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Sustainable Product Design Strategy: A Comparative Analysis on the M113

Sürdürülebilir Ürün Tasarım Stratejisi: M113 Üzerine Karşılaştırmalı Analiz

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ABSTRACT

This empirical study investigates the relationship between the inventory trends of M113 armored vehicles and sustainable design strategies in the defense sectors of Türkiye and the USA with the perspective of industrial design. Utilizing ARIMA modeling and linear correlation analysis, data collected up to 2022 reveals distinct patterns in vehicle inventory dynamics. The ARIMA analysis produced reliable coefficients despite limited data availability, suggesting feasible numerical assessments. Results indicate that in the USA, the introduction of alternative vehicles such as the Bradley, designed with sustainable principles, led to the phased reduction of M113s. Conversely, Türkiye's inventory trends reflect a linear relationship between the absence of vehicles with design integrity and sustained M113 usage, with modernization efforts prolonging its presence. The study underscores the economic advantages of implementing sustainable product design strategies in armored vehicle development, particularly evident in the USA's production of the Abrams tank and Bradley tracked armored carrier. Despite Türkiye's prolonged reliance on M113s, it highlights the necessity of comprehensive feedback mechanisms and professional units to perform sustainable design strategies. Moreover, it reveals the inefficiency of solely relying on modernization for operational vehicle counts in developing countries, emphasizing the importance of balancing technological advancements with vehicle design integrity. This study sheds light on the evolving nature of sustainable design strategies in defense sectors, urging countries to integrate comprehensive feedback mechanisms and design integrity principles into their armored vehicle development processes for long-term effectiveness and economic viability.

Keywords: Sustainable design, industrial design, M113, bradley, inventory comparison

JEL Code: O33

ÖZ

Bu deneysel çalışma, Türkiye ve ABD savunma sektörlerindeki M113 zırhlı araç envanter eğilimleri ile sürdürülebilir tasarım stratejileri arasındaki ilişkiyi endüstriyel tasarım açısından araştırmaktadır. ARIMA modellemesi ve doğrusal korelasyon analizi kullanılarak 2022'ye kadar toplanan veriler, araç envanteri dinamiklerinde belirgin desenler ortaya koymaktadır. Sınırlı veri bulunabilirliğine rağmen ARIMA analizi güvenilir katsayılar üretmiş ve uygulanabilir sayısal değerlendirmeler önermiştir. Bulgular, ABD'de, sürdürülebilir prensiplerle tasarlanmış Bradley gibi alternatif araçların tanıtılmasının, M113'lerin aşamalı olarak azalmasına yol açtığını göstermektedir. Buna karşılık, Türkiye'nin envanter trendleri, tasarım bütünlüğüne sahip araçların eksikliği ile sürdürülen M113 kullanımı arasında doğrusal bir ilişki yansıtmakta ve modernizasyon çabaları varlığını uzatmaktadır. Çalışma, zırhlı araç geliştirme sürecinde sürdürülebilir ürün tasarım stratejilerinin uygulanmasının ekonomik avantajlarını vurgulamakta, özellikle ABD'nin Abrams tankı ve Bradley paletli zırhlı taşıyıcısının üretiminde açıkça görülmektedir. Türkiye'de M113'lere uzun süreli bağımlılığa rağmen, sürdürülebilir tasarım stratejilerini uygulamak için kapsamlı geri bildirim mekanizmaları ve profesyonel birimlerin gerekliliği vurgulanmaktadır. Ayrıca, gelişmekte olan ülkelerde operasyonel araç sayıları sadece modernizasyona dayanmanın etkin olmadığını göstermektedir. Teknolojik gelişmelerle araç tasarım bütünlüğü arasında denge kurmanın önemi vurgulanmaktadır. Bu çalışma, savunma sektörlerinde sürdürülebilir tasarım stratejilerinin evrilen doğasına ışık tutmakta ve ülkeleri uzun vadeli etkinlik ve ekonomik sağlamlık için kapsamlı geri bildirim mekanizmalarını ve tasarım stratejilerinin evrilen doğasına ışık tutmakta ve ülkeleri uzun vadeli etkinlik ve ekonomik sağlamlık için kapsamlı geri bildirim mekanizmalarını ve tasarım bütünlüğü prensiplerini zırhlı araç geliştirme süreçlerine entegre etmeye çağırmaktadır.

Anahtar Kelimeler: sürdürülebilir tasarım, endüstriyel tasarım, M113, bradley, envanter karşılaştırması

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Introduction

Sustainability, which has become one of the greatest challenges of our modern world, aims to generate less greenhouse gas and leave a livable environment for future generations, akin to the one we currently inhabit. The escalating emissions of greenhouse gases and water consumption have become a threat to ecology and the sustainable continuation of industries. Climate change has initiated, with trends showing increases in both conflicts and diseases (Bowles et al., 2015). This situation leads to the formation of a world that is unfavorable for all of humanity. One of the sectors contributing to high greenhouse gas emissions and natural resource consumption from an economic and industrial perspective is the defense industry. Defense, being one of the fundamental needs of humanity, also encompasses products that cause the most harm to nature through the production of limitless technologies. This harm not only affects the ecology but also damages the economies of countries. Producing products that cannot be used as political leverage or creating products with longer lifespans at lower costs also have positive economic impacts on user armies. To capitalize on these scenarios ecologically and economically, the relationship between sustainable design and industrial design should be managed in the defense industry with effective and sound policies (Cooper, 1999).

This study aims to conduct numerical comparisons between the inventories of Türkiye and the USA of the M113, a tracked combat vehicle of US origin that has left its mark on world history, over the years. A comparative analysis based on the vehicle that will replace the M113 and the design strategies employed will be conducted in an empirical manner. In this process, open sources pertaining to the inventories of countries will be examined to create datasets for each year, and ARIMA analysis will be applied to these datasets to examine the changes in vehicle numbers over the years. The dependent variable in this analysis will be the number of vehicles. The elapsed time until the vehicle replacing the M113 is produced, the time until the vehicle produced with a sustainable design instead of the M113 is produced, and the defense budgets of countries for the years in which the data is collected will be assigned as independent variables. Subsequently, Pearson correlation analyses will be conducted to reveal relationships and reach empirical study results.

It has been observed that the sustainable design approach is completely lacking in the literature in the field of defense. With this study, conducted both to strengthen this field and to set an example for countries in determining their design strategies, the aim is to provide guidance for understanding the strategic sustainability of products in a rational manner. Within this framework, industrial design, sustainable design, and M113 data have been thoroughly examined through the literature.

Industrial design is a multidisciplinary field and deals with many issues, from determining the features that the product will have to include to concept design, from material selection to production method, from prototype production to product feedback. These responsibilities show that this branch of science plays an active role in the process, from the idea of a product to its transformation into a concrete product (Xia, 2011). However, the concepts of "sustainability and sustainable design", which have begun to mature since the 1970s, are seen today in line with the aim of creating a product that will last longer and will not harm the world of future generations within the framework of the product life cycle of industrial design and industrial designers (Bhamra & Lofhouse, 2007). With this situation, it has become clearer how vital the sustainability goals of countries are for future generations. However, considering that the leading projects in the development process of technology globally and the products produced with the most investment are related to the defense industry, it is understood that the concept of sustainability should be used scientifically and effectively in the field of the defense industry (Hellyer, 2018). Especially when we examine armored combat vehicles as products, we see that there are many metal, thermoplastic and thermoset materials used that harm the nature. The fact that product costs are quite high confirms that such products should be designed and used cost-effectively. When actions such as modernization of such products are carried out if their productive lifespan is not long, it can be said that these unsustainable products cause much more harm to nature and become a great burden on economies (Clark et al., 1999). Considering that the aim of defense products is to protect the country itself and its interests (directly and indirectly), it is very important to develop products within the framework of sustainable design strategies, especially for developed countries, since it is not possible to produce such products for a sustainable world. According to the research, it was aimed to learn how effective sustainable design will be in the product design of an armored fighting vehicle. Research has been conducted on the comparison of armored vehicles in developed countries, which are initially high-cost and designed to be sustainable, versus armored vehicles, whose cost is lower and will need to be modernized in the short term, against sustainable ones. The product comparison in question is based on the M113 armored vehicles, which can be seen in the best way, and modernization processes they have gone through from the past to the present. Considering that more than 80000 M113 armored vehicles have been produced worldwide and more than 50 countries use them operationally (ORYX, 2022), the difference (product strategy) between developed countries and others will be clearly seen (Nuckols & Cameron, 2016).

