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Importance of Material Procurement Processes and Domestication Studies in the Manufacturing Industry: The Case of Domestication of the Secondary Brake System Resistor of a Rock Truck

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Abstract

The machinery manufacturing sector is one of the most strategic industrial sectors in the Turkish economy, playing a vital role in manufacturing by providing industrial support, employment, and economic value. However, the heavy dependence on imported critical components in machine and equipment production increases the foreign trade deficit and highlights the importance of localization efforts. This study examines the effects of material procurement processes and localization strategies in the manufacturing industry. Focusing on the localization of the secondary braking system (retarder) resistor used in rock trucks, the study first analyzes procurement procedures and engineering decision-making mechanisms. It then evaluates the technical and economic advantages of domestic production. The study found that transitioning the imported retarder resistor to local manufacturing provided significant economic and logistical advantages, including an 85% cost reduction and a drastic improvement in delivery time. These findings demonstrate that the effective implementation of localization policies in the industry can enhance competitiveness by reducing production costs and improving procurement lead times.

Keywords: Industrial policies, Localization strategies, Machinery manufacturing, Material procurement processes, Retarder resistor.

1. Introduction

The machinery manufacturing sector is one of the most important industrial branches of the Turkish economy and holds a strategic position within the manufacturing industry. This sector serves as a cornerstone of economic development by providing essential support to other industries, generating employment, and creating significant added value. However, the heavy dependence on imported critical components in machinery manufacturing increases the foreign trade deficit, emphasizing the importance of localization efforts [1-6].

According to data from the Ministry of Industry and Technology, the total imported input density in the machinery sector is 33.83%, meaning that approximately 34 TL of imported inputs are used in the production of every 100 TL worth of machinery [1,3]. Of these imported inputs, around 21 TL is directly supplied by the machinery sector, while the remaining 13 TL come from other industrial branches. As of 2023, Türkiye's total machinery exports reached 28.1 billion USD, whereas machinery imports exceeded 32 billion USD during the same period, indicating that Türkiye remains a net importer of machinery. The development of the machinery industry in Türkiye has been a focal point of industrialization policies since the 1980s and has been further supported by a growing foreign trade volume in the 2000s. However, the sector's continued dependence on imports remains one of the major obstacles to its large-scale advancement [4,5,7,8]. Supporting domestic industry requires an integrated strategy that includes increased R&D and technology investments, financial incentives, and strategic government policies [6]. The effective implementation of localization policies not only improves raw material procurement processes but also offers environmental and economic benefits.

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Considering Türkiye's manufacturing industry exports, 31.6% consists of low-technology, 32.1% of medium-low technology, 31.7% of medium-high technology, and only 4.6% of high-technology products [9]. The low share of high-technology production weakens the industry's global competitiveness and heightens its dependence on imported high-tech products.

In recent years, the growing prominence of Industry 4.0 and digitalization in the manufacturing sector has underscored the importance of advanced material technologies, smart production systems, and efficient supply chain management in localization efforts [5]. However, localization remains crucial, particularly for low- to medium-high-technology materials, components, machinery, and systems. Engineers play a pivotal role in this process. This study aims to provide a comprehensive analysis for engineers by examining the impact of material procurement processes and localization strategies in the manufacturing industry, using the localization of a rock truck's secondary brake system resistor as a case study.

2. Material Procurement Processes

Material supply processes play a critical role in ensuring the continuity of the manufacturing industry and in optimizing operational costs [5,10,11]. In the machinery manufacturing sector, effective supply chain management ensures both quality and cost control in accessing raw materials and producing end products. Procurement processes often require the acquisition of various machine elements, each serving a specific role in ensuring the functionality, durability, and safety of engineered systems.

Table 1 categorizes key machine elements typically procured in sectors such as manufacturing, mining, energy, and metal production, along with their primary characteristics and procurement considerations. The preparation phase for the procurement of machine elements involves rigorous planning and analysis to ensure compliance with project requirements, cost-effectiveness, and on-time delivery. This phase encompasses several critical steps, each designed to mitigate risks and optimize procurement outcomes [12–18]: Needs assessment, market research, budget planning, risk assessment, and documentation and tender preparation. Figure 1 summarizes these steps.

