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Stock Detection of Iron and Steel Products with Image Processing and SDSS Decision Support System

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Abstract

The iron and steel industry is one of the leading sectors contributing to the economic power of countries. It is incorporated into numerous fields, including automotive, construction, manufacturing, agriculture, defense, and healthcare. Today, the increasing supply and demand balance in iron and steel products makes the stock management and control of the products crucial. The large quantity and variety of products in the iron and steel industry make stock management and control difficult. Creating stock for the business is a very costly process and is one of the important elements of the business. Successful stock management can make the business financially advantageous. This study aims to estimate the stock costs of different products and quantities according to different dates found in the business by using data mining. For this purpose, data mining classifier models are used, and estimated costs are found. By establishing a stock tracking system throughout the supply chain, the business should register all inventory movements of the products. It should work in an integrated way with stock management costing. Thus, unforeseen decreases and financial losses in products can be detected.

The iron and steel sector, a key player in enhancing competition among nations and shaping the economic landscape, caters to the needs of various industries through its commitment to sustainable steel production. The industry has encountered challenges due to the swift advancements in recent years, impacting the costs associated with iron and steel products and posing issues for the sector. Tackling these challenges is essential for fostering national development and enhancing the competitiveness of businesses. This research delves into the elements influencing the expenses within the iron and steel industry, emphasizing the importance of minimizing factors leading to elevated costs. An automation system was developed using image processing techniques, and iron and steel products were analyzed. In the automation system, k-means and twostep, one of the clustering analysis methods, was applied.A decision support system defined as SDSS (Steel Decision Support System) and BIPS (Burak's Image Processing System)has been developed to determine the inventory costs of iron and steel products, adopting a data mining approach and including clustering methods to reveal similar inventory costs. Measurements with the SDSS-BIPS automation system were 94.4% successful. Withcost levels were determined by matching the products in the iron and steel business database with their costs.

Keywords: Iron-Steel, Product Stock , Data Mining, Forecasting, Cost Analysis, Image Processing, Optimization, Decision Support System.

1. Introduction

The iron and steel sector, which significantly accelerates the development of countries, provides inputs to many sectors. It is one of the leading sectors that increase the day of competition in the global economy and direct the economy. It forms the basis of products in many areas, such as industry, construction, automotive, agriculture, furniture, and defense. In addition, the Russian-Ukrainian war and the COVID-19 effect directly affected the iron and steel sector, causing fluctuations in production and sales volumes. Changes in product tracking and inventory cost levels are complicated to track. Especially with the increasing use of technology-based systems in enterprises, effective inventory tracking is one of the critical issues to be developed to increase enterprises' competitiveness.

World crude steel production has fluctuated continuously over the years. Crude steel production was 155 million tons in 2022, down 6.1% from 2021. China ranks first in crude steel production with 81.7 million tons in 2022, down 11.2% from 2021. India ranks second with 10.8 million tons, up 4.7%. Japan ranks third with a production of 7.8 million tons, down 2.1%. Turkey ranks eighth with aproduction of 3.2 million tons, down 7.8% [92].

With the increase in the volume of iron and steel production and consumption, analyzing inventory in real-time has become very important. Inventory is all the products with monetary value that are kept idle in the production process for the consumption of goods or

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services in the production and sales process [75]. In order for a product to be considered an inventory as an idle resource, it must first have an economic value. At the same time, idle stock represents the resource reserved for future decisions and actions [6]. Idle inventories hold goods and services being produced for sale to sustain economic activities and offer them for resale. Businesses use idle inventory to meet their sudden needs that may arise by storing their products and materials for future use and to maintain the process without interruption [12], [13], [29]. In addition to the products they produce and prepare for sale, businesses maintain inventories of materials, raw materials, semi-finished products, tools, and equipment needed for production and distribution. Therefore, creating inventory by a company is considered a very costly process [32], [68].

Effective implementation of inventory management processes is one of the most important tasks of business management. According to the company's stock targets and efficient stock management, it determines product and material stock levels following the production plan [30]. Successful inventory management and control minimize unanticipated decreases in sales and financial losses [95]. Excessive accumulation of products in inventory can slow down production, reduce storage space and stop new purchases, resulting in financial losses [43]. It also plays a vital role in weakening customer relationships, reducing productivity, and reducing the proportion of the company's investment in inventory. Therefore, in order to minimize the cost of holding inventory, companies need to determine the minimum level of inventory they should hold using data mining techniques. They should establish an inventory tracking system throughout the supply chain and record all inventory movements. In addition, inventory management should be integrated with cost accounting[4], [5], [65], [66], [84], [90].

In today's world, where technological and system-based production is developing daily, the iron and steel sector applications have made this sector a critical area due to the increasing demand rate. Data mining techniques are one of the techniques used in various fields. It enables the products to be included in the system faster, safer, and more efficiently [76]. These techniques, used in almost every area, are effective in developing new methods by integrating them in different sectors. Existing applications used in the iron and steel industry cannot meet the needs in many areas, such as determining inventory quantities, analyzing the characteristic information of products, and estimating production and sales quantities. Studies on these issues worldwide and in Turkey are very limited. The current study is expected to make a difference by raising awareness of the importance of data analysis in the industry.

Software programs are used to control inventory levels [35]. However, there are shortcomings in meeting user needs in software programs. At this point, advanced techniques such as image processing should be used to analyze inventory.