The concept of sustainable design, which has been actively encountered in the world since the 1970s and 1980s, has been a result of the production and destruction brought about by various wars and high industrial production. Greenhouse gas emissions (carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3)) increased exponentially after the industrial revolution, and since industrial and war activities were produced with advanced technology in that period, environmental disasters became a serious problem (Didenko et al., 2017). Thus, the concept of a sustainable future (a livable world for future generations) for society and industry was formed. Design strategies such as eco design (an environmentally friendly approach within the framework of the product life cycle, products that can easily be destroyed in nature) and green design (the use of materials that are less harmful to nature in products) have been implemented to ensure that products create fewer carbon emissions. As the process progresses, sustainable design strategies have also been developed (Tischner, 2001). When sustainable design is mentioned, new concepts have begun to come to mind, apart from features such as natural materials and easy degradability in nature. Many concrete and abstract concepts, such as increasing business model efficiencies and paper waste resulting from engineering or design activities during the design of the product, have begun to be included in the subject of sustainability (Chen, 2018). Since collecting features in a single product instead of many products requires less energy and materials, it has been included in the scope of the sustainable design strategy. Making the products long-lasting and durable and reducing maintenance costs are both economically and environmentally sustainable product strategies (European Commission, 2022). Sustainability in every phase of a product (social, economic, engineering, design, art) is a developing concept today.

M113 Tracked Armored Vehicles and Modernizations

The M113 tracked armored vehicle, a product developed by the United States in 1960 (Defense News, 2016), provided a significant advantage in the Vietnam War in terms of the technology of the period (Carter, 2015). Thanks to the lightness of aluminium in the armor structure, the vehicle has higher mobility. This situation is directly related to the first and second world war defense products in the development of technology. When we look at it in general terms, with the development of design and technology, the mechanical combat vehicles used in the First World War used high density metal (the emergence of the ability to produce products in large molds and the development of powertrain systems) and have undergone great changes according to the diversity of their purpose of use (Willey & Hudson, 2017). Many different designs have emerged due to various countries applying various mission definitions and strategies for their vehicles, according to the geography and military strategies of the countries. As a result of this situation, it was observed that efforts were made to give different metallurgical properties to military combat vehicles in the Second World War (Parmentola et al., 2006). Intensive use of metal has given way to optimum mass calculation according to powertrain systems, and armor properties have improved in the form of less mass and stronger metal. With the development of technology, vehicle operational ranges have increased, and the designs and mission descriptions of war equipment have improved (expanded). Each country has developed the molding method or assembly method within the framework of its own technology and has presented practical, experimental data on what kind of vehicles should be preferred in today's war data. The designs of armored fighting vehicles were also developed within the scope of engineering science, and the development momentum increased according to the concrete data obtained from wars. Accordingly, the environment in which the operator will be positioned in the vehicles has constantly changed and improved (the operator is not disabled depending on the damage to the vehicle), ease of design has come to the fore according to mold and assembly production options, and designs have become easier to produce and stronger performance can be achieved compared to the powertrain systems creating higher torque (Margolin, 2013). According to the developing descriptions, within the scope of ergonomics science, the seating of the personnel in the vehicle, the use of weapon systems, and the armor or clothing to be worn have also continued to develop.

The most important features of the M113 armored fighting vehicle in terms of its design are: It can be said that it is easy to produce and easy to transport in terms of logistics (Robinson & Kosmatka, 2011). Since it is an armored fighting vehicle that can be transported by land, air, and sea thanks to its aluminum-structured armor, it is a product with a very wide market share. According to the technology of the period, it managed to provide very good protection against low-caliber weapons. In terms of body design, it can be said in terms of design science that smooth linear geometries have a highly efficient use of space and are easy to produce. However, as time progressed, the long-term use of M113s in operational regions created a disadvantage in terms of fuel, which was an important factor that triggered the production of the A1 variant. Along with the A1 variant, the armored fighting vehicle with the commercial name M113A1 (1964) was fielded with a diesel engine (Webster, 1981). The A2 variant was developed in the 1979s due to the development of powertrain systems, the need to increase operational range, the need to increase mobile capabilities, and the lack of need for amphibious features. Vehicles; With its use in South America, Asia, and Africa and the development of the modern warfare concept of the time (development of defense technology and required features according to the weapons used periodically in wars), the M113A3 variant was created (Army Technology, 2004). Powertrain systems and the development of armor that protects the parts that keep the vehicle operational and protects personnel have come to the fore in this variant. Since more than 50.000 M113s are used in more than 40 countries around the world, countries also carry out modernizations designed and produced by different manufacturers according to their individual needs (BAE Systems, 2011). Examples include the M113A4 variant of the FNSS company operating in Türkiye (with the conversion of A1 and A2s), and the variant called M113A S4 designed and produced according to the needs of the Australian Armed Forces under BAE Systems.

US-origin M113 armored vehicles were introduced to the US in 1960. With its entry into its inventory, it started licensed production in factories in various European countries. With this process, the ability to easily respond to orders worldwide has been improved, and it has quickly produced the required number of vehicles for its own inventory. Thus, the USA, which increased the number of M113 vehicles by 10,000 over time, has reduced this number for various reasons today. The Republic of Türkiye placed its first M113 orders in 1961 and entered an inventory renewal process that increased over time (ASFAT, 2020). It converted all tracked personnel carriers to M113 and increased the number within the framework of the number of personnel. Today, it has active use exceeding 3500 vehicles and has not yet been reduced (analysis were made until 2022 within the framework of the research, which means access to recent data may pose risks).

Data Collection, Analysis and Methodology

In this study, the ARIMA Modeling approach will be applied to analyze the vehicle numbers of two sample countries comparatively over time. During the application, limitations will be identified. The new product development timelines for understanding the sustainable design strategies of the sample countries, the product development timelines within design integrity, and the economic levels with reverse effects will be applied as independent variables, while the vehicle numbers will be applied as dependent variables. Linear correlation analysis will be conducted on these parameters to reveal the direct or negative relationships between the dependent and independent variables.

The ARIMA model is typically denoted as ARIMA (p, d, q), where 'p' is the order of the autoregressive component, 'd' is the degree of differencing, and 'q' is the order of the moving average component. It's a widely used statistical method for time-series forecasting and analysis. ARIMA models are capable of capturing a suite of different standard temporal structures in time-series data. ARIMA models are particularly useful for modeling time series data that exhibits non-stationary behavior. Time Series Lab 2.6.0 software was used for the analysis in this study. They are widely used in various fields, including economics, finance, and meteorology, for tasks such as forecasting future values, identifying patterns, and making data-driven decisions based on historical data (Shumway & Stoffer, 2006).

ARIMA (p, d, q) is represented by the following equation,

$$yt=c+\phi 1yt-1+\phi 2yt-2+\ldots+\varepsilon t \qquad (1)$$

y_t is the value of the time series at time 't'. c is a constant. ϕ_p are the autoregressive parameters to be estimated. εt is white noise at time 't'. $\Delta^d y_t$ where Δ is the difference operator, and 'd' is the degree of differencing. The differenced series is given by,

$$\Delta^d y_t = (1 - B)^d y_t \qquad (2)$$

'B' is the backshift operator, which shifts the time series back. ARIMA model of order 'q' is represented by the following,

$$yt=\mu+\vartheta 1\varepsilon t-1+\vartheta 2\varepsilon t-2+\ldots+\varepsilon t \qquad (3)$$

μ is represents the mean of the time series. $\vartheta 1$, $\vartheta 2$ are the moving average parameters to be estimated. εt is white noise at time 't'. By combining the AR, I, and MA parts, we get the ARIMA model,

$$(1-\phi_1 B-\phi_2 B^2-\ldots-\phi_p B^p)\Delta^d y_t=\mu+(1+\theta_1 B+\theta_2 B^2+\ldots+\theta_q B^q)\varepsilon_t \qquad (4)$$

B is the backshift operator. According to ARIMA analysis results, the next step will be the Pearson correlation coefficient. It used to measure the strength and direction of the linear relationship between two variables (Field, 2017). It's often shown as 'r'. The formula,

$$r=\frac{\sum(X-\bar{X})\cdot(Y-\bar{Y})}{n\cdot s_X\cdot s_Y} \qquad (5)$$

X¯ and Y¯ are the means of variables X and Y. n is the number of data points. sX and sY are the standard deviations of variables X and Y. The resulting correlation coefficient 'r' will range from -1 to 1. 0 means no linear relationship. 1 means positive and -1 means negative linear relationship.