Needs assessment is the first step in preparing for the procurement of a machine element, requiring an accurate determination of the project's requirements. The process begins with defining the operational role of the machine element, namely its functional requirements. For example, bearings used to support rotating shafts in turbines or conveyor systems; gears used to transmit torque in mining equipment. The working environment also plays a crucial role in procurement decisions: High-temperature furnaces in metal production require fasteners and bearings with high thermal resistance and durability; wind turbine gearboxes in the energy sector require corrosion-resistant components due to exposure to salt-laden air in coastal environments. The final step of the needs assessment is analyzing the compatibility of the component with existing systems and components. For example, in mining operations, hydraulic pumps must be compatible with the specifications of existing hydraulic systems to avoid pressure mismatches or performance issues.

Table 1. Commonly supplied machine elements and examples of the sectors in which they are used.

Category	Examples	Primary Sectors
Bearings	Ball, roller and thrust bearings	Mining, Manufacturing, Energy
Fasteners	Bolts, screws, rivets	Construction, Automotive
Gears	Spur, helical, bevel gears	Mining, Robotics, Energy
Welding and cutting	Electrodes, TIG/MIG machines	Manufacturing, Repair
Hydraulic and pneumatic	Cylinders, valves, pumps	Metal production, mining
Electrical and electronic	Motors, sensors, controllers	Energy, automated Systems

Figure 1. Key milestones of machine components procurement processes.

A clear understanding of market alternatives is essential for identifying the most suitable suppliers and technologies. In planning the procurement of machine components, it is important to research developments in materials and production technologies, contact suppliers specialized in machine components, and compare potential suppliers in terms of quality, cost, delivery times and after-sales support [15,16,18].

Careful budgeting ensures that the procurement process aligns with financial constraints while maintaining quality. A cost analysis is required, taking into account materials, production, transportation, and customs duties. For example, bulk procurement of gears and bearings reduces costs but requires advance financial planning to manage cash flow. Maintenance, repair, and replacement costs also need to be included in the total cost analysis. For example, electric motors, which have higher initial costs but lower maintenance requirements, can provide long-term savings in power plants. Another factor to consider is contingency planning for unexpected expenses, such as currency fluctuations or emergency orders [12,13,15].

Identifying and mitigating risks is crucial for a successful supply strategy. Supply chain risks should be taken into account to evaluate the reliability of suppliers in terms of delivery times and quality. For example, in metal production, delays in the delivery of hydraulic cylinders can stop production lines and cause significant losses. Ensuring compliance with international standards and local regulations is also essential. For example, the supply of welding electrodes should comply with the ISO 2560 standard for welding consumables. Potential issues related to product specifications and functional compatibility should also be assessed. For example, insufficient fastener strength leading to structural failures in automated assembly lines can be a major problem. Additionally, it is important that parts are suitable for material recovery or recycling at the end of their useful life [11,14-17,19].

Documentation and tender preparation involve the creation of detailed procurement documents to facilitate transparent and efficient supplier participation. Technical specifications should clearly define material properties, dimensional tolerances, and performance criteria. For example, hardness levels and surface quality should be specified for gears to be used in robotic arms to ensure smooth transmission. Performance criteria, warranty conditions, and after-sales support should be included in the supplier evaluation framework. For example, for bearings that will operate under high load conditions, load-carrying capacity and expected service life should be emphasized. As a final step, a request for proposal, supplier qualification requirements, and contract terms and conditions should be prepared [19,20].