In this study, the counting process of iron and steel products was made by taking pictures of each product and product data were collected in detail in terms of width, height, weight, product type and production dates. The features of the products were determined by image processing, the amount of idle stock in the enterprise was determined by data mining in the application section, the financial values were calculated and a decision support system was established.

2. Related work

This section analyzes the research on image processing and decision support systems used in all sectors, especially in the iron and steel sector, from two aspects.

2.1. Image Processing

All the processes, such as identification, inspection, and combination of images obtained with the help of cameras, are called image processing [14], [41]. Image processing applications have significantly developed in recent years [37], [80]. It is widely used in many fields, especially in defense, security, industry, law, health, and agriculture [20], [23], [42], [48], [73], [89], [91]. In applications developed using image processing techniques, the process begins with the acquisition of images and ends with the analysis of the output [25], [27], [86].

With the increasing use of image processing applications, it is widely used in analyzing targets in the defense industry [7], [9], [10], [40], developing facial recognition systems in security cameras [52], investigating forensic cases [17], [53], analyzing products in industrial organizations[2], [11], [16], [22], [36], [55], [61], [94], developing medical devices in the field of health, making medical diagnoses [45], and analyzing products in the field of agricuture-grain [49], [67]. In these analyses, the attributes of the objects are determined by performing recognition, classification, and clustering operations [74], [77].

In the iron and steel sector, the use of image processing applications remains very limited due to the investment cost of the equipment, performance problems, the adoption of traditional methods, and the inability to eliminate user competencies [56], [78], [79]. With the system developed in this context, significant improvements such as ease of use, performance improvement, and increased quality are achieved.

2.2. Decision Support Systems

Decision support systems (DSS) ensure that the management processes of enterprises are more effective and efficient [24]. They help companies to adapt to competitive conditions and to increase their profitability levels, as well as to take a more advantageous position by predicting market conditions [62], [81], [93]. While this situation significantly benefits the iron and steel sector, it also contributes to the industry's sustainability [44], [64].Today, existing DSSs focus on production processes rather than the cost levels of products [21], [59], [60], [70], [71].Although DSSs provide different outputs with different variables according to their intended use, they do not include outputs related to cost levels, which is the basic need of the sector. Many variables affect the cost of products, such as market conditions, exchange rate parameters, and financial conditions. Thus, it will contribute to developing existing DSSs for the iron and steel sector.

Several decision support systems have been developed in the iron and steel industry for production, sales, inventory, quality, finance, and human resource management[1], [18], [57]. Other existing systems contribute to the sector's sustainability and help keep carbon emissions at optimal levels. However, since the techniques developed in the current systems do not work in integration and do not produce outputs—they cause various problems in the decision-making process. Nowadays, when business processes are getting faster and faster, output is of critical importance. At the same time, the developed systems should be easy to use [26], [50], [82]. In this context, DSS applications should be developed that enable fast and accurate processing of the data collected for the iron and steel sector, meet the needs, and contribute to the development of the sector.

2.3. Cost Analysis

In the 1980s, the concept of cost emerged due to the decline in profit rates with the rapid hardening of global competition conditions. In the 2000s, with the widespread use of technology and the increase in its use in production, the fact that the effect of universal elements on business costs is evident has created the concept of cost management (Karıcıoğlu, 2000). These developments have also had an impact on business decisions and caused the concept of cost management to change. The cost managed by accounting has made it difficult to make accurate decisions with the changes. Thus, it is seen that new approaches have been created and used by business managements.

Although the concept of cost management is broader in scope than cost accounting, based on the perspective of cost accounting, cost reporting is targeted, while cost management plays an active role in the planning and management of costs [15]. Cost management is a way of thinking, process and behavior created to obtain more return at lower cost [58]. With the implementation of cost management, it is the process of determining the main goals, objectives and needs. Cost management has an impact on today's business decisions and offers financial options for decision makers to make decisions [33], [34]. Cost management is an approach to measure the cost indicators and performances of both managers and decision makers while fulfilling short and long term planning and control processes (Karıcoğlu, 2000). Today, cost analysis is performed in many sectors [3], [8], [19], [28], [31], [38], [39], [46], [47], [51], [54], [69], [72], [85], [87], [88].

3. Proposed Solution

As in many other industries, market conditions in the iron and steel sector change rapidly. The profitability of companies that adapt to competitive conditions increases, and their foresight gains are high. Companies continuously monitor their inventory levels. In the stage of determining the main objectives of the study; various production facilities were examined, expert opinions were taken and swot analysis was carried out.

3.1. Strengths

- Performing stock analysis in the iron and steel industry with a high level of success,
- Real-time cost-market price comparison,
- Being superior in competitive conditions with a dynamic decision mechanism,
- Technological infrastructure,
- Obtaining a more flexible position against market conditions,
- Continuous monitoring of Production-Stock-Sales quantities,
- Examining stock information in detail,
- Business management with high technology and equipment,

3.2. Weaknesses

- High cost levels of iron and steel industry products,
- High financial expenses,
- Inability to adapt to market conditions due to inability to conduct cost analysis effectively,
- Low success level in determining stock quantities,
- Low awareness of research and development,
- Personnel prejudices hinder business processes.

3.3. Opportunities

- Advancement in the iron and steel industry,
- Low cost-maximum profit for businesses,
- It can be adopted and utilized in all heavy industries, particularly in the iron and steel sector.

3.4. Threads

- Reduced public and private contributions,
- Increased competition in the diffusion of technology,
- Misapplication of the system by users.