The European Commission, which introduces sustainable design strategies to the literature, promotes products designed under ecodesign directives to utilize robust, long-lasting, environmentally friendly materials. These strategies aim to ensure energy and resource efficiency, reusability, improvable design, repairability, circular material usage, and the incorporation of recycled materials (European Commission, 2022). Therefore, when calculating the new product development timeline, considering sustainable design strategies,

$$Date\ of\ Production\ of\ the\ Alternative\ Vehicle\ -$$
$$The\ Date\ When\ the\ First\ M113\ Was\ Put\ into\ Use\ = PDT \qquad (6)$$

When calculating the product development timelines within the design integrity (part compatibility),

$$The\ Date\ When\ Design\ Integrity\ Was\ Achieved - The\ Date\ When\ the\ First\ M113\ Was\ Put\ into\ Use = DIT \qquad (7)$$

the formulas will be used. To numerically approximate the PDT or DIT values to 1 through scaling by economic developments,

$$Def.Budget\ as\ Billion\ USD\frac{1}{100} = ELV \qquad (8)$$

will be calculated with. According to the provided definitions, in 2022, the defense budget amounts were 10.6 billion USD for Türkiye and 877 billion USD for the USA (Stockholm International Peace Research Institute, 2022). All the independent variables mentioned above will take either positive or negative values over time, and the defense budget values will also be included for the years corresponding to the vehicle numbers.

Table 1

Limitations and Reasons

Numbers	Limitiations	Reasons
1	Data collection until 2022.	Current data is difficult to find and sharing is prohibited, mostly.
2	Data frequency is low.	Such data is difficult and expensive to find.
3	Sustainable design literature is limited.	Although it is a new and current issue, it is necessary to search for sustainability moves made unconsciously in the past under different headings.
4	Sustainable design literature in defense sector is too weak.	The sustainability movement is new and not yet widespread even in everyday industries.
5	Design strategies in defense sector are not possible to reach.	The technological development level of countries is confidential for each country. Especially in the defense sector.

The limitations of this study are given in Table 1 with reasons. It is necessary to do an analysis with quantitative data on M113 vehicles in the inventories of the Republic of Türkiye and the United States, which have different levels of economic situation and high numbers of active users. With this analysis, the differences between design and military strategies will be understood by examining the number of uses in the countries' inventories (according to data obtained from open sources) and the events in which vehicles cease to be used or their numbers increase. The relationship of this data, which is thought to be directly related to sustainable design strategies, with vehicle modernization or direct new model vehicle production will also be examined. The graphs were made according to the tables below. Those tables explain how and where the data was calculated.

Graph 1

The Quantity of Active M113 Armored Vehicles in the US Inventory by Years

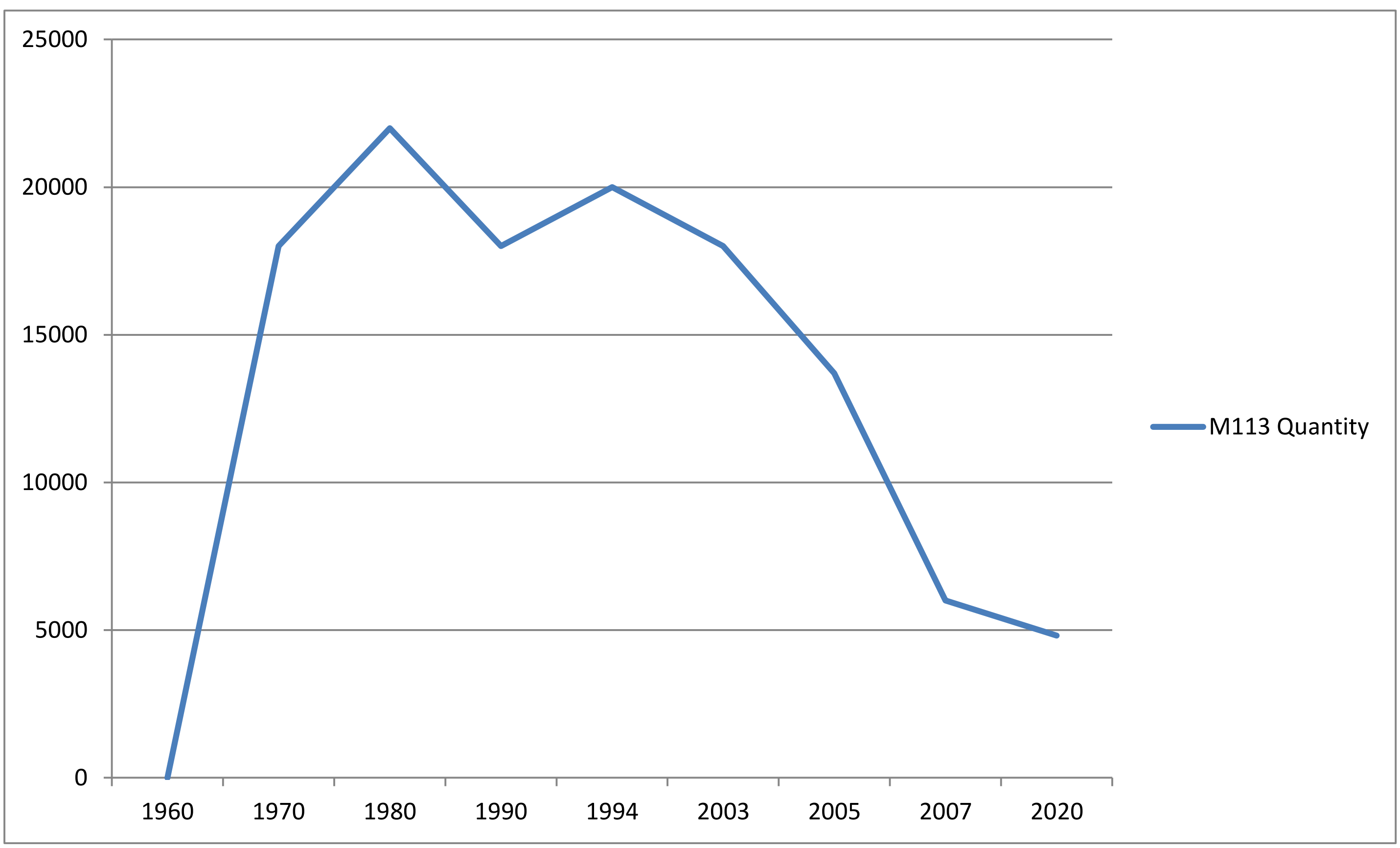


Table 2

Data Collection and Sources for M113 vehicles in U.S. Inventory

Year	Amount	Authors' Comments	Source
1960	0	According to source, the M113 was fielded in 1960, so the minimum value been chosen as 0.	Defense News. (2016, December 15). BAE Systems Presents First AMPV Prototype to US Army [Press Release].
1970	18000	According to source, the units in the U.S. inventory is more than 18000.	Congressional Budget Office (2006). The Army's Future Combat Systems Program And Alternatives, 2006.
1970's	6300	6300 M59 vehicles are replaced with M113 over the time.	Green, M., Stewart, G. (2003). Modern U.S. Tanks and AFVs. MBI Publishing, USA, ISBN 0-7603-1467-5, 33-95.
1980	22000	According to source, the units in the U.S. inventory is more than 22000.	Congressional Budget Office (2006). The Army's Future Combat Systems Program And Alternatives, 2006.
1990	18000	According to source, the units in the U.S. inventory is more than 18000.	
1994	20000	According to source, the units in the U.S. inventory is more than 20000.	
2003	18000	The source shows that there are about 18000 M113 based vehicles.	
2005	13700	According to source, the units in the U.S. inventory is more than 13700.	
2007	6000	According to press releases, 6000 units of M113 are on the service.	National Defense Magazine. (2012, December 17). Vendors Pour Funding Into Armored Vehicle Development [Press Release].
2020	4819	The source says 2897 quantities of M113 will be modernized and 1922 quantities of M113 will be decided. It means the minimum quantity of vehicle is 4819 overall.	Reuters. (2014, December 24). UPDATE 1-BAE wins U.S. Army contract worth up to $1.2 bln for new armored vehicle [Press Release].

