reworking rate (C <sub>5</sub> )	0.1820 (3)	Major changes in market demand (C <sub>51</sub> )	0.4342 (1)	0.0790 (5)
		Customer order transfer (C <sub>52</sub> )	0.3340 (2)	0.0608 (7)
		Readiness of internal personnel and materials (C <sub>53</sub> )	0.2318 (3)	0.0422 (12)

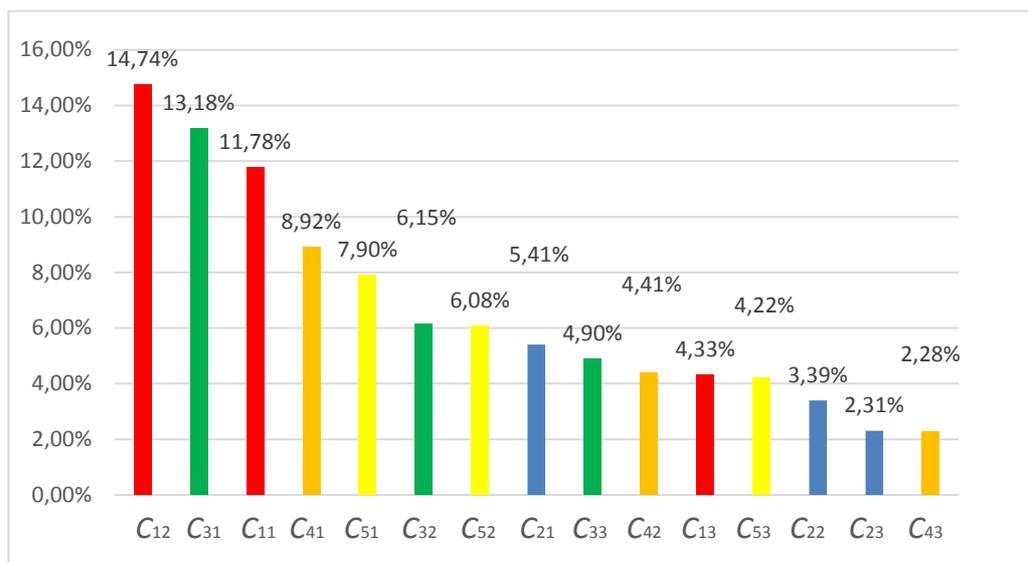
Note: The numbers in parentheses after the weight consist of the ranking order.



**Fig. 2** The bar chart of weights of assessment dimensions



**Fig. 3** The bar chart of weights of assessment criteria



**Fig. 4** The Pareto chart of the prioritized criteria

It can be seen that the important findings at the S factory include the following:

1. Figure 2 depicts the weights of the five assessment dimensions of inventory control appearing in the following order: "C<sub>1</sub> (0.3085)," "C<sub>3</sub> (0.2423)," "C<sub>5</sub> (0.1820)," "C<sub>4</sub> (0.1561)," and "C<sub>2</sub> (0.1111)." The "rolling customer demand forecast accuracy (C<sub>1</sub>)" is the most important among these dimensions.
2. Figure 3 depicts the assessment criteria beneath the five assessment dimensions with the following rank in terms of importance:

- (1) In the dimension " $C_1$ ," "forecasting accuracy ( $C_{12}$ )" is the most important assessment criterion.
  - (2) In the dimension " $C_2$ ," "TPM ( $C_{21}$ )" is the most important assessment criterion.
  - (3) In the dimension " $C_3$ ," "purchases in China ( $C_{31}$ )" is the most important assessment criterion.
  - (4) In the dimension " $C_4$ ," "skilled worker turnover rate ( $C_{41}$ )" is the most important assessment criterion.
  - (5) In the dimension " $C_5$ ," "major changes in market demand ( $C_{51}$ )" is the most important assessment criterion.
3. Daniel [55] believed that most enterprises have two to six factors that determine their success, and if a company wishes to be successful, it must seek to excel at these factors. The weight of a key assessment criterion is assumed to be greater than the average weight of all assessment criteria ( $1/15$  or  $0.0667$ ) before it can be selected as a meaningful key indicator. Accordingly, since the weights of the preceding five assessment criteria were all greater than  $0.0667$ , and the aggregate weight of these five key assessment criteria was  $0.5652$  (close to  $60\%$ ), in this study these five assessment criteria serve as key inventory indicators at the S company.