Image processing systems, data mining applications and decision support systems are analyzed to form the main framework of this study. Burak's Image Processing System (BIPS) conceptual framework for image processing system and Steel Decision Support System (SDSS) conceptual framework for decision support system were created. Within the scope of the developed system, literature research was conducted, existing systems were examined and the methodological approach of the study was established.

In the first stage of developing BIPS, the systems in the literature were analyzed and the model was developed. As a result of the examinations, a system that can meet the requirements of the sector was created. In this context, the infrastructure of the system was prepared, coded and tested. At the same time, opinions and recommendations were received from sector experts and the system design was organized accordingly.

While developing the SDSS system, systems in the literature were examined and a model was created. As a result of the research, a system was developed to meet the needs of the sector.

In the current study, BIPS automation system was developed using EmguCV, Aforce, and OpenCV libraries. The system was coded in Microsoft Visual Studio using

C# programming language. The system performs weight calculation by examining images of iron and steel products in real-time. In this direction, the cost levels are determined by comparing the costs of the products in the company database.

In the study, data collection and preparation processes, which are stages of data mining, have been conducted on product data. Outliers have been removed, and erroneous data have been corrected during the data preparation process. The data mining stages are illustrated in Figure 1.

In this context, the infrastructure of the SDSS system was prepared, coded and tested. The flow chart of BIPS and SDSS systems is given in Figure 2.

Figure 2 shows that in the BIPS system, the reference distance algorithm was first developed to minimize the error level in the measurements of iron and steel products in the warehouse and for maximum reliability. Thus, the distance between the product and the camera is given as input to the automation system and the thickness level of the product is determined. With the integration of the distance value into the system, the threshold value and radii variables can also be updated by the user. In this direction, RGB color levels are also updated by the user in order to control environmental factors such as light at the location of the product. Canny, one of the image processing methods, was used in the BIPS system. BIPS outputs were saved in the database. Data preparation processes, one of the data mining stages, were applied. The cost values in the financial records of the company were matched to each iron and steel package measured. At this point, the cost differences between the financial records and measurements are shown in Table 3. In the iron and steel industry, where traditional measurements are frequently used, differences are detected due to the high cost of each product. While 210 tons were determined by traditional measurement, 222 tons were measured in the BIPS system. In order to confirm the difference, the packages were weighed on the scale and the amount was determined to be 219 tons. All measurements were 94.4% successful. Management has confirmed the measurements and the cost differences arising from the measurement differences. Figure 3 shows the process. Due to the high financial value of the differences, businesses have difficulties in competitive conditions. Differences that business managements cannot detect cause them to fall behind their competitors in future production-sales strategy. With the developed BIPS system, it enables the determination of product dimensions and weights by image processing rather than the traditional method of determining product dimensions and weights. K-means and TwoStep cluster, which are data mining methods, were integrated into the SDSS system. Thus, it is ensured that the analysis of the products in the warehouse of the enterprise is carried out instantly and with a high level of success.

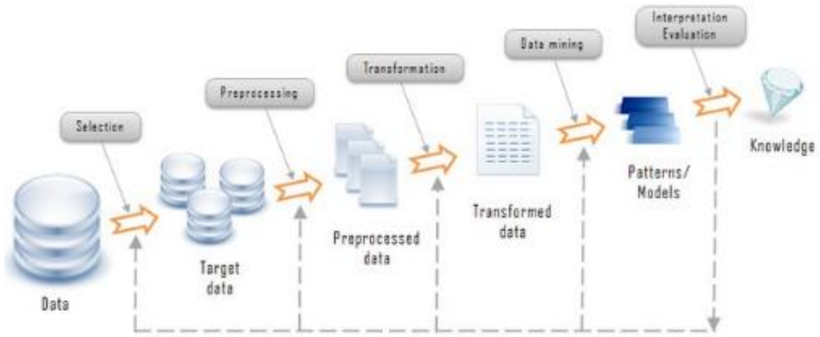

Figure 1. Data mining flow chart

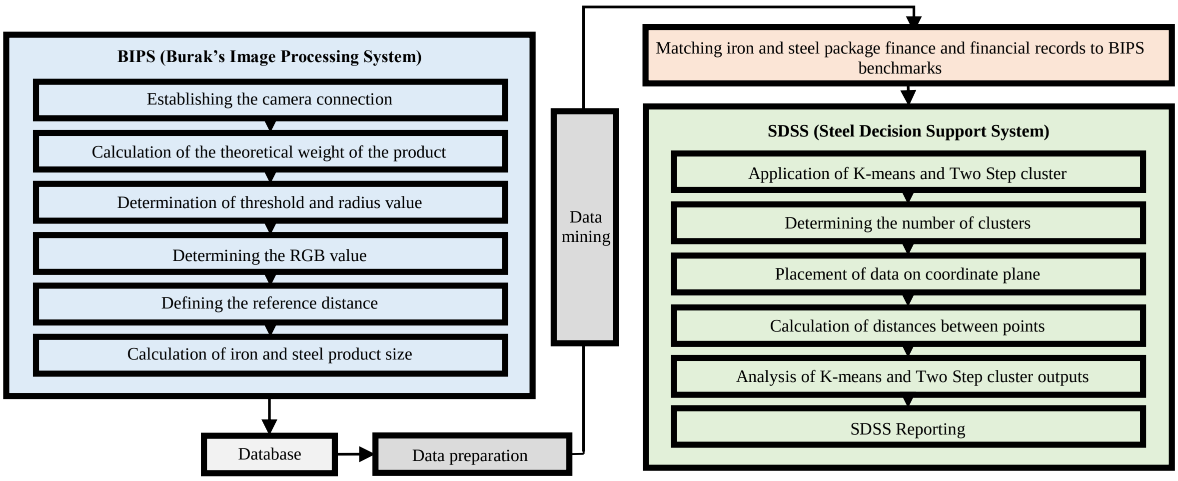

Figure 2. BIPS-SDSS systems flow chart

The system analyzes by applying filters and algorithms to images of iron and steel products in their environment with a high-resolution camera. The price level ranges of iron and steel products are defined in Table 1.