Graph 1 was prepared according to the data given in Table 2. Although various variants of the vehicle were developed, such as A1 and A2, its lifespan was extended, but with the advancement of technology and the U.S., since it became clear that it could not meet the needs of the army, new designs were developed within the scope of the army's land force personnel carrier needs (Schubert & Kraus, 1995). Armored System Modernization (ASM) was a modernization and new vehicle development effort that started during this period and was cancelled in 1992. As a result of this programme, M1 Abrams, M2 Bradley and M109 Howitzer vehicles were developed within a certain design integrity (U.S. Government Accountability Office, 2015). This integrity was of great importance for battle strategies like tanks, armored personnel carriers and self-propelled artillery vehicles. The integrity of the design ensured that important parts were in harmony with each other. Important parts mean parts will directly affect vehicle movement and protection. This approach, which facilitates activities such as fortification, maintenance, and repair, has been of great importance for modern armies as a sustainable design strategy.

Graph 2

Comparison of the Quantities of M113 and Bradley Armored Vehicles in the US Inventory

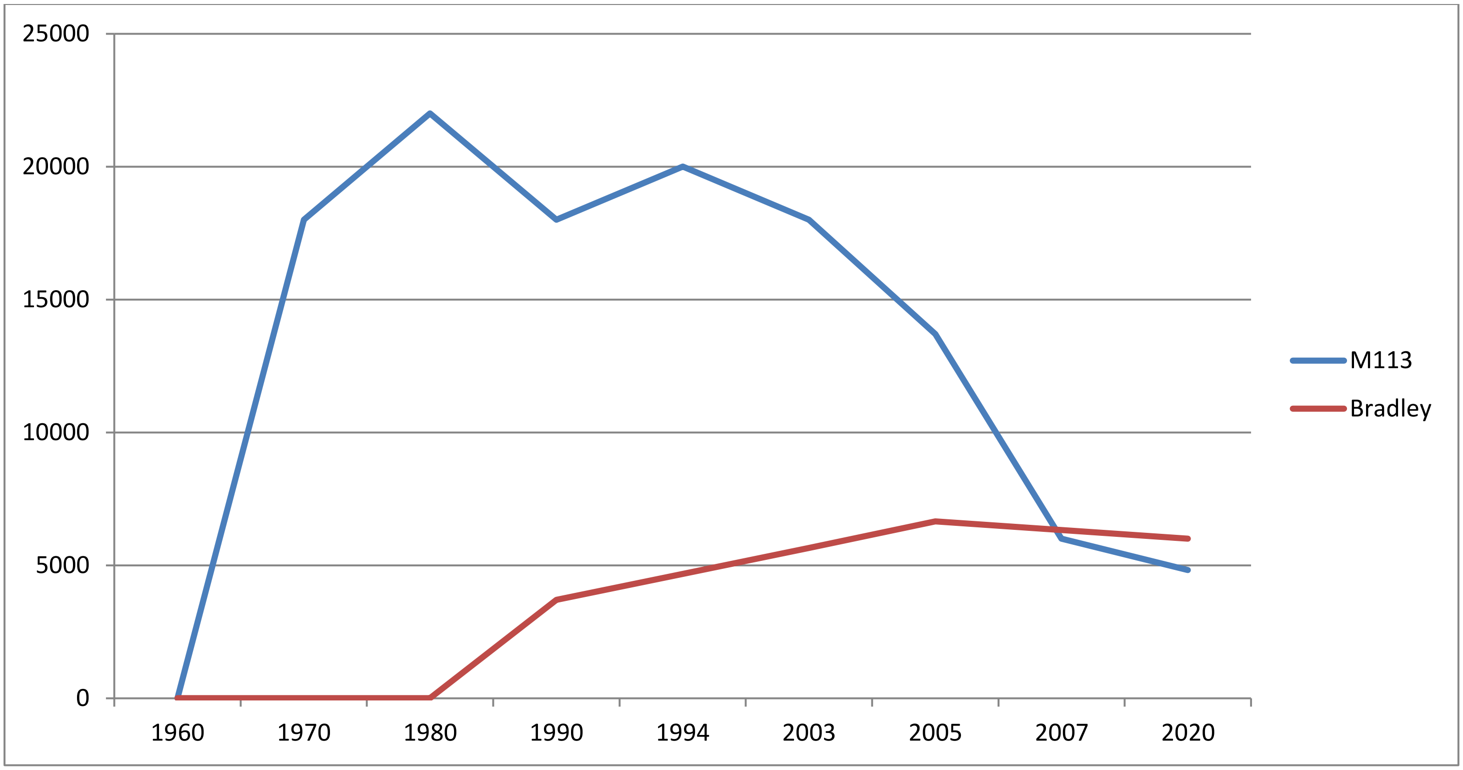


Table 3

Data Collection and Sources for Bradley vehicles in U.S. Inventory

Year	Amount	Authors' Comments	Source
1981	0	Acceptance to inventory started in 1981.	Foss, C.F. (2011). Jane's Armour & Artillery Upgrades 2011-2012. Jane's Information Group, U.K., ISBN 978-07-106-2976-0, 458-464.
1984	2300	The inventory data has been collected according to official reports.	Congressional Budget Office (2006). The Army's Future Combat Systems Program And Alternatives, 2006.
1988	3700		
2003	5650		
2005	6650		
2022	6000	According to public sources, the U.S. is holding a certain number of Bradley vehicles and modernising aged vehicles with different weapon systems.	Hooper, C. (2022, December 30). America's Tough M2/M3 Bradley Fighting Vehicles Are Perfect For Ukraine Fight [Press Release].

For creating Graph 2, the data in Table 3 was used, and the sources were also included. After the peak of M113 armored vehicles, which is given in Graph 2, the main reason for the decrease in the number of active vehicles is that M2 Bradley armored vehicles were designed with integrity among army vehicles and were designed with strategies for modernization within the framework of internal volume requirements and ease of adaptation to new technologies (U.S. Department of Defense, 2021). However, by 2022, M113 armored vehicles have not been completely removed from the inventory and their number varies inversely with Bradley (Breaking Defense, 2015). When we look at the year 2022, it is known that more than 6000 Bradley armored vehicles are in the inventory, and Bradley also had many modernizations and different models. The main distinction between different models is the required armor package and operational area. Another important point is why M113 armored vehicles were not directly removed from the inventory. Although it is known that this issue is a matter of great debate, research shows that in 2014, 4819 armored vehicles were gradually modernized and included in an agreement to keep up with today's battle conditions (Reuters, 2014). Within the framework of this agreement, vehicles will be gradually updated and will be able to keep up with current battle conditions. At the same time, the modernization of Bradley armored vehicles within the framework of current technologies continues, and even an electric motor version is being tested. It is thought that the relationship between the M113 and the Bradley and the main reason why the M113s have not yet been completely removed from the inventory is whether the Bradley vehicle is suitable for modernization to keep up with the new technological battle conditions (Berman, 1995). In 2023, the US army continues to design tanks and personnel carriers in direct relationship with each other and test prototypes against current technological developments.

