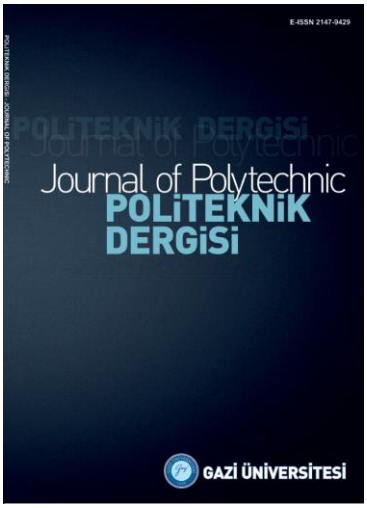

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AQL sampling plan proposal based on two-stage cluster sampling in production systems with high unit product amount

Birim ürün miktarı yüksek üretim sistemlerinde iki aşamalı küme örneklemesi temelli KKL örnekleme planı önerisi

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AQL Sampling Plan Proposal Based on Two-Stage Cluster Sampling in Production Systems with High Unit Product Amount

Highlights

- *A new AQL (Acceptance Quality Limit) approach has been introduced to the literature for use in production systems with high unit product quantities.*
- *For the first time, AQL has applied in two stages in production systems with high unit product quantities.*
- *Two important approaches have been developed for the AQL plan to be used in production systems with high unit product quantities, with case study application. It has been accepted that the first approach is the most appropriate approach for the business where the case study is applied.*
- *In the first proposed approach, 2 boxes have been selected from a pallet with a total of 7 boxes, determined according to the AQL value and according to the random selection method. From a total of 3.000 screws in these 2 boxes, 125 screws, determined according to their AQL value and selected according to the random selection method, have been examined. It has been determined that a total of 6 personnel are needed in this approach. The monthly cost of this transaction has been calculated to be 42.762 ₺.*

Graphical Abstract

In this study, a new model was developed to select samples according to AQL value in production systems with high unit product quantities. The flowchart of the study is shown in Figure 1.

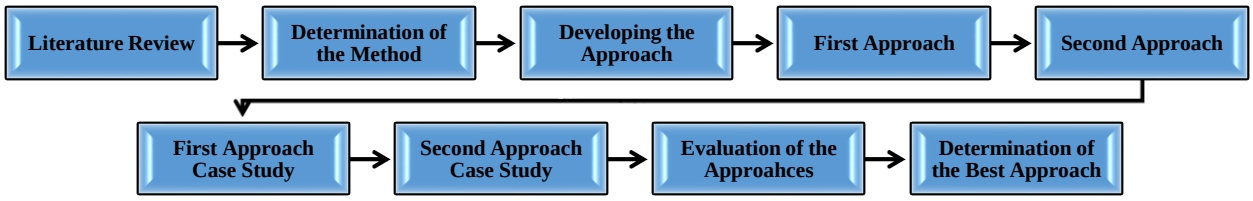

Figure. Application flowchart

Aim

The main purpose of this study is to ensure sample selection according to AQL value in production systems in the high unit product quantities. Subsequently, it is to ensure that the examination of these samples is carried out with the most appropriate number of workers, in the shortest time and at the most economical cost.

Design & Methodology

In the developed model in this study, two different sampling approaches were tested comparatively, based on the two-stage cluster sampling method approach. The application of the proposed model was carried out in a high-volume lots type bolt factory.

Originality

Studies on AQL in the literature have generally been conducted on systems that produce low unit product quantities. However, this study was conducted on systems that produce high unit product quantities. In addition, for the first time in the study, a two-stage AQL plan was developed for systems producing high unit product quantities. In addition to this two-stage AQL plan, two approaches have been developed that have been demonstrated in practice on case studies.

Findings

The case study was completed as a result of the some results and it was understood that the most logical approach was the first approach in terms of both time and personnel. As a result of the first approach to be applied, it has been determined that a total of six personnel are needed to work in two shifts. As a result of the monthly calculations we made with the sample study, it was determined that the monthly cost of the AQL unit was approximately 42,762 ₺.

Conclusion

Two new methodologies were determined by brainstorming and their suitability was tested on the same samples. As a result of the study, it was understood that the applicability of the first approach was better.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AQL Sampling Plan Proposal Based on Two-Stage Cluster Sampling in Production Systems with High Unit Product Amount

(Bu çalışma ICENSOS 2022 konferansında sunulmuştur. / This study was presented at ICENSOS 2022 conference.)