Table 1 presents the year-wise categorization of prices. The iron and steel product cost levels within the plant inventory were organized based on the information provided in Table 1. Figure 4 illustrates the model of the BIPS-SDSS automation system.

The applications were carried out without changing the location of the packages, saving energy, labor and resource utilization, which are the biggest costs for the enterprises. BIPS-SDSS automation was applied to each package in the current location of the iron and steel product as shown in Figure 5.

In BIPS-SDSS automation, the reference distance algorithm was first developed to minimize the error level in measuring iron and steel products in the company's warehouse and achieve maximum reliability. Thus, the distance between the product and the camera is given as input to the automation system, and the thickness level of the product is determined. By integrating the distance value into the system, the user can also update the threshold and radius variables. Similarly, the user also updates RGB color levels to control environmental factors such as light at the product location.

Each iron and steel bar processed in BIPS automation is measured independently, and the data is displayed as output to the user in the system. Following the storage of processed bars and the package image in the system, the k-means clustering technique, a data mining method, is implemented. The representation of the clustering panel is depicted in Figure 7.

Table 1. Iron and steel prices by year (Tonnage/USD) [83].

Years	Minimum Price (USD)	Median Price (USD)	Maximum Price (USD)
2014	493	549	605
2015	353	373	393
2016	485	507	529
2017	520	618	716
2018	369	506	643
2019	342	479	616
2020	608	692	776
2021	872	1553	2234
2022	470	913	1356

Figure 3. BIPS-SDSS systems application and control

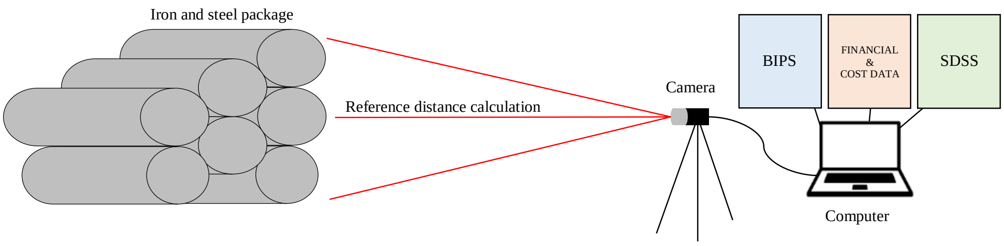

Figure 4. BIPS-SDSS automation system

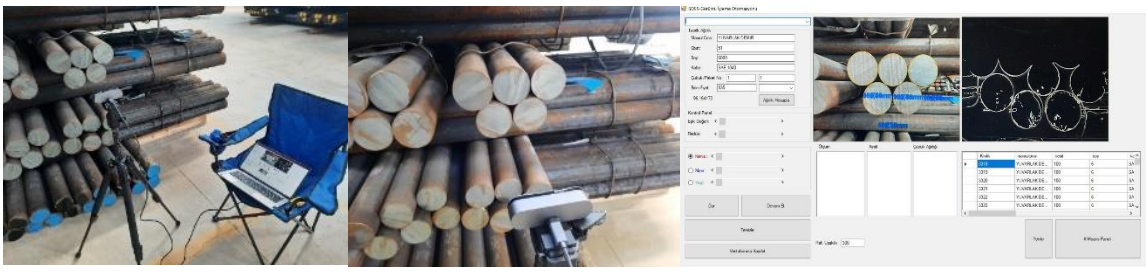

Figure 5. BIPS-SDSSapplication image

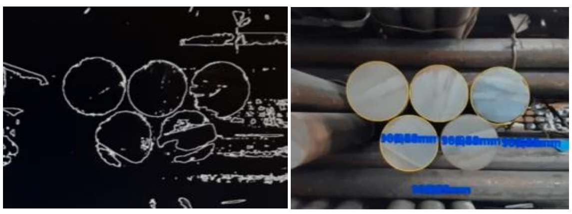

Figure 6. BIPSautomation outputs

As seen in Figure 6, measurements of iron and steel products have been conducted in their current positions. Despite environmental factors such as light, paint, rust, etc., measurements have been successfully carried out without moving the products from their current positions.

A screenshot of the results of K-means and TwoStep analysis for each packet processed in BIPS-SDSS automation is shown in Figure 8.

As a outcome of the clustering analysis, Table 2 displays the clusters and their respective members for K=3.

Table 2. Cluster members

Cluster Number	Cluster Members
1	40 mm, 42 mm, 50 mm, 60 mm, 75 mm, 90 mm, 100 mm
2	42 mm, 50 mm, 60 mm, 75 mm, 90 mm, 100 mm
3	40 mm, 42 mm, 50 mm, 60 mm, 75 mm, 90 mm, 100 mm

Table 2 reveals that product packages with similar cross-sectional dimensions are in different clusters because they have different cost levels.