Graph 3

The Quantity of Active M113 Armored Vehicles in Türkiye's Inventory by Years

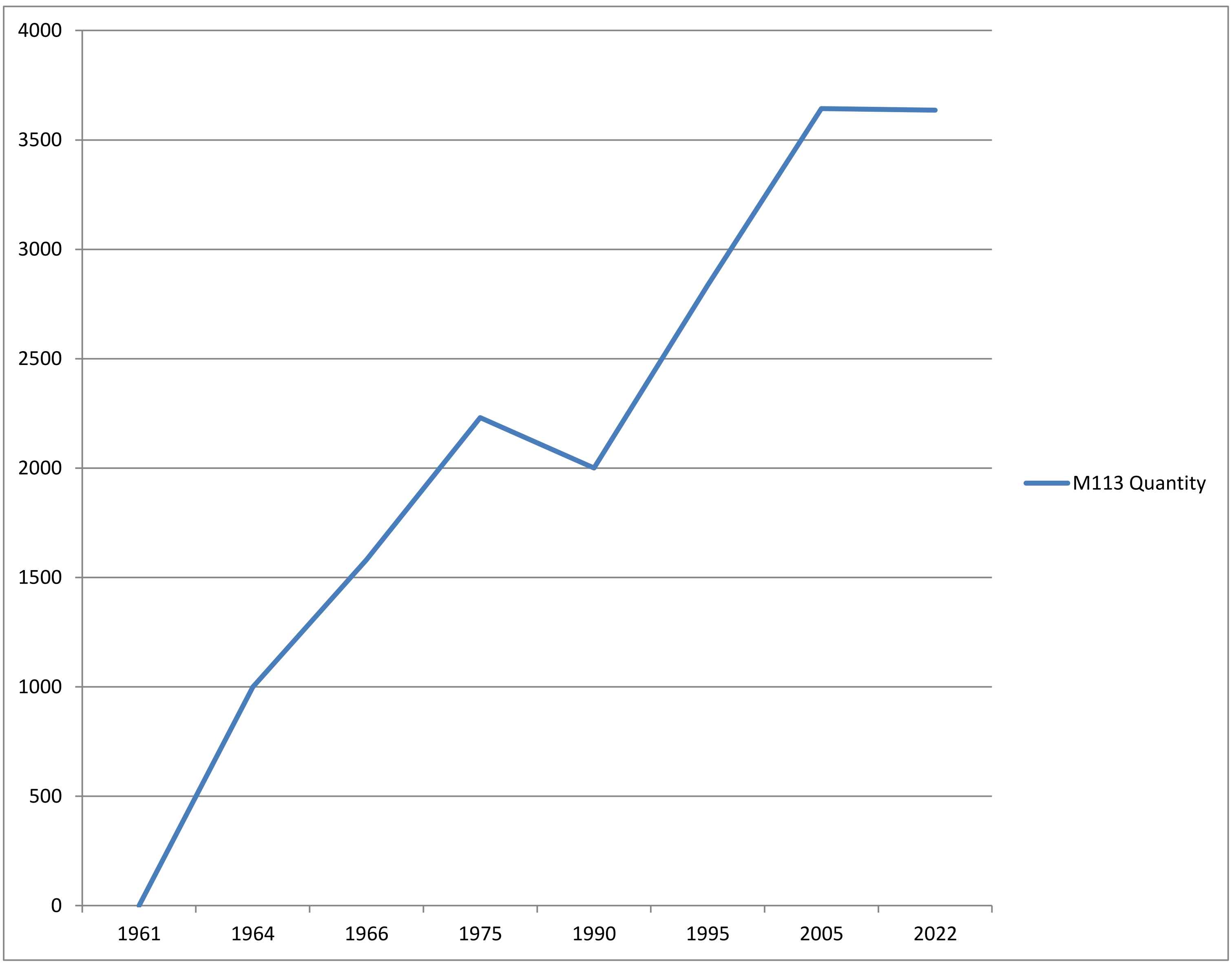


Table 4

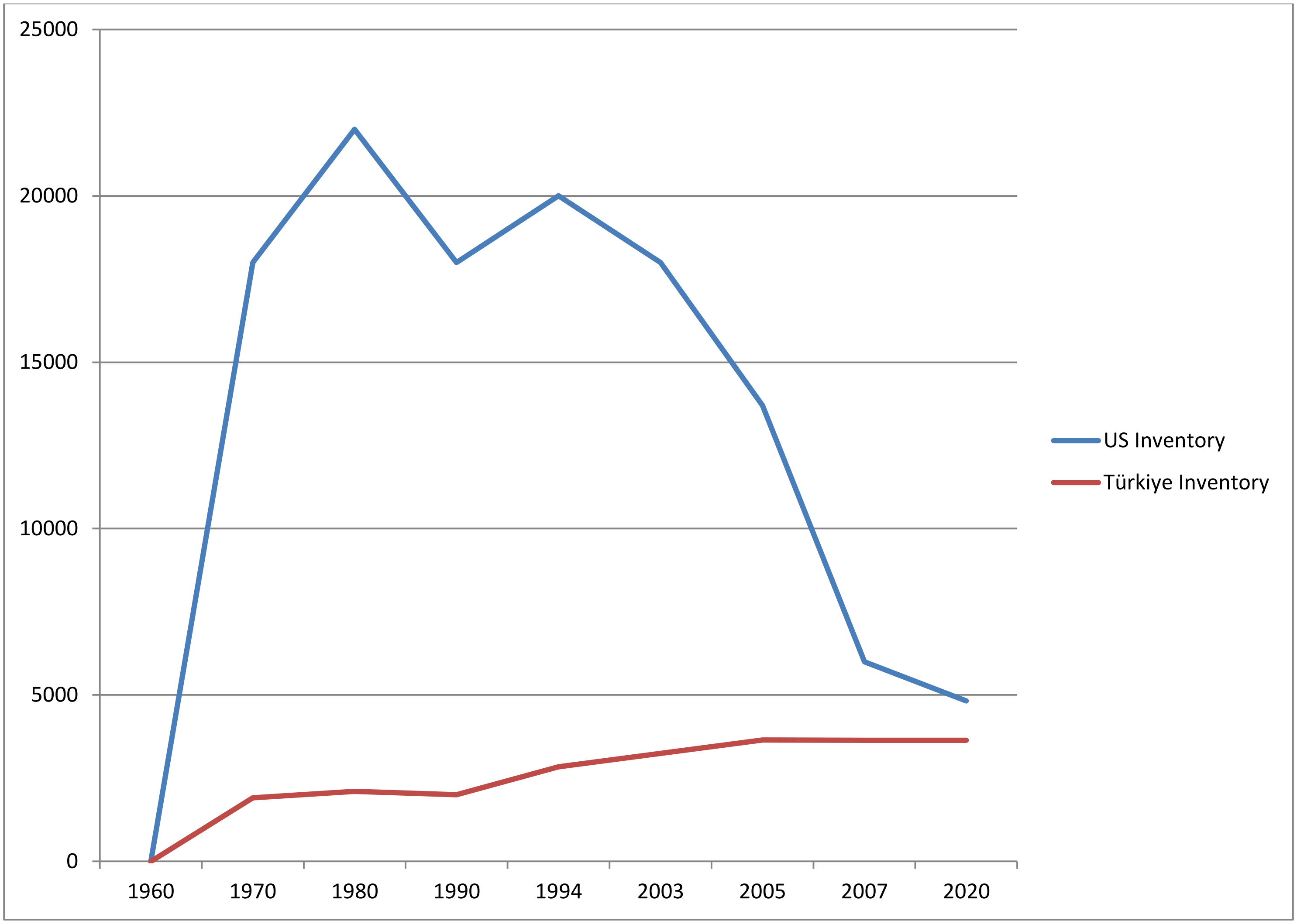
Data Collection and Sources for M113 vehicles in Inventory of Türkiye

Year	Amount	Authors' Comments	Source
1961	0	Beginning of imports.	Stockholm International Peace Research Institute. (2022). SIPRI Arms Transfers Database, 1959-2003 [Data Set].
1964	1000	According to the International Firearms Database, the total amounts have increased approximately mentioned numbers.	
1966	1581		
1975	2231		
1990	2000	The Firearms Database and Government reports confirm each other.	Central Intelligence Agency – CIA (1988). The Military Balance Between Greece and Turkey: How It Stands- Where It Is Headed- What It Means (Public Release in 2013). Interagency Intelligence Memorandum.
1995	2837	According to suppliers, minimum amounts of 2837 M113 existed in 1995.	Stockholm International Peace Research Institute. (2022). SIPRI Arms Transfers Database, 1959-2003 [Data Set].
2005	3643	IISS Data shows the total number of M113 and modernized vehicles which are not called M113.	Langton, C. (Ed.). (2004). The Military Balance 2004-2005. The International Institute of Strategic Studies. Oxford University Press. ISBN 13: 9780198566229.
2022	3636		Hackett, J. (Ed.). (2022). The Military Balance 2022, The International Institute of Strategic Studies. Routledge, ISSN 0459-7222, 155-163.