Araştırma Makalesi / Research Article

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ABSTRACT

In this study, a proposal has been developed aimed at the establishment of an AQL sampling plan in enterprises that produce lots type with a high number of unit products and group packaging. In the developed model, two different sampling approaches were tested comparatively, based on the two-stage cluster sampling method approach. The application of the proposed model was carried out in a high-volume lots type bolt factory. In the first approach, the boxes (clusters) to be sampled were determined based on the number of boxes in the determined lot. In the second stage, the sample amount was determined by calculating the AQL over the unit number of products in the randomly selected boxes and an equal amount of sample was taken from the selected boxes. In the second approach, the boxes to be sampled were determined again based on the number of boxes in the determined lot, and the sample amount to be taken from the determined boxes was calculated based on the number of unit products in the whole lot. Trials were made for the acceptance quality limits of 2,5, 4 and 6,5 for both approaches and the acceptance/rejection statuses were compared.

Anahtar Kelimeler: KKL (Kabuledilebilir-Kalite Limiti), iki-aşamalı küme örneklemesi, yüksek birim üretimi.

Birim Ürün Miktarı Yüksek Üretim Sistemlerinde İki Aşamalı Küme Örneklemesi Temelli KKL Örnekleme Planı Önerisi

ÖZ

Bu çalışmada, birim ürün adedi yüksek ve grup paketlemeli parti tipi üretim yapan işletmelerde KKL (Kabuledilebilir-Kalite Limiti) örnekleme planı oluşturulmasına yönelik bir öneri geliştirilmiştir. Geliştirilen modelde, iki aşamalı küme örnekleme yöntemi yaklaşımı temel alınarak iki farklı numune alma yaklaşımı karşılaştırmalı olarak test edilmiştir. Önerilen modelin uygulaması yüksek hacimli parti tipi üretim yapan bir cıvata fabrikasında gerçekleştirilmiştir. Birinci yaklaşımda, belirlenen partideki kutu adedi baz alınarak örneklem alınacak kutular (kümeler) belirlenmiştir. İkinci aşamada ise, rassal olarak seçilen kutulardaki birim ürün adedi üzerinden KKL hesaplaması yapılarak numune miktarı belirlenmiş ve seçilen kutulardan eşit miktarda örnek alınmıştır. İkinci yaklaşımda ise, yine belirlenen partideki kutu adedi baz alınarak örneklem alınacak kutular belirlenmiş olup belirlenen kutulardan alınacak numune miktarı partinin tamamındaki birim ürün adedi baz alınarak hesaplanmıştır. Her iki yaklaşım için 2,5, 4 ve 6.5 kabul kalite sınırları için denemeler yapılmış ve kabul/red durumları karşılaştırılmıştır.

Keywords: AQL (Acceptance Quality Limit), two-stage cluster sampling, high unit production.

1. INTRODUCTION

Businesses carry out final control activities to determine whether the products produced meet the features requested by the customer. When these controls require a destructive inspection, sampling methods are appealed. The standardized AQL method, which is used in many sectors and has certain levels of reliability, is also a sampling method widely preferred by customers. The AQL plan uses a number of probability theories to determine whether each of the products produced in large quantities meets the quality standards. In their study, Govindarajan and Bebbington [1] said that the AQL scheme was cost-effective for consumers with lower than optimal production quality levels. They also stated that it is also useful for consumers who make best quality and control mistakes. However, it is possible to state that the standards created according to the characteristics of the products and production systems may be insufficient. No study has been found on the application of the AQL method in production systems with very high lot sizes and grouped with boxes. When the AQL sampling plans, which is also prepared by the Turkish Standards Institute

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(TSE) and presented in standard form, are examined, it is seen that the calculations are made on the number of units.

In recent years, supply chain management (SCM) has been studied in detail and recognized as very important by supply chain members and academia. In SCM, sampling methods are used to protect the interests of both the producer and the consumer in product delivery. AQL plans can generally be divided into single sampling, double sampling, multiple sampling and other unique sampling plans, and AQL for each stage is determined by industry experience and customer standards. For example, the "MIL-STD-105E" AQL plan is generally used during the inspection phase of the product testing factories of the IC enterprise. In addition, AQL values at each stage generally vary according to the experience of the manufacturer or fixed values are given according to the characteristics of the production and product [2]. In this article, a two-stage cluster sampling method was applied in a high-volume and group-shaped bolt production company, and AQL was determined to meet the risks of both parties at the same time. While determining the sample size to be taken in this case study, the most appropriate minor, major and critical parameters were selected and the time and cost at this stage were calculated.