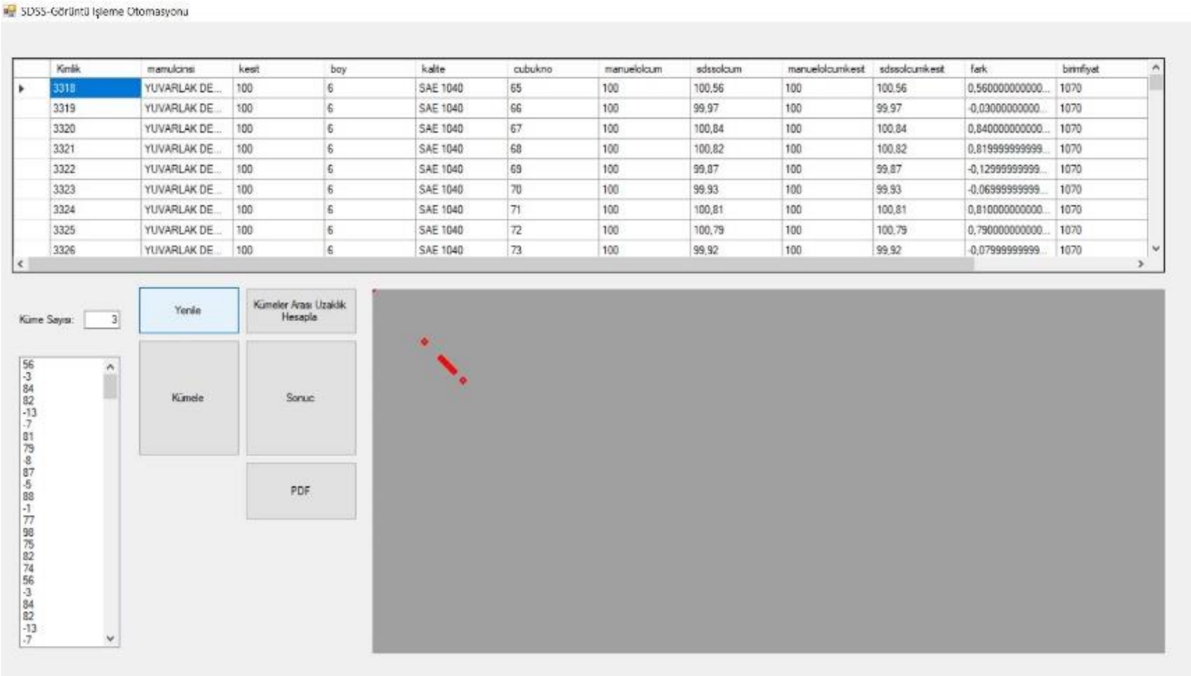

Figure 7. Clustering panel in decision support system

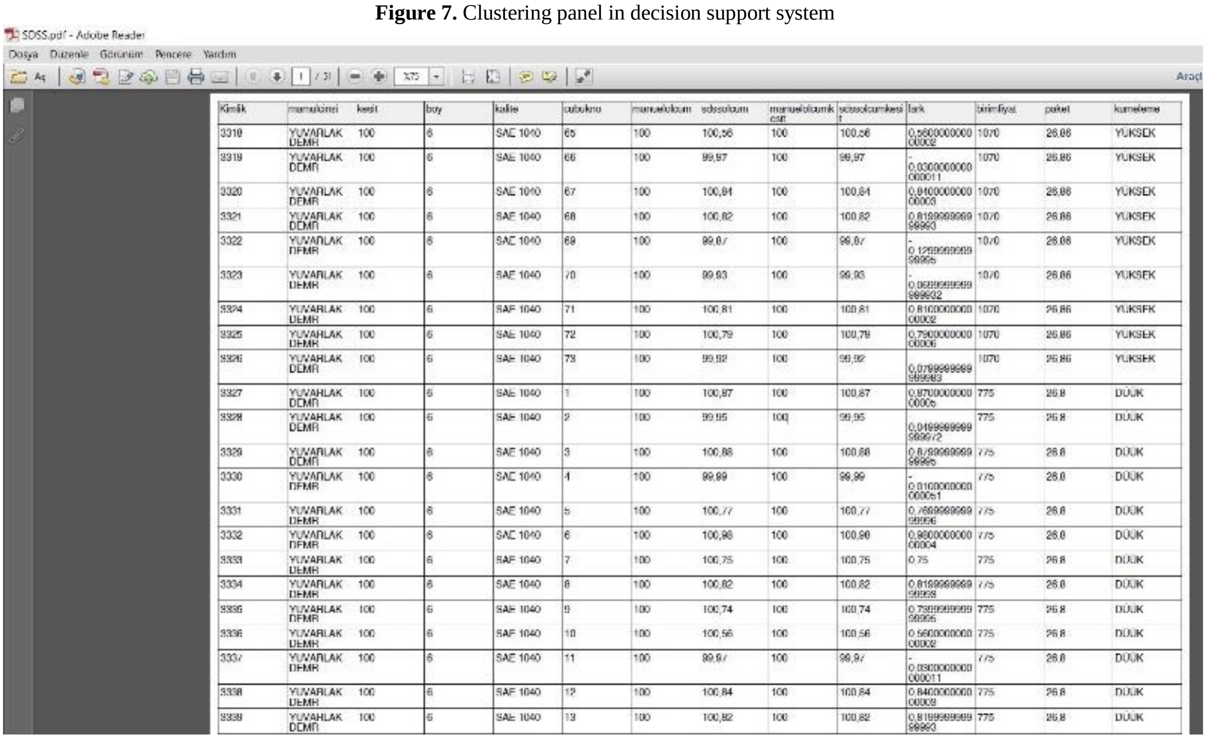

Figure 8. SDSS-BIPS analysis report

4. Findings

4.1. Descriptive Statistics

The round products with 19 different sizes analyzed in Table 3 were examined on 2684 bars in the study. Although the weight in stock for the specified products was 210 tons, it was calculated to be 222 tons due to the measurement.