For creating Graph 3, the data in Table 4 is used. It includes the data and its sources. M113 armored vehicles, which replaced the M59 armored vehicles, were ordered for the first time by the Republic of Türkiye in 1961. M113s, which started to enter the inventory that year, will be actively used in the Republic of Türkiye in 2023. While the inventory mainly includes the A1 version, there is also the A2 version. The number of M113s reached 2000 units by the 1990s (Central Intelligence Agency, 1988), and with the modernization of the FNSS company under the name A4 in 1992, they began to be equipped with armor and weapons that would extend their lives and adapt to current battle conditions (FNSS, 2021). The main purpose of the modernization was to add an active lifespan to the vehicle in the range of 15-20 years. It is known that according to 2022 data, around 3600 M113 armored vehicles are actively in the inventory (Hackett, 2022). The ACV series is also included in the calculations for Türkiye as M113. According to Graph 3, there were sharp increases in the 1990's. The main reason for this increase was modernizations and new orders. Technically, since there is no main battle tank and tracked personnel carrier production in the Republic of Türkiye (except licensed production), no vehicles were produced within the framework of design integrity. It can be seen that there were 31 years between 1992 and 1961 and that the vehicles modernized in this context were a maximum of 31 years old and a minimum of 0 years old. It is understood that there are 30 years between 2022 and 1992 and that the vehicles modernized in this context have been actively operating for a maximum of 30 years.

Graph 4

USA and Republic of Türkiye Inventory Comparison (for M113 Quantities)



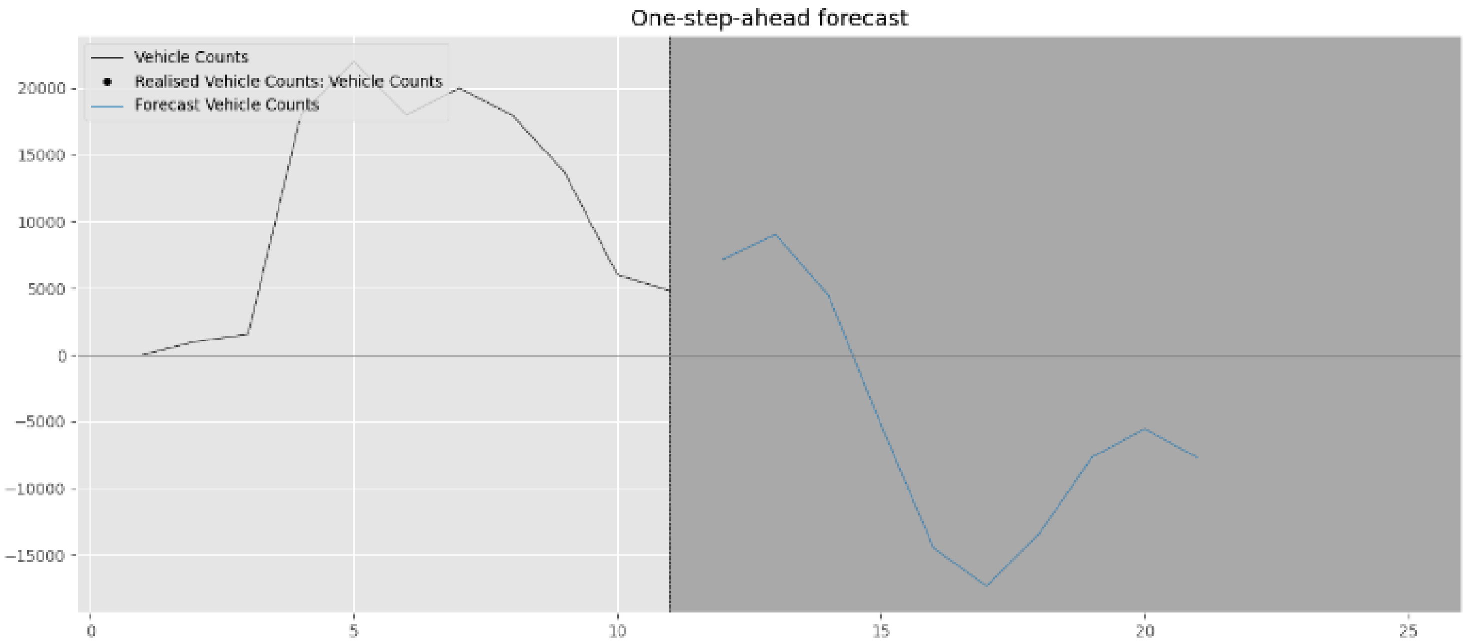
While the USA began adding M113 armored vehicles to its inventory in 1960, the Republic of Türkiye started in 1961. When the processes are compared, which can be seen in Graph 4, the USA due to the Bradley vehicles of 1981. It appears to be the beginning of reducing the number of M113s in terms of inventory (Foss, 2011). It is understood that the 21-year period between 1981 and 1960 was the minimum amount of time for technology development and field experience to produce newer models (Tobias, 1993). For the Republic of Türkiye, the growth momentum in the number of vehicles has not yet reached 0, and, therefore, the peak point has not yet been reached. Modernization efforts continue in the 61-year period between 2022 and 1961. The 41-year period between 2022 and 1981 can be described as the correct design strategies. Due to the sustainable design of Bradley armored vehicles within the framework of army needs and their compatibility with the main battle tank, the production process has not reached saturation for 41 years.

Findings

ARIMA analyses were conducted with separately created datasets for Türkiye and the USA with the Time Series Lab software, version 2.6.0. Linear correlation calculations were conducted with IBM SPSS Statistics 21.0 software. Linear correlation analyses were then performed using the resulting data to reveal the relationships between the parameters. Based on the strategies pursued by the countries, whether they apply sustainable approaches or not is presented under specific parameters.

Graph 5

ARIMA Analysis for numbers of M113 in USA Inventory



Graph 5 depicts the process of M113s being phased out of inventory for the USA, along with future forecasts. In Table 2, the graph drawn based on the data collections provided shows the trends of increase or decrease in vehicle numbers. The analysis resulted in ARIMA (5,0,0), indicating reasonably good performance. The BIC value of 57.943 suggests a good level of relationship. An MAE value of 7039.508 indicates reasonably accurate predictions, while an MSE value of 8.1683e+07 suggests relatively accurate predictions. Detailed ARIMA results for the USA can be found in Table 5, below.