The study's results indicate that the most important five key inventory indicators are " $C_{12}$ ," " $C_{31}$ ," " $C_{11}$ ," " $C_{41}$ ," and " $C_{51}$ ," as can be seen from Figure 4. These findings also indicate that the most important five assessment criteria are mainly under the dimension " $C_1$ "; and include the two key assessment criteria of "forecasting accuracy ( $C_{12}$ )" and "PSI meeting ( $C_{11}$ ).". In contrast, the dimension " $C_3$ " has only the single key assessment criterion of "purchases in China ( $C_{31}$ )," the dimension " $C_4$ " has only the key assessment criterion of "skilled worker turnover rate ( $C_{41}$ ).". The dimension " $C_5$ " has only the key assessment criterion of "major changes in market demand ( $C_{51}$ ).". In addition, among the five key assessment criteria, the weights of the first three criteria are all over  $0.1$ , indicating that the three leading key assessment criteria are especially important in inventory control decision-making.

### 4.3 DISCUSSIONS

The initial research results indicate that the five leading key inventory indicators consist of "forecasting accuracy," "purchases in China," "PSI meeting," "skilled worker turnover rate," and "major changes in market demand." The following section discusses the five key indicators found in this study, explains their practical implications, and makes suggestions for practice.

#### 4.3.1 FORECASTING ACCURACY

Factory production scheduling must consider the number of orders, delivery dates required by customers, operability of production equipment, the maximum load on production capabilities, state of materials supply, and allocation of production line personnel. Forecasting accuracy is crucial for factories' production scheduling and is related to corporate profitability. Only enterprises that can accurately forecast market demand can effectively utilize their funds, equipment, and materials through sound production planning. Conversely, if a company has poor forecasting ability, this will ultimately cause its operating profit to fall. Furthermore, a company's sales department must stay in direct contact with customers and understand user-

end needs. This will provide the company with long-term first-hand knowledge of customers' operations and markets, allowing it to closely monitor changes in market demand and obtain accurate 12-month rolling demand forecasts.

#### 4.3.2 PURCHASES IN CHINA

Compared with foreign purchases, buying in China offers advantages in terms of supply distance, shipping charges, lead time, etc. In the Kanban management subsystem of Toyota's world-famous TPS lean manufacturing system, the Kanban formula is as follows:

$$(Daily\ demand \times lead\ time\ in\ days + safety\ stock) / minimum\ order\ quantity = number\ of\ cards$$

In this formula, the delivery lead time directly affects the resulting number of Kanban cards and the amount of inventory. When supply chains are long, the lead time will directly affect transport costs; so enterprises, to reduce transport costs, will seek to make larger purchases, which will keep inventory persistently high. Consequently, if the distance between a center plant and its satellite suppliers is shortened, the agile supply of small batches of varied products will be facilitated and the inventory effectively reduced. The purchases in this study made from local Chinese suppliers can lead to the "direct supply to the point of use" sought in lean manufacturing. The supply of small batches of varied items can reduce the "eight types of waste," thereby facilitating greater profitability.

#### 4.3.3 PSI MEETING

Production departments must plan machinery, equipment, and workforce needs based on forecast demand and deploy machinery, personnel, and capacity in response to high and low seasons. Enterprises must try to smooth out production peaks and valleys while still responding to forecast demand. For instance, they may cope with long-term fixed demand by maintaining a certain rate of production during the low season and storing excess output, which can be used to increase market coverage during the high season. At Company S, most high-unit-price products made in small batches can be cleared from inventory during the high season. The sales department must provide a comparative look at changes in rolling demand during the past and forecasts for each of the coming 12 months and must assess forecasting accuracy during the past month. When accuracy is poor, the department must determine the cause of discrepancies and draft a remedial action plan. The inventory purchasing unit must subtract existing inventory from forecast demand and calculate when more material will be needed to achieve minimum inventory and minimum tied-up funds while ensuring that the production department does not run short of materials. These calculations must consider material delivery lead times while the purchasing unit should try to give sufficiently early notification of orders to suppliers. Furthermore, the inventory purchasing unit must be able to predict the value of inventory reductions. Accordingly, the PSI meeting functions like an intelligence and command center in wartime and aims to ensure that all departments at the company are effectively coordinated.