Below is the information on products measured in Tablo 3 manually and in the BIPS-SDSS automation. Measurements were conducted on a total of 614 bars from 14 different product sections. While the manual measurement resulted in a weight of 210 tons, the BIPS-SDSS automation determined the weight to be 222 tons. To confirm the quantities, the respective packages were weighed on the operational scale, and the weight was determined to be 219 tons. Accordingly, it is understood that there is a measurement accuracy of 94.4%. The measurement difference resulted in a cost saving of 4841 USD in the company's stock.The relevant calculation is given in the difference cost (SDSS-ERP) section of table 3.

In this study, K-means and TwoStep cluster algorithms from clustering methods were used for analysis. The analysis utilized IBM SPSS 13.0 data mining software. The data mining procedures within IBM SPSS Modeler are structured in a data flow format. In this sequential flow, each process, represented by nodes, is interconnected by arrows. The examination was conducted on an inventory database, encompassing product records such as unit price, length, cross-section, number of packages, and the quantity of bars within the company's inventory over a specific timeframe. Expert opinions were sought during the variable selection process for product records, and an investigation into how inventory tracking is implemented in enterprises was conducted. The variables within the product records are itemized in Table 4.

Table 4. Customer and return eligibility records

Variables
Unit Cost
Length
Cross-Sectional Measurement (Manual)
Piece Weight (Manual)
Number of Packages
Number of Pieces
Piece No
Production Receipt Date
Cross-Sectional Measurement (SDSS)
Piece Weight (SDSS)
Cost level of the product
Unit Cost (SDSS/Tonnage)
Unit Cost (SDSS/Piece)
Unit cost difference (SDSS-Manual)

Table 3. Product data and measurement analysis

Size/MM	Erp Tonnage	Warehouse Tonnage	Number of Bars	Total Bars	Unit Weight	Measurement Quantity Result	Package Cost (USD)	Difference Cost (SDSS-ERP) (USD)	Measurement Weight Result
65 MM	9.440	9.440	12	60	157.333	9.565	583	73	159,416
75 MM	2.100	2.100	10	10	210.000	2.143	682	29	214,538
65 MM	800	800.000	7	6	114.290	809	540	4,86	153.830
60 MM	16.280	16.280	15	120	135.667	17.819	505	777	148.490
95 MM	2.000	2.000	6	6	333.333	2.076	601	46	345.995
55 MM	720	720	16	8	90.000	772	538	27,976	96.500
55 MM	1.380	1.380	18	9	153.333	1.397	750	13	155.200
50 MM	62.800	62.800	22	693	90.620	70.915	357	2.897	102.330
45 MM	55.120	55.120	26	702	78.519	55.408	708	204	78.930
45 MM	39.660	39.660	26	520	76.269	40.301	526	337	77.501
42 MM	2.180	2.180	30	60	36.333	2.223	550	24	37.043
32 MM	2.000	2.000	48	48	41.667	2.020	748	15	42.090
45 MM	2.220	2.220	26	26	85.385	2.288	709	48	87.993
29 MM	1.920	1.920	64	64	30.000	2.049	580	75	32.008
28 MM	1.960	1.960	63	63	31.111	2.078	618	73	32.992
24 MM	1.840	1.840	88	88	20.909	1.900	588	35	21.592
36 MM	3.920	3.920	42	84	46.667	3.957	664	25	47.104
32 MM	1.820	1.820	51	51	35.686	1.938	603	71	37.993
35 MM	2.340	2.340	44	66	35.455	2.443	650	67	37.008

4.2. Data Mining Clustering Findings

In the analysis, the factors affecting the inventory cost levels are determined as unit cost, length, manual measurement section, piece weight (manual), number of packages, piece no, production receipt date, cross-sectional measurement (SDSS), bar weight (SDSS), and cost of input (SDSS). The screenshot of the variables taken for the clustering method is given in Figure 9.

Descriptive statistics regarding the round products in the inventory of the iron and steel enterprise are shown in Figure 10.

Figure 10 shows that the average and deviation for the unit price variable is 932 USD and the standard deviation is +/- 142 USD for the 7517 records analyzed. It is seen that the average of the manual section measurement is 65 mm and the standard deviation is +/- 22 mm. It was determined that the SDSS cross-section measurement was 66 mm on average and the standard deviation was +/- 23 mm. While the bar weight was determined as 118 kg on average, its standard deviation was determined as +/- 13 kg. It is seen that the average number of packages is 10.

K-means and TwoStep clustering algorithms were compared in the clustering analysis of factors affecting inventory cost levels. The clustering comparisons are shown in Figure 11.

Figure 11 depicts that the silhoutte measure for K-means is 0.643, while it is 0.525 for Two Step. For both methods, the correlation between the actual and predicted values is close to 1, indicating a high prediction success [26].

The Silhouette Index was developed by Rousseuw in 1987 to determine whether each unit fits into the cluster in which it is located [63]. A Silhouette value nearing 1 suggests the attainment of the suitable cluster. The Silhouette index was employed to ascertain the optimal number of clusters. The ideal number of clusters identified for the analysis of 2684 bars across 19 distinct product groups was determined to be 3.