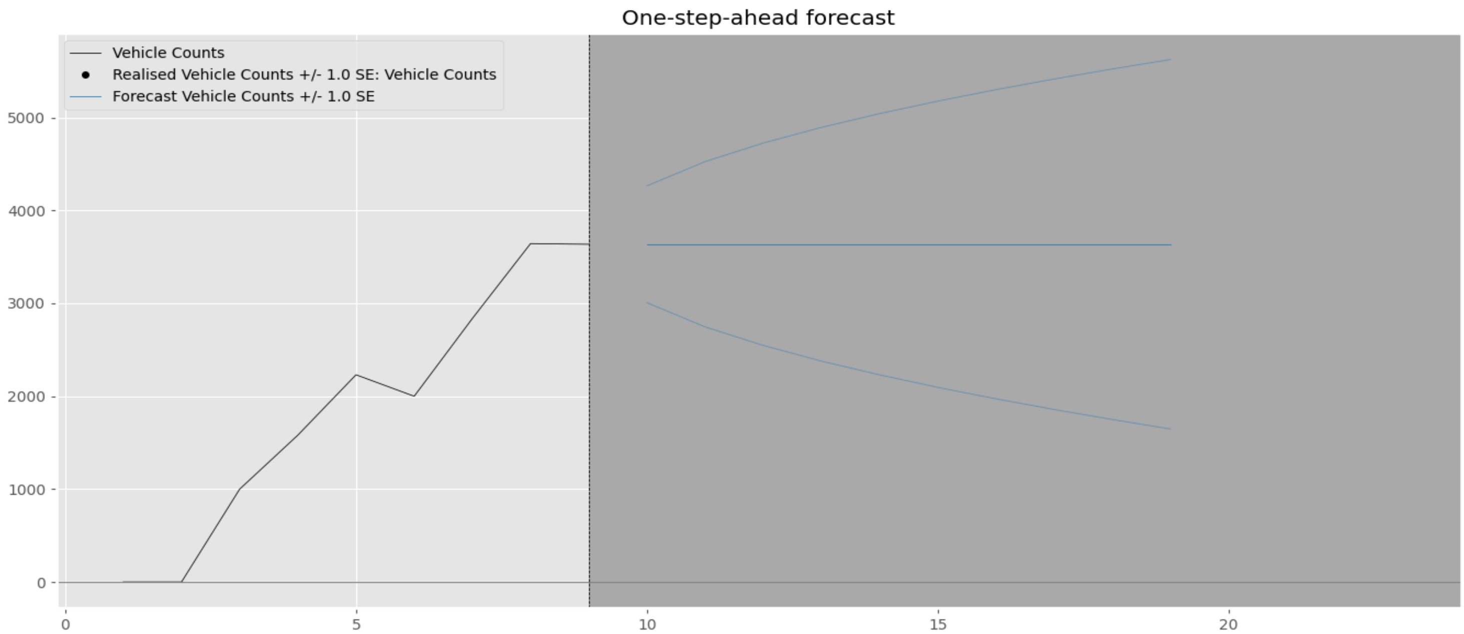
Table 5

ARIMA Results for the USA

Definitions	**Results**			
ARIMA (p,d,q)	ARIMA (5,0,0)			
ARMA (p,q)	-1880.9 (value)	99.92 (Std. Err)	-18.82 (t-stat)	1.5487e-08 (prob)
Irregular Variance			9.9692e+07 (value)	1 (q-ratio)
Log Likelihood			-21.778	
Akaike Information Criterion (AIC)			55.556	
Bias corrected AIC (AICc)			76.556	
Bayesian Information Criterion (BIC)			57.943	
In-sample MSE			8.1683e+07	
Root Mean Squared Error (RMSE)			9037.862	
Mean Absolute Error (MAE)			7039.508	
Mean Absolute Percentage Error (MAPE)			58.331	
Sample Size			11	

Graph 6

ARIMA Analysis for numbers of M113 in Inventory of Türkiye



Graph 6 presents the ARIMA analysis of M113 numbers in the inventory of Türkiye. It was challenging to determine whether the M113s were being phased in or out of inventory, resulting in various paths for future forecasts alongside the analysis. The findings indicate that the ARIMA value for Türkiye is (0,1,0), which is considered reasonable due to data limitations. The BIC value of 128.003 suggests that this analysis is preferable. An MAE value of 587.429 indicates acceptability, and an MSE value of 4.5195e+05 also suggests acceptability. Detailed information is given in Table 6, below.

Table 6

ARIMA Results for the Türkiye

Definitions	**Results**			
ARIMA (p,d,q)	ARIMA (0,1,0)			
ARMA (p,q)	3643.0 (value)	25.08 (Std. Err)	145.3 (t-stat)	1.9318e-13 (prob)
Irregular Variance			3.9546e+05 (value)	1 (q-ratio)
Log Likelihood			-62.903	
Akaike Information Criterion (AIC)			127.805	
Bias corrected AIC (AICc)			128.377	
Bayesian Information Criterion (BIC)			128.003	
In-sample MSE			4.5195e+05	
Root Mean Squared Error (RMSE)			672.275	
Mean Absolute Error (MAE)			587.429	
Mean Absolute Percentage Error (MAPE)			32.751	
Sample Size			9	

When comparing the ARIMA analyses, it is observed that a more complex model emerged for the USA due to the collection of more data, whereas the results for Türkiye, based on limited and precise data, are expected to contain fewer errors. According to the comparison of Root Mean Square Error (RMSE), it is seen that the analyses conducted for Türkiye have a stronger predictive aspect.

For the calculation of ARIMA and linear correlation analyses for Türkiye,

$$1992\ (Military\ Factory, FNSS\ ACV-15) - 1961\ = 31\ (PDT_{Türkiye})$$

When calculating the product development timelines within design integrity (part compatibility) for Türkiye,

$$2022 - 1961 = 61\ (DIT_{Türkiye})$$

The value has been obtained. Currently, such a vehicle does not exist in Türkiye. Since economic advancements inversely scale the PDT or DIT values towards 1 numerically,

$$10.6\ \frac{1}{100} = 0.106\ (ELV_{Türkiye})$$

The variables have been reached. When calculating PDT for the USA,

$$1981\ - 1960\ = 21\ (PDT_{USA})$$

When calculating DIT for the USA,

$$1981\ - 1960\ = 21\ (DIT_{USA})$$

When calculating ELV for the USA,

$$877\ \frac{1}{100} = 8.77\ (ELV_{USA})$$

The values have been obtained. The values have created new datasets over the years, either negatively or positively. According to the formulas given above, PDT, DIT, and ELV data have been calculated, and detailed data for Türkiye and the USA are provided in Table 7 and Table 8.

Table 7

Calculated Database for Türkiye

Year	Vehicle Counts	PDT	DIT	ELV
1961	0	-31	0	0.003
1964	1000	-28	3	0.003
1966	1581	-26	5	0.004
1975	2231	-17	14	0.02
1990	2000	-2	29	0.05
1995	2837	3	34	0.06
2005	3643	13	44	0.12
2022	3636	30	61	0.106

When linear correlation analyses were conducted for the Turkish data in Table 7, vehicle counts were taken as the dependent variable, while PDT, DIT, and ELV values were taken as independent variables. Upon reviewing the results for Türkiye,

Vehicle Counts and PDT = 0.18485.

Vehicle Counts and DIT = 4.00582

Vehicle Counts and ELV = −0.02306.

There is little to no linear relationship between the production of the alternative vehicle and the usa of the M113. This suggests that the introduction of the alternative vehicle does not significantly impact the usa of the M113. There is a very high linear relationship between design integrity and M113 usage. This indicates that an increase in design integrity is strongly associated with an increase in the usa of the M113. However, this positive correlation might be interpreted negatively, suggesting that the sustained usage of the M113 may hinder the development of vehicles with higher design integrity. There is a negative relationship between the ELV (Economic Level Value) and the increase in the number of M113s. This implies that an increase in the country's budget leads to a decrease in the number of M113s. This may indicate a shift towards the development or utilization of other vehicles. Economic fluctuations also negatively impact the ELV, as they are a significant factor in reducing defense budgets.

Table 8

Calculated Database for USA

Year	Vehicle Counts	PDT	DIT	ELV
1960	0	-21	-21	0.47
1964	1000	-17	-17	0.53
1966	1581	-15	-15	0.66
1970	18000	-11	-11	0.83
1980	22000	-1	-1	1.43
1990	18000	9	9	3.25
1994	20000	13	13	3.08
2003	18000	22	22	4.4
2005	13700	24	24	5.33
2007	6000	26	26	5.89
2020	4819	39	39	7.78

When examining the linear correlation analyses for the USA data in Table 8,

Vehicle Counts and PDT = 0.1644

Vehicle Counts and DIT = 0.1644

Vehicle Counts and ELV = 0.9438.

When examining the linear correlation analyses for the USA data in Table 6, it was found that due to the alternative vehicle usage being the same as the vehicle used for design integrity (Bradley vehicle), the PDT and DIT values were the same. Within the scope of PDT and DIT values, there was a low positive linear relationship between the number of M113s and the number of alternative vehicles developed. The prolonged high production of M113 vehicles has negatively impacted this relationship. Additionally, a linear relationship was observed between ELV (Economic Level Value), which represents an increase in the number of M113s, and the budget. It was observed that the increased budget led to a rapid increase in the number of vehicles, contributing to the decline in M113s. The concrete decline in M113s in USA strategies occurred with the decrease in M113 sales to other countries.

For example, in the USA, the design of the Abrams Main Battle Tank and the Bradley Tracked Personnel Carrier is within a framework of complementarity, which constitutes design integrity and can be described as a sustainable design movement (Congressional Budget Office, 2021). It has also been observed that many developing countries lack the same level of design integrity and sustainable design practices. Currently, there is no personnel carrier vehicle supporting the Altay Main Battle Tank in full design integrity (BMC, 2023), but these features are partially presented in the vehicle that is Otokar’s Tulpar, which is produced with the prototype of Altay MBT (Otokar, 2021). However, since the main battle tank, which BMC is trying to put into mass production, has undergone changes and armoring works within the framework of various operational capabilities, its design integrity has seriously decreased in terms of physical dimensions. Until 2022, the Altay Main Battle Tank lacks design integrity with any tracked personnel carrier in Türkiye.

M113A1: As a result of the multiplication of general width, length and height values, M2 Bradley has a volume value of 32.56 cubic meters; It has an overall volume value of 70.26 cubic meters. This difference has occurred with the US army's strategy of being able to respond to different missions by making armor package developments or weapon system developments instead of changing vehicle models in the face of future armor updates. This situation can also be called sustainable design strategy. Instead of the cost of vehicle production from scratch and the loss of time, general geometries that would accommodate many modernizations were designed in coordination with the Abrams Main Battle Tank and presented to the US army. The fact that the volumetric difference between the M113 and the Bradley is so high has a direct relationship with the areas to be covered by future armor systems, protection levels and weapon systems that can be added.