In today's industry, high quality products are produced thanks to statistical quality control (IQC) techniques. Also the quality of these products is a considerable competitive factor [3]. According to Montgomery [4], the quality of a product; should be considered as a whole in terms of durability, serviceability, performance, reliability, compliance with the desired quality and standards. On the one hand, product quality is of great importance for customers to purchase that product, on the other hand, it is an issue that manufacturers pay great attention to at all stages of production, from the delivery of the product to the final consumer [5]. Moreover, Gaspers [6], stated that the quality of manufactured products has different dimensions that can be used as a basis for strategic planning. He named them as performance, features, suitability, reliability, durability, serviceability, aesthetics, perceived quality. Quality control, is defined as the activities of using techniques to achieve the quality of a product or service, to maintain this quality and to improve it when necessary. In this context, the quality of products produced for delivery can be tested by an appropriate sampling method. Given the time and cost of testing all products, a sample taken with the right methods can directly indicate the discrepancy between expected and actual quality [6]. However, at this stage, the following should be noted: the sample taken involves the risk of not detecting every defective product in that lot. This risk is further increased by the excellent progress in production technology and the stringent control demands of customers. For this reason, the number of samples must be large in order to capture the real lot quality, especially in enterprises producing million units [9].

In this study, two different AQL approaches were created for large-volume samples. The implementation times of these two approaches, the required number of personnel and the general operating costs were also compared by conducting a work study. As a result of the analyzes made, it was evaluated that creating a sampling plan was more advantageous than the first approach. The main purpose of this study is to deliver the products to the customers by completing the AQL studies of the enterprises that produce high volumes with small volume products in the most accurate and fastest way. With this study, two new methodologies were developed for AQL and the applicability of the methodologies were compared within themselves.

In the continuation of the study, examples from the literature have been given and in-depth explanations and comparisons have been made about AQL. Subsequently, in the material and method section, the purpose of the study, AQL quality control points and error types have been mentioned. Then, data collection methods and approaches to be implemented in the AQL plan have been mentioned and these approaches have been applied in two case studies. At the end of the study, the data obtained as a result of the applications made with the mentioned approaches have been explained. Ultimately, it has been revealed which approach was most appropriate.

2. LITERATURE REVIEW

Defined Muhammad et al. [8] the sampling process as the evaluation of a few randomly taken products from any finished product. The sampling method is very important in deciding whether to accept the product based on the examination of samples taken from the whole, and the chosen method indicates how many items from the produced lot should be selected as samples. It specifies how many or how many defects are allowed in this example to please the producer and the consumer at the same time. This is called the AQL.

Considered Fallahnezhad and Qazvini [9] the control of raw materials, semi-finished products or finished products as a dimension of quality assurance. They defined it as acceptance sampling when the control is carried out with the aim of accepting or rejecting a product by adhering to certain standards. Acceptance sampling plans are often used when product testing is devastating, 100% inspection costs expensive, 100% inspection is time consuming, and product volume is very large [10]. Sampling methods satisfy both buyers and seller's curiosity about the quality of the product in advance. However, if it is not checked 100%, it is inevitable that defective products will be accepted or intact products will be rejected. A well-designed sampling method will drastically reduce the gap between what should be and what is a product [7].

In our study, two-stage cluster sampling method, one of the multi-stage sampling methods, was used. This method is a scalable cluster analysis algorithm designed

to process very large data sets. The most important features of this algorithm are; i) it can be applied in large data sets, ii) it can process categorical and continuous variables, iii) the items that do not fit with the obtained sets can be removed when desired Tkaczynski [9], and iv) it can automatically determine the most appropriate number of clusters [12]. In this method, it is important that the measurements of the variables included in clustering in clustering algorithms are categorical or metric. While some algorithms are applied only to metric variables, some algorithms are applied to categorical variables. However, it is also possible to have both metric measures and categorical variables in a group. This method is a hybrid clustering technique that is formed by combining the non-hierarchical clustering techniques "k Means" and the hierarchical techniques "Ward's Smallest Variance". Compared to classical clustering algorithms, the two-stage cluster sampling method has found application by many researchers from different disciplines, as it provides more qualified categories [13]. In this method, sampling units are selected in two steps. At the first stage, the universe is divided into clusters (*K*) that are homogeneous among themselves, but heterogeneous within themselves. The reason for this is to ensure that each cluster is able to represent the universe. These clusters created are called primary sampling units. Then, fewer clusters are selected from the primary sampling units created by the simple random sampling method. These units are called secondary or final sampling units [14]. This situation is briefly illustrated in Figure 2.