#### 4.3.4 SKILLED WORKER TURNOVER RATE

The last of the "eight types of waste" in lean manufacturing consists of "employee suggestions that are not accepted," which tells us the importance of skilled workers. Skilled workers can help an enterprise create innovative new products, suggest production methods and solutions,

enhance performance, and ensure more consistent quality. Conversely, the resignation of skilled workers is a major loss for a company. This is because when skilled workers leave, the company must then acquire new personnel, which requires the commitment of large amounts of personnel and resources for recruiting and training, etc. There is no guarantee that new employees can match skilled workers in terms of productivity within a short time, and new employees' lack of familiarity with production methods and product quality requirements will increase the risk of defective products. This may cause major losses for the company and those consumers who ultimately use its products. Consequently, skilled workers are a very important resource for a company. Apart from giving raises to retain skilled workers effectively, the company must also arrange a training plan to ensure that workers can gain greater equipment operating expertise, enhance their technical skills, and improve product quality.

#### **4.3.5 MAJOR CHANGES IN MARKET DEMAND**

Although the sales department may stay in close contact with the user end and provide adequate rolling demand forecasts, markets are fickle, and global shifts, natural disasters, and the vicissitudes of the human world are hard to predict. For instance, when the COVID-19 virus appeared at the end of 2019 and spread worldwide, global economic activity entered a state of a deep freeze. In 2011, the Japanese tsunami caused a major production and supply chain disruption. A financial crisis seems to occur every few years, battering the economy. Now that technology has advanced to the 5G era, enterprises in many industries have found that competitors seem to be springing up everywhere. These circumstances where failing to make continuous progress is the same as going backward have caused significant disruptions in usual market demand. Managers must have intense crisis consciousness and must gather facts concerning the actual situation to acquire the "three truths of management": (1) Seeing the actual location; (2) observing the actual matters; and (3) grasping the actual situation. Therefore, managers must maintain keen sensitivity and agile control capabilities to cope with fickle markets.

## **5. CONCLUDING REMARKS**

This paper addressed the vital research topic of how factory managers should gather a set of assessment criteria suitable for assessing inventory control proposals and determining key inventory control indicators. We used the AHP method to investigate key inventory control indicators at a manufacturer. The initial set of important influencing factors obtained from the investigation of the case company and interviews with experts included five major assessment dimensions and 15 assessment criteria. We then used an AHP expert questionnaire to perform an empirical survey. This paper made the following findings:

1. "Rolling customer demand forecast accuracy" is a key assessment dimension in evaluating inventory control proposals;
2. The most important five key inventory indicators consisted of "forecasting accuracy," "purchases in China," "PSI meeting," "skilled worker turnover rate," and "major changes in market demand."

Based on the finding of these five key indicators, we make the following practical recommendations:

- *Recommendations concerning forecasting accuracy:* Forecasting accuracy is the leading indicator used in inventory control. Therefore, we recommend that sales personnel stay in close contact with users to maintain accurate forecasts. Sales personnel must keep close ties with customers, understand their production needs, and grasp market changes. Another recommendation is that managers use the marketing 6-level funnel concept to understand which of the six stages the SKU of each product is in and regularly update its status.
- *Recommendations concerning purchases in China:* The Covid-19 pandemic has directed even greater attention to the need to shorten supply chains and has made importing materials from overseas a fatal weakness. In addition to the controls of goods and materials imposed by many countries, international shipping has become a more convenient proposition in the wake of the pandemic. We consequently recommend that the case company obtain supplies locally and develop nearby suppliers in China. This will shorten supply lead time and greatly increase the effectiveness of inventory reduction. Secondly, we also recommend that the company's key performance indicators include the accuracy of daily demand forecasts, the shortening of materials' lead times, the stability of the safety factor, and the feasibility of adjusting minimum orders. The use of these performance indicators will facilitate calculating the number of Kanban cards and assist with inventory reduction.
- *Recommendations concerning the PSI meeting:* By sharing information resources, the PSI meeting can serve as an effective cost-reduction process and reduce waste by dispelling misunderstandings concerning market demand. In particular, during times of considerable market fluctuations, the PSI meeting can be held more frequently to reflect the market mechanism promptly. Accordingly, we recommend that company's top executive host the PSI meeting. The participation of the top executive in the PSI meeting at the beginning of the month and the KPI summary at the end of the month will ensure that managers can compare actual output and sales with forecast values and thereby gain an up-to-date understanding of the company's operating status.
- *Recommendations concerning the skilled worker turnover rate:* Establishing a healthy corporate culture depends on talent cultivation. Skilled workers are the individuals who best understand the five elements of a company's corporate culture, namely safety, quality, delivery, inventory, and performance. We suggest that only a good corporate culture and effective institutional systems can retain the talented employees that a company needs to ensure its continued success. In addition, it takes many years of cultivation and cooperation to forge an effective corporate culture. Secondly, to put a company in a lasting position of growth, it must retain talented employees, which requires the transmission of positive practices and retention of those skilled workers who can help shape the corporate culture.
- *Recommendations concerning major changes in market demand:* Running a business requires a constant state of crisis consciousness. While customer loyalty is very important, suppliers must also maintain a high level of responsiveness and be ready to react to major changes and crises. We, therefore, recommend that corporate managers stay in touch with users and understand their situation. Secondly, the case company should strive to maintain its-leadership position in its industry, which will help it preserve its lead over competitors and followers. Furthermore, companies should actively develop new products to ensure that their industries keep up with global trends.