The integration of advanced decision-making approaches and software tools is crucial for optimizing procurement processes, especially in the procurement of machinery and machine components in sectors such as energy, metal production, machinery manufacturing, and mining. Modern procurement utilizes data-driven decision-making processes to improve efficiency and effectiveness. This includes the use of procurement analytics, which involves the collection, classification, and analysis of procurement data from multiple sources. This information is presented through visual dashboards or business intelligence tools to support strategic purchasing decisions. Advanced analytics and artificial intelligence (AI) are transforming procurement functions by providing predictive analytics, risk assessment, and supplier performance evaluation. These technologies enable procurement teams to forecast demand, assess supplier risks, and make informed purchasing decisions. Software solutions provide decision support for project prioritization and supplier selection using multi-criteria decision-making (MCDM) methodologies and help evaluate various factors to make informed purchasing decisions [10,11,14-17,19].

However, the views of engineers should not be ignored in this process. Decisions made without engineering input can result in the selection of components that do not meet specifications or operational requirements, leading to integration difficulties and technical incompatibilities, including potential system failures. Inappropriate components can lead to increased maintenance needs, reduced efficiency, and higher operating costs over time. Engineers play a crucial role in ensuring that procured components comply with safety standards. Excluding them can jeopardize compliance with safety regulations and pose risks to personnel and equipment [20].

As a result, the material procurement process in the machinery manufacturing sector follows a multi-phase and interdependent structure. Balancing quality, cost, and lead times is critical for competitive production. Key strategies in this regard can be listed as follows [16,21,22]:

- Sourcing high-quality and sustainable materials,
- Regular evaluation and risk analysis of suppliers,
- Optimizing logistics and inventory management,
- Effective implementation of quality control processes,
- Diversification of domestic and international supply sources.

As industrial and machinery production grows in Türkiye, strengthening domestic supply chains and implementing localization policies will enable the sector to become more competitive.

3. Localization Strategies

As one of the cornerstones of the national economy, Türkiye's machinery manufacturing sector is at the forefront of industrialization and technological development. This sector is of strategic importance not only for its production capacity but also for the support it provides to other industries and the value-added it creates. The Turkish machinery industry holds a privileged position within the framework of Türkiye's goal of becoming a developed and industrialized country [1,5,21].

In this context, localization efforts in the machinery manufacturing sector play a critical role not only in reducing imports but also in increasing the competitiveness of domestic producers in international markets and ensuring technological independence. However, the dependence on imports of some critical components used in machinery manufacturing negatively impacts the foreign trade deficit, further underscoring the importance of localization efforts in the sector [5,21].

Localization, in general terms, is a strategy aimed at replacing imported products with domestic production to reduce foreign dependency. Within the scope of Türkiye's high-tech industrial transition program, product groups such as refrigeration compressors for the machinery sector, machining centers for metal processing, plastic injection molding machines, oil hydraulic power transmission control valves, and industrial robots have been identified as priority areas for localization. Localization and domestication strategies aim to strengthen the national industry by reducing dependence on imported inputs and developing domestic supply chains.

According to 2023 data, Türkiye's machinery imports exceeded 32 billion USD [5]. This situation highlights the necessity of increasing domestic production capacity. In addition to ensuring economic independence, domestication in industry also facilitates technology transfer and enhances domestic R&D activities [5,21].

In order to accelerate the localization process of the Turkish industry and ensure its transition from the medium-low technology to the medium-high technology group, the following strategies should be implemented [1-3,5,6,21,22]:

- Long-term planning and defining strategic goals,
- Reviewing and harmonizing of incentive systems for industry,
- Regulating the jurisdiction of institutions with different legislation,
- Promoting support and incentives to sectors,
- Improving the infrastructure of organized industrial zones,
- Relocating scattered industrial facilities to organized industrial zones.

Structural transformations are necessary to increase exports of high value-added and technology-intensive products. To accelerate these transformations, it is important to encourage the commercialization of R&D studies and provide special incentives for the transition of industries into high-tech production. In addition, providing investment incentives for the domestic production of imported parts in regions where local production is strong and supporting SMEs in areas such as process optimization and energy efficiency will make significant contributions to the domestication process [1,5,21].

Domestication strategies will accelerate production processes and reduce costs by ensuring that the required materials are procured domestically. Additionally, reducing imports will retain financial resources within the national economy and support economic growth [5].