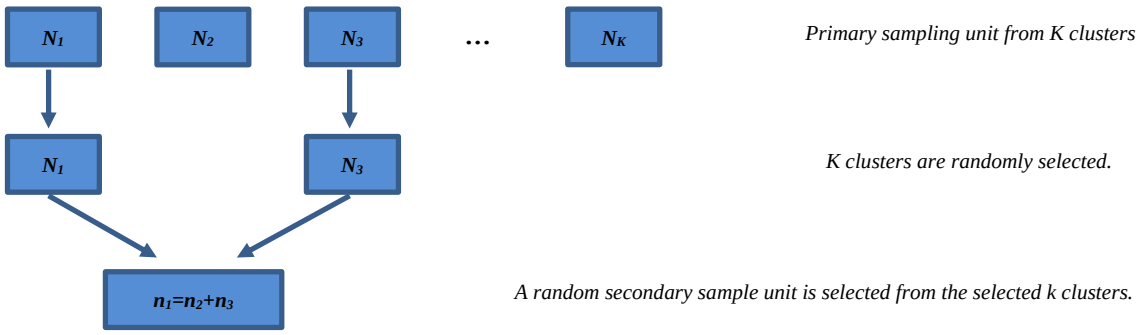

Figure 2. Two-stage cluster sampling method

The repeated sampling method, in which the acceptance or rejection of a product group is dependent on the results of repeated samples of the same lot, was introduced by Stephens and Dodge [15]. First, Soundararajan and Ramaswamy [16] used different sample sizes in the repeated sampling method, when control was normal and intensively required. The procedures and detailed tables required for the application and selection of this method are given by Rivest et al. [17]. Used Choi et al. [18] a two-stage sampling method in their study. They wanted to estimate the size of deer populations in Southern Quebec. However, they realized that it is impossible to learn the exact number of deer due to the dense forest cover of the deer rows. To overcome this problem, they used two-stage sampling method. In the first stage, they searched for aircraft in accordance with the stratified sampling plan. In the second stage, they made a helicopter search in an area where there are many deer with varying probabilities. To arrive at the number of results, they used a regression of the number of deer detected in the helicopter search with the variables measured during the aircraft search. Namvar et al. [19] studied the two-stage clustering method for multihop wireless sensor networks in their work. They have achieved significant energy savings through the new clustering configuration provided by the two-stage clustering method. Used Çetin and Irmak [20] the two-stage clustering method to categorize bank customers according to demographic information such as education level, age, and occupation. Arı et al. [21] used two-stage clustering analysis in their study to determine the perceptions of security and risk in electronic shopping by academics from 40 different universities. As a result of the cluster analysis, they concluded that the participants gathered in 4 different clusters according to their risk perceptions. Ishak and Zalukhu [22] used the two-stage clustering method in their study to examine the performances of the financial ratios determined from the publicly available financial statements of 90 companies traded in “Borsa Istanbul” (BIST).

Some studies related to the sector in which the study was implemented are as follows; In a study conducted by Syaefulloh et al. [23], although the percentage of defects was determined as +5% in a company that produces spare parts for metal bolts, nuts and rubber gaskets, they found an annual average defect percentage >13,72%. In order to overcome this problem, they performed a failure analysis for the necessary improvements by using the DMAIC (define, measure, analyze, improve, control) and FMEA (Failure Mode Effect and Analysis) methods and the six sigma approach. Found Ishakand and Zalukhu [22] an average defect percentage of 2.62% in an enterprise that produces high quality bolts, screws and spine nails, while the percentage of defects in the products produced was 2%. For the solution of this problem, they used the DMAIC method and the six sigma approach, and also the Multi-Attribute Failure Mode Analysis (MAFMA) method to find the root cause of the problem.