Field	Measurement	Values	Missing	Check	Role
BirimFiyat	Continuous	[775.0,1070.0]		None	Input
Boy	Continuous	[6.0,6.0]		None	Input
ManuelOlcumKesit	Continuous	[40.0,100.0]		None	Input
ManuelCubukAgirligi	Continuous	[59.232,370.2000000...		None	Input
PaketSayisi	Continuous	[6.544,11.040000000...		None	Input
CubukNo	Continuous	[1.0,444.0]		None	Input
MalGirisTarihi	Continuous	[2022-01-31,2023-01...		None	Input
SDSSOlcumKesit	Continuous	[39.87,100.98]		None	Input
SDSSCubukAgirligi	Continuous	[58.8476176379999...		None	Input
Kümeleme	Nominal	DUSUK,ORTA,YUKS...		None	Target
SDSSMaliyet (TON)	Continuous	[28.0593772628530...		None	Input
SDSSMaliyet (Çubuk)	Continuous	[0.06810594051251...		None	Input
SDSS-Manuel FiyatFarki	Continuous	[-0.98178212092362...		None	Input

Figure 9. Variables used for clustering method

1	BirimFiyat		Continuous	775	1,070	7,002,230	295	931.519	141.791	20,104.843	1.635	-0.086	0.028
2	Boy		Continuous	6	6	45,102	0	6	0	0	0		0.028
3	ManuelOlcumKesit		Continuous	40	100	493,352	60	65.632	22.877	523.385	0.264	0.263	0.028
4	ManuelCubukAgirligi		Continuous	59.232	370.2	1,344,308.889	310.968	178.836	116.91	13,668.043	1.348	0.466	0.028
5	PaketSayisi		Continuous	6.544	11.04	79,390.616	4.496	10.561	0.74	0.548	0.009	-4.067	0.028
6	CubukNo		Continuous	1	444	886,732	443	117.964	109.017	11,884.615	1.257	1.19	0.028
7	MalGirisTarihi		Continuous	2022-01-31	2023-01-10	--	344	--	--	--	--	--	--
8	SDSSOlcumKesit		Continuous	39.87	100.98	497,218.07	61.11	66.146	22.881	523.54	0.264	0.263	0.028
9	SDSSCubukAgirligi		Continuous	58.848	377.491	1,363,217.791	318.644	181.351	117.797	13,876.028	1.359	0.465	0.028
10	Kümeleme		Nominal	--	--	--	--	--	--	--	--	--	--
11	SDSSMaliyet (TON)		Continuous	28.059	54.315	266,144.532	26.255	35.408	5.92	35.047	0.068	0.348	0.028
12	SDSSMaliyet (Çubuk)		Continuous	0.068	1.021	1,810.342	0.953	0.241	0.168	0.028	0.002	1.119	0.028
13	SDSS-Manuel FiyatFarki		Continuous	-0.962	7.442	5,558.979	8.424	0.74	1.08	1.167	0.012	1.652	0.028

Figure 10. Screenshot of descriptive statistics results

Sort by: Use   (•) Ascending   ( ) Descending   Delete Unused Models   View: Training set

Use?	Graph	Model	Build Time (mins)	Silhouette	Number of Clusters	Smallest Cluster (N)	Smallest Cluster (%)	Largest Cluster (N)	Largest Cluster (%)	Smallest/ Largest	Importance
☑		K-means 1	< 1	0.643	5	177	2	2780	36	0.064	1.0
☐		TwoStep 1	< 1	0.525	2	2664	35	4853	64	0.549	0.198

Figure 11. Performance comparison of clustering methods

4.2.1. K-Means Clustering Analysis

K-means was formulated by MacQueen in 1976. It is a non-hierarchical unsupervised algorithm that classifies a given dataset into a specific number of discrete clusters. The K-means algorithm randomly chooses k values to serve as the initial cluster points.It takes each point in the dataset and associates it with the nearest center point using Euclidean distance. Once the distance measurement of all the data is complete, the k value is recalculated. The process continues until the iteration, where the k-value does not vary [82]. The results of the k-means analysis are presented in Figure 12.

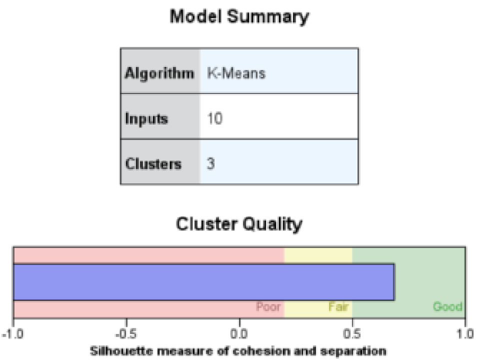

Figure 12. K-Means model success

Figure 12 reveals that the clustering success is 0.7. It was noticeable that ten different variables that affect the clustering result are divided into three different clusters. The clusters are cluster-1 49.4%, cluster-2 28.5%, and cluster-3 22%. The cluster information is detailed in Figure 13.

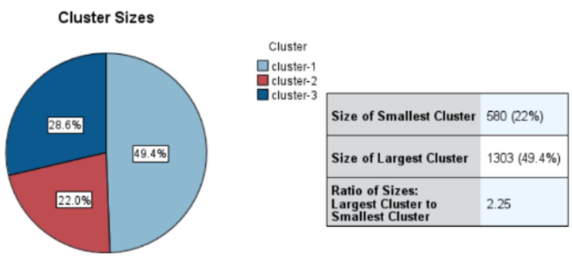

Figure 13. K-Cluster result screenshot

In Figure 13, the products have been divided into 3 clusters. The size of the smallest cluster is determined to be 580, while the size of the largest cluster is 1303. The clustering rate is calculated as 2.25 using the K-means method.