4. Localization of the Secondary Brake System (Retarder) Resistor of a Rock Truck

A retarder is a device that helps reduce or slow down the speed of a vehicle. It is used for cars, trucks, buses, and other large vehicles. The retarder provides an effective method of deceleration in addition to the braking system of vehicles and can extend the life of the braking system by reducing wear on frequently used brakes. They are used on heavy vehicles, on roads with rolling hills that require prolonged breaking, or in traffic conditions that require constant stop-and-go. In such cases, instead of continuous braking, retarders are used to reduce the speed of the vehicle and minimize both the wear and heating of the brake pads [23-25].

Retarders can also be called engine brakes, but the actual engine brake is a different system that allows the vehicle to reduce its speed using the compression power of its engine. Retarders can be mounted on the vehicle's transmission or near the differential. Hydraulic, electromagnetic, mechanical, or electromagnetic systems are commonly used to reduce the speed of vehicles [23,24].

Hydraulic retarders, which work by changing the viscosity of the hydraulic oil, are usually located close to the transmission of the vehicle. The system includes a pump and an oil tank. The driver can use a button or lever to control how much power the retarder applies. Hydraulic retarders provide fast and effective deceleration, reducing wear on the brake pads. Electromagnetic retarders work through the interaction of a magnetic field. This system converts the vehicle's kinetic energy into electrical energy, thereby reducing its speed. They are usually mounted close to the vehicle's differential. Mechanical retarders operate with mechanical components added to the vehicle's transmission. They typically include gear mechanisms and friction plates. Mechanical retarders have a simpler structure than other types and require less maintenance [23-25].

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In the facility where the study was carried out, there are 10 rock trucks, and one rock truck contains 12 retarder resistors. When the retarder resistors were needed, market research revealed that the procurement period was six months.

The technical specifications and material (Fe-Cr-Al) of the retarder resistor specified in Table 2 were determined and localization work was carried out in order to shorten both production and procurement time. The studies were carried out in the form of the workflow shown in Figure 2.

Table 2. Technical specifications of the secondary brake system (retarder) resistance of the rock truck

Resistance value	0.5 ohm (±10%, at 25 °C)
Resistance in tension with respect to the chassis	3 kV/1 min, 50 Hz
DC isolation resistance	5 kV - 20 GΩ
Dimensions	715 x 650 x 100 mm
Net weight	26.6 kg

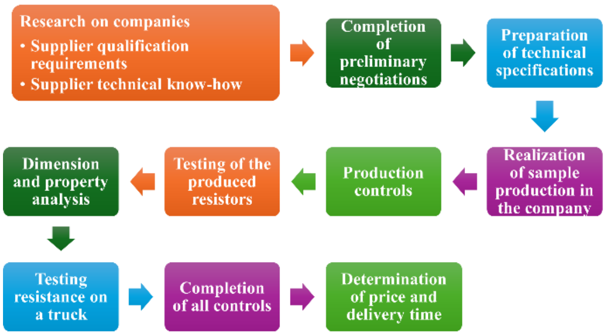

Figure 2. Workflow chart of production and controls

First of all, a company that had previously worked with such resistors and possessed technical knowledge was contacted, and a sample was given to the company that guaranteed it could carry out the production. After the order was placed with the company that would manufacture the retarder resistor domestically, two technical visits were made during the manufacturing process.

The on-site assembly of the locally produced resistor onto the rock truck's secondary brake system is shown in Figure 3. The resistor units were mechanically fastened by technicians after being mounted into the existing chassis slots. Before electrical testing, this procedure is essential to guarantee secure fit and dimensional compatibility. Dimensional conformity was confirmed using a precision caliper (±0.02 mm)

Figure 3. Installation of locally produced resistor

The completed and domestically produced resistor unit is shown in Figure 4. The resistor assembly's front aspect is depicted in the left figure, emphasizing how the Fe-Cr-Al resistor elements are arranged inside the supporting frame. The same unit, packaged and prepared for field deployment, is shown in the right image from the back and side.