As a result of the literature research, it is seen that AQL applications are encountered very frequently in the literature. In addition, it is understood that many authors in the literature include the two-stage AQL application in their works and many businesses in their practices. However, it is considered that AQL applications and even two-stage AQL applications are not included in production systems with high unit product quantities.

3. MATERIALS AND METHOD

The materials and methods used during the study are explained in detail.

3.1. Purpose of Study

As a result of the internal inspections carried out in Tekno Fasteners Marketing and Trade Inc., which operates in the manufacturing sector, it was seen that there was no control mechanism after the packaging process, the quality control unit made the final inspection just before the packaging process and did not make any controls during and after the packaging process. It has been brought up whether the AQL method can be used in order to find faulty products that are overlooked in the final inspection, to detect rusted products due to waiting in the warehouse, and to increase customer satisfaction in particular.

Subsequently, the departments that will work for AQL in the fastener factory were determined as quality control and quality management departments, and AQL training was given to the relevant personnel. In the related training, what AQL is and how it is applied, a brainstorming was made on how to set up the AQL system to be applied in the company operating in the fasteners sector. As a result of this; It was understood that it would be difficult to apply AQL over lots, since the company works with high number of products, and it was decided to apply two-stage AQL in order to reduce the number of lots.

For two-stage AQL, two different approaches were determined and it was decided to try both to determine the suitability of these approaches. In the first approach, AQL was applied to the total number of products in the determined boxes by applying AQL to the total number of boxes on a pallet. In the second approach, AQL is applied to the total number of products in a pallet, AQL is applied to the total number of boxes, and samples are taken from the determined boxes according to the determined number of units.

It is aimed to determine the time to be spent, the number of required personnel and the cost by conducting a time study for these approaches. Before making AQL, the relevant control points were determined by asking the quality control side for which products to look at during the control.

Table 1. Control point and type of error

Type of Product	Control Point	Minor	Critical	Major
Screw	Head Diameter		+	
Screw-Bolt	Rivet Length			+
Screw-Bolt	Rivet Diameter			+
Screw-Bolt	Length			+
Screw-Bolt	Top Land		+	
Screw	End Control			+
Screw	Bits Control		+	
Screw	Stamp Thickness	+		
Screw-Bolt	Headroom	+		
Bolt-Nut	Wrench Flat			+
Bolt-Nut	Diagonal Length	+		
Nut	Thickness		+	
Nut	Bore Diameter		+	
Nut	Countersink Diameter			+
Nut	Valve Seat		+	
Nut	Flange Diameter		+	
Nut	Flange Wall Thickness		+	
Screw-Bolt-Nut	Surface Hardness			+
Screw	Pearcing Test			+
Screw	Ultimate Test			+
Screw	Calmping-Dismantling Test			+
Screw	Feeler Control		+	

Table 1 was created by grouping the controls related to brainstorming as minor, critical and major.

3.2. Methodology

Since there is no AQL used in production systems with high unit product quantity in the literature, the AQL tables values shown in Figure 3 and Figure 4, used in production systems with low unit product quantity, have been adapted to the new approach. This new approach is stated as two types of approaches in order to be alternative and comparable in practice. Both approaches were implemented in two stages due to the large amount of product. In the first stage of the first approach, the AQL table was looked at when selecting boxes from the pallet. Since there are 7 boxes in each pallet and 1.500 products in each box, 2 of them were selected according

to the AQL table. These boxes were chosen randomly. Since there were a total of 3.000 products in these 2 boxes selected in the second stage, 125 products were selected and checked by looking at the AQL table for the second time.

Lot Size	General Inspection Levels I	II	III	Special Inspection Levels S1	S2	S3	S4
2 to 8	A	A	B	A	A	A	A
9 to 15	A	B	C	A	A	A	A
16 to 25	B	C	D	A	A	B	B
26 to 50	C	D	E	A	B	B	C
51 to 90	C	E	F	B	B	C	C
91 to 150	D	F	G	B	B	C	D
151 to 280	E	G	H	B	C	D	E
281 to 500	F	H	J	B	C	D	E
501 to 1,200	G	J	K	C	C	E	F
1,201 to 3,200	H	K	L	C	D	E	G
3,201 to 10,000	J	L	M	C	D	F	G
10,001 to 35,000	K	M	N	C	D	F	H
35,001 to 150,000	L	N	P	D	E	G	J
150,001 to 500,000	M	P	Q	D	E	G	J
500,001 and over	N	Q	R	D	E	H	K