4.2.2. TwoStep Cluster Analysis

The TwoStep method was developed by Punj and Steward in 1983. TwoStep uses a distance measure to categorize the data in the dataset into groups and uses a hybrid method to select the most appropriate subgroup model (Benassi et al. 2020). The outcomes of the TwoStep analysis are depicted in Figure 14.

Figure 14 indicates that the clustering success is 0.5. Ten different variables affecting the clustering result were observed to be divided into three different clusters. The clusters are cluster-1 36.7%, cluster-2 34.1%, and cluster-3 29.2%. The cluster information is listed in Figure 15.

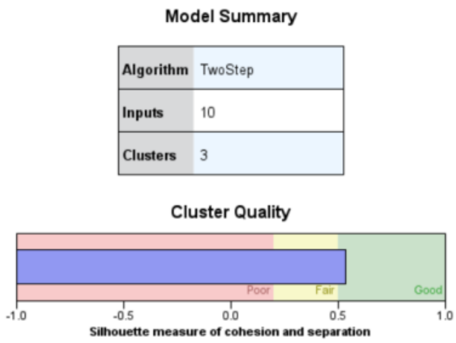

Figure 14. TwoStep model success

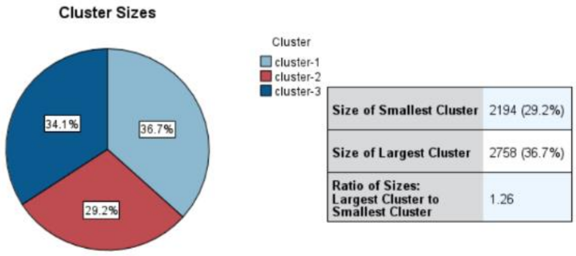

Figure 15. TwoStep result screenshot

In Figure 15, the products have been grouped into 3 clusters. The size of the smallest cluster is determined to be 2194, while the size of the largest cluster is 2758. The clustering rate is calculated as 1.26 using the TwoStep method.

5. Conclusion

The volume of crude steel production and consumption, one of the essential inputs of national economies, is constantly increasing. Turkey ranks within the top 10 countries globally in both crude steel production and consumption.

It is necessary to produce more value-added products in order to increase the ranking of Turkish steel in the world steel sector to higher levels and thus increase the competitiveness of companies. In the competitive environment, companies must make decisions and measures for future periods to maintain their existence. For these actions and decisions, companies use forecasting studies to measure their situation in the sector.

It has been decided that in order to manage business inventories more effectively, companies should establish an inventory management mechanism, make unique plans for the sale of idle inventories, utilize business resources more effectively, and convert inventories into business financial resources more quickly. It is anticipated that by leveraging information in this manner, the input costs for iron and steel enterprises in Turkey will decrease, leading to an increase in production volume and overall business scale.

The increase of crude steel production in the world and Turkey brings many problems, such as the need to increase the share of companies allocated to steel capital, to provide financial returns of the products very quickly, and to use the products in stock effectively. It is necessary to develop solution proposals using data mining techniques to overcome these problems and take measures to solve the analyses. Consequently, an elevation in customer satisfaction is anticipated, and there will be an improvement in product quality standards due to heightened competition among enterprises.

More effective inventory cost control and inventory management processes in iron and steel products are essential in terms of the cost of products produced and expenses incurred, pricing, and decision-making policies. Companies should plan and control their priorities according to inventory cost analysis. In addition, considering the continuity principle in inventory cost analysis, production needs should be determined in advance, and new sales strategies should be developed for products with low sales volume. The inventory forecasting results generated by the model need to be reported to the sales and production units of the enterprise.

In this research, the enumeration of iron and steel products was conducted by capturing images of each product, and comprehensive product data were gathered, including width, height, weight, product type, and production dates. Product features were identified through image processing, and the surplus stock within the enterprise was quantified using data mining in the practical segment. Financial values were computed, leading to the establishment of a decision support system.

BIPS automation system was developed using EmguCV and OpenCV libraries. The system was coded in Microsoft Visual Studio using C# programming language. The system calculates weights by analyzing real-time images of iron and steel products. Consequently, cost levels are established by comparing the costs of the products with those in the company's database. Measurements were carried out on a collective of 614 bars spanning 14 distinct product sections. The manual measurement registered a weight of 210 tons, whereas the BIPS-SDSS automation recorded the weight as 222 tons. The measurements executed through BIPS-SDSS automation demonstrated a success rate of 94.4%. The disparity in measurements translated into a cost reduction of 4841 USD in the company's stock. While the clustering quality is calculated as 0.7 with the K-means method, it is determined as 0.5 with the TwoStep method.

This article focuses on using BIPS and SDSS (Steel Decision Support System) as new methods for identifying and clustering inventory quantities in determining inventory costs of iron and steel products.SDSS, which enables iron and steel companies to monitor their inventory levels continuously and has been developed in this direction, can instantly monitor the inventory levels of companies and determine the actual weights of products. SDSS has enabled more precise and accurate calculation of product costs and made business decisions more reliable.

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.

Data availability

No data was used for the research described in the article.

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