Figure 4. 100% local production resistance

In addition, reports on the tests were obtained from the relevant company and examined. After the manufacturing and installation were completed, performance trials were carried out on the rock truck to test the locally produced resistor and to verify whether the material quality and dimensional properties met the desired specifications. All tests, including the insulation resistance test, withstand voltage test, and load performance test, were performed at 20 °C and 41%

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relative humidity. Each test was repeated three times to ensure reliability of the results.

A calibrated digital micro-ohmmeter (accuracy ±0.1%) was used to measure the electrical resistance at 20±2 °C. The measured resistance values confirmed compliance with the given design requirement, being within the tolerance range of 0.5 Ω ±10%. In order to assess the insulating resistance between the resistor element and chassis, the applied voltage was progressively increased from 500 V to 1000 V, 2500 V, and 5000 V DC. As can be seen in Figure 5, the insulation resistance at 5000 V was 100 GΩ, which is much higher than the 20 GΩ minimum design limit.

Figure 5. An example of insulation resistance production and controls

A high voltage hipot tester operating at 3 kV AC, 50 Hz for one minute was used to evaluate the dielectric's withstand capability. During testing, no malfunction or unusual leak was found, confirming the insulating system's structural soundness. The results of the load/current performance test are displayed in Figure 6. After testing, the initial current, which was 143 A under operating load conditions, decreased to 142 A, representing a mere 0.7% power loss. This outcome shows consistent performance while the current flow is constant.

Figure 6. Performance test results

As a result of the preliminary work carried out by the company, they stated that the resistor could be 100% locally produced and that they could deliver it within one month if an order was placed. For a retarder resistor, which was initially offered at 217,860 TL with a delivery time of six months, the domestic production offer was 31,500 TL with a delivery time of one month.

As a result, a part previously imported from abroad was successfully manufactured domestically, achieving an 85% cost reduction compared to the original. In addition, the procurement period was reduced from six months to one month.

If the steps followed in the localization process are summarized:

- Sample analysis and technical drawings,
- Collaboration with local companies and implementation of testing phases,
- Testing local production solutions and evaluating their quality and cost advantages.

Results:

- The price of the resistor was reduced by 85% (31,500 TL instead of 217,860 TL).
- The procurement process was shortened from six months to one month.
- Quality and durability tests were successfully completed.

5. Conclusion

“Machinery and equipment not elsewhere classified (C28)” is central to Türkiye's economy and plays a key role. Localization and domestication in industry is an important strategy for a country's economic independence and competitiveness. They involve essential steps to accelerate the domestication process of Turkish industry and ensure the transition from the medium-low technology to the medium-high technology group. These steps aim to enhance the ability of domestic industrialists and technology entrepreneurs to produce economically sustainable products.

Domestication in industry offers multifaceted benefits such as cost advantages, rapid procurement, economic independence, and increased domestic R&D capacity. The specific example that this study focuses on is the localization of the secondary brake system (retarder) resistor used in rock trucks. A total of 120 retarder resistors are used in 10 rock trucks in an enterprise. The localization efforts shortened the supply duration considerably, allowing the component to be delivered in only one month compared to the significantly longer import lead time.

The example of the localization of the rock truck secondary braking system resistor demonstrates that strengthening the domestic industry is critical to reducing import dependency. Expanding domestication policies will enhance Türkiye's industrial competitiveness and support long-term economic growth.

Although this study focuses on a single component within a particular operating situation, the applied technique and results can be utilized as a model for other important components in the machinery sector. The shown localization approach, which includes sample analysis, collaboration with capable local producers, and structured validation, can help other equipment parts that have similar procurement challenges, particularly those with long import lead times or high cost. In this way, the case study of the retarder resistor shows how small localization efforts can strategically impact the entire industrial environment. This approach can also be used by industry stakeholders and policymakers to prioritize domestication components based on technological viability, economic return, and supply risk.

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Author's Contributions

Barış Oğuz: Performed the experiments and result analysis, drafted and wrote the manuscript,

Arzum Işıtan: Drafted and wrote the manuscript, supervised the experiment's progress, and result interpretation.

Ethics

There are no ethical issues after the publication of this manuscript.

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