Figure 3: AQL values (sample size code letter)

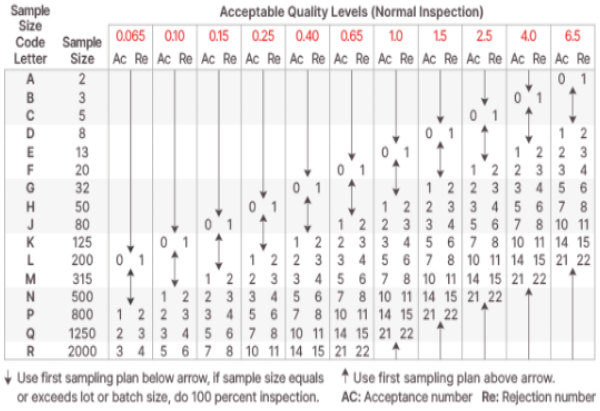

Figure 4: AQL values
(single sampling plans for normal inspections)

In the first stage of the second approach, since there are 7 boxes on each pallet and there are 10.500 products in total, 315 products need to be checked according to the AQL table. In the second stage, since 2 boxes had to be selected from 7 boxes according to the AQL table, 2 boxes were chosen randomly and 315 products taken from them were checked.

The study contributes to the literature by proposing a two-stage sample selection system for the first time in production systems with high unit product quantities. Subsequently, it is also important to introduce two new approaches to the literature after practically testing them in terms of the implementation of the AQL plan.

3.3. Data Collection

A time study was carried out by applying AQL to M12X1.75 DIN 934 10 KLT nuts, which are 7 boxes on 1 pallet selected as an example from the shipping section, over 2 determined approaches.

"TS ISO 2859-1 Sampling Methods for Inspection and Test-According to Qualitative Characteristics-Part 1: Lot by Lot -Indexed Sampling Programs Standard According to AQL for Lot Inspection" was used to determine the sample size and acceptance criteria used for the related study. The measurement was made by determining the normal from the control points determined as loose, normal and tight in the relevant standard.

3.3.1. Determining the boxes to be AQL on the specified palette

The first step for both approaches is to determine the number of boxes to be checked on the relevant pallet. The data included in the palette specified as an example are shown in the table below.

Table 2. AQL pallet information to be made

Number of Pallets	Number of Boxes in Pallet	Number of Nuts in Each Box	Total Number in Pallet
1	7	1.500	10.500

In the AQL, it was decided that the General Inspection 2,5 level would be checked as the control mechanism, and the boxes on the pallet containing the M12X1.75 DIN 934 10 KLT nuts were given numbers from 1 to 7 and boxes numbered 3 to 4 were determined by the method of choosing the number from the bag. The acceptance and rejection rates for the relevant selection at the 2,5 control level are as follows.

Table 3. Determination of boxes for AQL

First Approach First Stage	Sample Size	General Inspection Level (II) Preferred	Sample Size	Accepted	Reject	Total Number of Products in Boxes	Control Ratio
Selected Status	7	A	2	0	1	0	2,5

3.3.2. First approach AQL application

The first AQL is applied over the number of boxes on the pallet to be AQL. At this stage, the number of boxes to be opened is found as the sample size. In the second stage, the second AQL is applied to the total number of boxes determined in the first stage. It is determined how many samples will be taken from each box by dividing the number of boxes found in the result of the second AQL by the number of boxes found in the result of the first AQL. Table 3 shows the calculation in the first stage and it was determined that two boxes out of seven should be checked. There are 1.500 products in each of the boxes in which the relevant product is placed. The final number of products to be controlled is determined by applying the second AQL to 3000, which is the total number of products in the two boxes determined in the first stage. In Table 4, the sample size was determined as a result of the application of the second step.

Table 4. Determination of product quantities for AQL

First Approach Second Stage	Sample Size	General Inspection Level (II) Preferred	Sample Size	Accepted	Reject	Total Number of Products in Boxes	Control Ratio
Selected Status	3.000	K	125	7	8	63	2,5

As a result of the calculation made in Table 4, it was decided that 63 products should be checked in each of the two selected boxes, and a total of 126 products were checked. The control methods determined for the two selected boxes and the number of defective products are shown in the Table 5.