Lastly, this paper addresses the implications of our findings for business practice, academic research, and management.

- *Business practice:* After obtaining key inventory control indicators, personnel at Company S will better understand the importance and urgency of various courses of action and resolve problems at the most fundamental level. After realizing that the key to understanding whether inventory is excessive or insufficient lies in the accuracy of future demand forecasts, they will be more willing to participate in PSI meetings and will no longer consider these meetings to be a waste of time. Furthermore, personnel at the company will also realize that the TPS/lean management system is a tool that must be studied in order to be used effectively. Another insight is the possibility of increasing the inventory turnover rate as long as the availability of materials can be guaranteed. With the effective inventory control, the factory will not have to violate the sequence of operations on production orders due to shortages of materials, which will boost company-wide production efficiency. Furthermore, our findings concerning key inventory control indicators verified that the factory has indeed successfully reduced its inventory. In addition, personnel has begun using the AHP method to analyze ways of reducing inventory. Finally, we have shown that using TPS/lean management systems is necessary tool for modern business administration.
- *Academic research:* Our findings again verify the appeal of TPS/lean management and show the applicability of the Kanban management model to large companies, small enterprises, and all management situations involving inventory. Most corporate personnel cannot obtain the full benefit from Kanban management because they have not done the necessary preliminary tasks. The accuracy of the daily demand in the Kanban formula depends on gathering accurate forecasts at the PSI meeting. In addition, the cooperation of competent suppliers who should ideally be able to make deliveries in small batches from nearby sources, is needed to reduce lead time. The amount of safe inventory that must be kept on hand will be determined by both suppliers' delivery lead time and quality stability. Reducing the number of Kanban cards can therefore enable the reduction of total inventory. TPS/lean management includes many practical tools, and managers must be thoroughly acquainted with TPS/lean working methods and the synergistic linkage between these tools. As illustrated in this paper, efforts to reduce inventory must also reduce the "eight major forms of waste" in lean management, which will boost the company's overall efficiency.
- *Implications for management:* In actual business situations, excessive inventory will tie down funds, while insufficient inventory will lead to the shut-down of production lines for lack of materials. Therefore, a correct solution to this dilemma can significantly improve a company's inventory management. This paper showed that demand forecasting accuracy and the PSI meeting play complementary roles among key inventory control indicators and give managers a good grasp of their company's state of operations. Other necessary preconditions to effective inventory management include maintaining keen sensitivity to the market, systematic planning of machinery maintenance and allocation of the workforce by the production department, and, most importantly, effective logistics to support the supply of materials. Lastly, companies must constantly listen to their customers, be ready to meet customers' seasonal demands, and achieve the highest level of customer satisfaction to ensure customer loyalty. One notable finding that all experts affirmed was that apart from forecasting accuracy and the PSI meeting, the domestic procurement of supplies is also a major key factor. The ongoing Covid-19 pandemic, particularly, has highlighted the importance of local sourcing and logistics.

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