Table 5. First approach- first box and second box sample measurement results

Box	Thickness	Wrench Flat	Diagonal Length	Bore Diameter	Go Gage	No Go Gage	Total Number of Faulty Products
First Box	1	0	0	0	2	6	9
Second Box	0	0	0	1	1	2	4

If the relevant measurements are not stopped when the rejection rate is reached and are made until the end, the time spent will be like Table 6.

Table 6. Time spent for first approach (125 products)

First Approach	First Box (Seconds)	Second Box (Seconds)	Box Selection/ Product Selection Phase (Seconds)	Total Time (Seconds)	Total Minutes
125 Products	795	693	165	1.653	28

If the 8 error is found for the AQL to be made in the first case, the relevant pallet will be rejected. If the work was stopped when the eighth error was reached, the work on the 43rd product should be finished. In this case, the time spent will be as Table 7.

Table 7. Time spent for first approach (43rd product)

First Approach	First Box (Seconds)	Second Box (Seconds)	Box Selection/ Product Selection Phase (Seconds)	Total Time (Seconds)	Total Minutes
43rd Product	543	473	165	1.180	20

When the Table-6 and Table-7 are examined, 28 minutes will be spent for the all product and 20 minutes spent until the 43rd product.

3.3.3. Second approach AQL application

In this approach, the first stage of AQL is determined based on the total number of products on the pallet that is planned to be AQL. The determined sample size is divided by the number of boxes in which AQL is applied, and it is determined how many products will be examined in each box. There are a total of 10.500 products on the pallet determined as an example. When 10.500 items were checked in the related AQL table, it was seen that a total of 315 products should be checked. The related study is shown in Table 8.

Table 8. Determination of product quantities for AQL

Second Approach First Stage	Sample Size Number of Products Taken	General Inspection Level (II) Preferred	Sample Size	Accepted	Reject	Quantity to Checked in Each Box	Control Ratio
Selected Status	10.500	M	315	14	15	158	2,5

Table 8 shows the calculation in the second stage, and it was determined that two boxes out of seven should be checked. In this case, it was concluded that 315 items were divided into two boxes and 158 items from each box should be checked. The control methods determined for the 2 selected boxes and the number of defective products are presented Table 9.

Table 9. Second approach- first box and second box sample measurement results

Box	Thickness	Wrench Flat	Diagonal Length	Bore Diameter	Go Gage	No Go Gage	Total Number of Faulty Products
Box 1	1	0	0	0	3	13	17
Box 2	0	0	0	1	1	7	9

If the relevant measurements are not stopped when the rejection rate is reached and are made until the end, the time to be spent is shown in Table 10.

Table 10. Time spent for second approach (315 products)

Second Approach	Box 1 (Seconds)	Box 2 (Seconds)	Box Selection/ Product Selection Phase (Seconds)	Total Time (Seconds)	Total Minutes
315 Product	1.893	2.223	413	4.529	75

If the fifteenth error is found for the AQL to be made in the first case, the relevant pallet will be rejected. For example, if the work is stopped when the fifteenth error is reached, the work must be completed on the 115th product. The time to be spent in this case is shown in Table 11.

Table 11. Time spent for second approach (115th product)

Second Approach	Box 1 (Seconds)	Box 2 (Seconds)	Box Selection/Product Selection Phase (Seconds)	Total Time (Seconds)	Total Minutes
115th Product	1.378	1.618	413	3.409	57

When the Table-10 and Table-11 are examined, 75 minutes will be spent for the all product and 57 minutes spent until the 115th product.

4. RESULTS AND DISCUSSION

4.1. One Week Sample AQL Case Study

A weekly shipping list was requested from the shipping department. It has been calculated how much time will be spent if AQL is applied to all of the products in the received list (except for products with bags). Trial AQL studies were carried out by a two-person team. It is determined how long the two-person team will spend for a one-week shipment. Since it is not known when the relevant rejection level will be reached, the calculation was calculated by considering the application of AQL to the entire sample size. Since the shipping unit works in two shifts, it is foreseen that the AQL department will work in two shifts.

4.2. For First Approach AQL Application

In the study, it was seen that each product was controlled in approximately 12 seconds. For each shipment, the number of products in a box was taken into account according to the KKL values table in Table 3 and Table 4. As a result of the quality control process, the time per process was calculated. By adding distribution times to this time, it was concluded that 6 people were required, keeping a total working time of 15 hours constant in the two-shift system. The results obtained in the application with two personnel are presented in Table 12.

Table 12. Number of personnel required for a weekly shipment with the first approach

Shift	Number of People	Total Number of Samples to Be Taken from Each Box	Duration (Hour)
1st	2	5.701	78
2nd	2	982	23
3rd	2	1.811	16
4th	2	4.928	52
5th	2	6.395	81
6th	2	63	1
Average	2	3.313	41,72
Average	6	3.313	15

It is foreseen that a total of six personnel will be needed for two shifts in the first case of AQL.

4.3. The Second Approach is for AQL Application

In the study, it was determined that each product was controlled in approximately 13 seconds. For each shipment, the number of products in a box was taken into account according to the AQL values table in Table 3 and Table 4. As a result of the quality control process, the time per process was calculated. By adding distribution times to this time, it was concluded that 9 people were required, keeping a total working time of 15 hours constant in the two-shift system. The results obtained in the application with two personnel are presented in Table 13.

Table 13. Number of personnel required for a weekly shipment with the second approach

Shift	Number of People	Total Number of Samples to Be Taken from Each Box	Duration (Hour)
1st	2	8.010	134
2nd	2	1.529	42
3rd	2	2.346	24
4th	2	6.559	87
5th	2	9.141	135
6th	2	100	2
Average	2	4.614	70,65
Average	9	4.614	15

In the second case, it is foreseen that a total of nine personnel are needed for two shifts in AQL.

4.4. Cost Calculation for AQL

In this section, the necessary personnel for the AQL application and the opening circle (the boxes are placed on the pallets after they pass to the shipping section) and the cost for the box are calculated. The relevant calculation was made over a one-week sample shipment. The cost items and the total cost that emerged as a result of the study are shown in Table 14.

Table 14. Total cost for AQL implementation

Expense Item	Price	Quantity Used in One Week	Amount of Boxes in One Week	Amount of Damaged Boxes in One Week	Amount of Spent Product	Cost
Packing Tape (100 m)	8,85	140,5	7.359	1.505	28,73	254,29
Circle (3000 m)	377,6	3,5	7.359	1.505	0,72	270,28
Personnel	6.603,75	6	7.359	1.505	6,00	39.622,50
Total One Week Material Cost						524,58
Total One Month Material Cost						2.098,31
Packaging Reprocess Labor Cost						1.041,49
Total Monthly AQL Cost - ₺						42.762,29

The resulting cost applies in both cases. In this case, the cost of establishing the AQL system was determined as 42.76,29 ₺. The tools and space to be used by the personnel are not included in the relevant expense items.

5. CONCLUSION

A control level of 2,5 is used for AQL. The conditions in our AQL study according to the control level change are presented in Table 15.

Table 15. Acceptance/rejection measures by AQL levels

Level of Control	Acceptance (First Approach)	Rejection (First Approach)	Acceptance (Second Approach)	Rejection (Second Approach)
2,5	7	8	14	15
4	10	11	21	22
6,5	14	15	21	22

Acceptance/Rejection of the Trial by AQL Levels are presented in Table 16.

Table 16. Acceptance/rejection of the trial by AQL levels

Level of Control	First Approach	Second Approach
2,5	13	26
4	13	26
6,5	13	26

The case study was completed as a result of the above results and it was understood that the most logical approach was the first approach in terms of both time and personnel. As a result of the first approach to be applied, it has been determined that a total of six personnel are needed to work in two shifts. As a result of the monthly calculations we made with the sample study, it was determined that the monthly cost of the AQL unit was approximately 42.762 ₺. Our AQL study is a study aimed at increasing customer satisfaction. The contribution of the study will be understood as a result of the improvements to be made by detecting faulty products over time.

The aim of this study is to facilitate the application of the AQL method by the enterprises that produce small products in large volumes. For this, first of all, a literature review was made. However, in the results obtained, no studies were found for bolts, screws, nuts and similar small products. Two new methodologies were determined by brainstorming and their suitability was tested on the same samples. As a result of the study, it was understood that the applicability of the first methodology was better.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods they have used in their studies don't need any ethical committee permission and/or any legal-private permission.

AUTHORS' CONTRIBUTIONS

Mustafa DESTE: Performed the theoretical calculations and analyses.

Ezgi GÜNAYDIN: Controlled the calculations and wrote the article.

Aziz YURTTAŞ: Performed the theoretical calculations and analyses. Controlled and helped the writing and translating of the article.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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