Conclusions

In this empirical study, where ARIMA analysis was conducted with limited data and resources, followed by Pearson correlation analysis, the relationship between dependent and independent variables emerged. Despite the limited data, the ARIMA analyses conducted for the inventories of both sample countries managed to maintain reliable numerical assessment coefficients. It is understood from the literature that studies in design strategies, particularly in the defense sector and sustainable design strategies, are often presented with hidden or high economic costs. Such studies conducted by countries for their own strategies are crucial for a sustainable world, and they highlight the importance of countries designing their product strategies well to gain economic advantages.

According to the results of the analysis, it is evident that due to periodic conditions such as the Vietnam War, there was a need for high production of M113s in the USA inventory. As a result of feedback received, a series of vehicles, including Bradley, were introduced within the framework of design integrity in 1981. Subsequently, a gradual reduction of M113s from the inventory was observed based on the modernization of the two vehicles and the efficiency gained. The linear correlation relationship between M113 and Bradley corroborated this situation. Despite the increase in Bradley vehicles accompanying the decrease in M113s, the significance of the linear correlation supported the hypothesis that, in the case of a vehicle created with sustainable design, the M113 would be phased out. Examining the situation of M113s in the inventory of Türkiye reveals a definite linear relationship between the inability to develop a vehicle with design integrity and the number of M113s. There is also a partial linear relationship between the number of M113s and the modernized M113s introduced as alternatives. The fact that some modernized vehicles are as old as certain M113s negatively affects this linear relationship, indicating the ongoing need for alternative vehicles. In the 61-year-long process, it is observed that alongside Türkiye’s flagship project, the Altay MBT, there is no tracked personnel carrier vehicle with design integrity. There is no vehicle with the possibility of integrity or change of important parts directly affecting mobility or protection, similar in size to the Altay MBT.

The popularization of the concept of sustainable design in the 1980s, along with the US army's production of the Abrams tank and the Bradley personnel carrier within their design integrity, has influenced the understanding of design integrity within the context of sustainable design today, despite not being explicitly termed as such in the 1980s. Design integrity, which led to reduced expenses on maintenance, repair, and personnel training during that period, is now considered a component of various sustainable design strategies. In this context, sustainable product design strategy is a design strategy directly related to the subject. It can be said that it is correct in terms of economic advantages that technically developed countries should implement sustainable product design strategies in their armored vehicle strategies. However, it is obvious that design strategy alone cannot achieve a result. Developed countries must have professional and comprehensive units in their armies that deal with this issue.

When examining the situation from the perspective of the Republic of Türkiye, the 62-year-old M113 adventure continues with various modernizations and although it has designed a main battle tank, it is seen that there is no personnel carrier with the design features of this vehicle. M113’s have not yet reached their peak in the inventory. Contrasting this with the US Army inventory, we can see 1981 as the entry of the Bradley vehicle into the inventory and the final peak of the M113 vehicle (The New York Times, 1981). This means a 21-year period in which the USA analyzes its military needs within the framework of sustainable design strategies and produces new vehicle designs. Within the framework of the feedback obtained from the M113 over the 21-year period, modernizations were made with variants such as A1 and A2, and the new design was also developed within the framework of army needs. It is understood that such a design strategy can be implemented as a result of the army receiving direct, rapid and comprehensive feedback from the field and processing it comprehensively. While there may be certain reasons why such works have not emerged clearly in Türkiye's 62-year adventure, it can also be said that it has gained production capability with modernizations.

Although developing countries such as the Republic of Türkiye are turning to armored vehicle modernization as an effective solution in terms of obtaining the number of operational vehicles in the short term, it is understood that it is also a very inefficient solution in the long term. Developing military technologies bring higher-volume armor packages to the agenda. In addition, when higher volume weapon systems come with them, more than the modernized vehicle can carry is integrated into the vehicle. The balance of elements within the design is disrupted. The usable volume of the vehicle is decreasing, and less personnel transportation is on the agenda at the expense of high costs. Due to various logistics activities (such as maximum width, length, height for transportation by train) and the age of the modernized vehicle, outward growth is restricted at certain points (additional armor packages added to the exterior), and this is an important factor in the vehicle not reaching the desired level of protection. The significant volume difference between the M113 and Bradley arises from this situation. The Bradley is designed for experimental and futuristic threat levels, including an electric power train system. This includes weapon systems. Except for the armor packages and weapon systems that have been assembled since 1981, the radical change in the main body has been less than 15%.

Recommendations

For countries to determine their design strategies in the defense sector, they need to prepare larger and more advanced datasets. There are studies in which empirical approaches are used to investigate the relationship between factors such as technological advancement, economy, and design strategy scientifically, and this study serves as an example in this field. However, due to the limited data and workforce, the study can be considered an example of the approach rather than what institutions can follow. With larger databases, ARIMAX studies can also be conducted alongside ARIMA, eliminating the need for an additional Pearson correlation analysis. The definitions made as independent variables can be directly analyzed in ARIMAX. A method has been practically presented in the literature that enables technology, design, and industry to determine policies based on concepts that can impose design constraints and numerical product quantities. Thus, a practical approach has been proposed for technology, design, and directly from the industry, which institutions or individuals can use.

It is also suggested that developed and developing countries should base their land forces on a sustainable product design strategy in terms of a sustainable world, a sustainable economy, and highly efficient use. The tracked personnel carrier and the main battle tank must be designed with integrity (geographical conditions may dictate the types of military vehicles required). The user army must have comprehensive units that can receive, report, and process feedback from the field. These units should consist of not only civilian engineers but also personnel working in the field. These units should become a control mechanism that will put pressure on vehicle designs to be offered through the private sector. Army needs should be determined within the scope of long-term predictions, design constraints should be created; and the companies that will tender should comply with these constraints. The unit in question to be established within the army should update its predictions with continuous and active feedback. Updated forecasts should not be 180 degrees opposite to recent tenders. Such a mishap proves that the unit is not functioning properly and means a huge problem in terms of loss of money and time. Since no country will transparently share its design and design strategies in the field of defense with another country, the designs reflect the country's own knowledge and development. Design services cannot go beyond the solutions developed by the country where the service is provided to its own threats. For this reason, designs and data should be created with the developed or developing country's own data. Today, the fact that countries such as the USA, the UK, France, Germany, Italy, Japan, China and Russia have been developing their design and design strategies sincethe Second World War is directly related to their individual knowledge and institutional memory. For this reason, these countries still have the potential to develop designs that will lead the world in land vehicles. Although it is not impossible for developing countries to reach this position, it is possible to reduce the gap with the right strategy and personnel/units. It should not be forgotten that no country will transparently provide design services to another country in the field of defense. The quality of the service received is again related to the correct strategy and quality of the personnel, units or responsible units receiving the service.

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Genişletilmiş Özet

Giriş

Modern dünyamızın en büyük zorluklarından biri hâline gelen sürdürülebilirlik, sera gazı üretimini azaltmayı ve gelecek nesillerin yaşayabileceği bir dünya bırakmayı hedeflemektedir. Artan sera gazı emisyonları ve su tüketimi, ekoloji ve endüstrilerin sürdürülebilir devamı için bir tehdit hâline gelmiştir. İklim değişikliği, hem çatışmaların hem de hastalıkların arttığını gösteren eğilimlerle başlamıştır (Bowles et al., 2015). Bu durum, tüm insanlık için olumsuz bir dünya oluşmasına neden olmaktadır. İnsanlığın temel ihtiyaçlarından biri olan savunma, sınırsız teknolojilerin üretimi yoluyla doğaya en çok zarar veren ürünleri de içermektedir. Bu zarar sadece ekolojiyi değil, aynı zamanda ülkelerin ekonomilerini de etkilemektedir. Politik olarak, kullanılamayan ürünler üretmemek veya daha uzun ömürlü ürünler üretmek, kullanıcı ordular üzerinde olumlu ekonomik etkilere sahiptir. Bu senaryolardan ekolojik ve ekonomik olarak yararlanmak için savunma endüstrisinde sürdürülebilir tasarım ve endüstriyel tasarım arasındaki ilişki etkili ve sağlam politikalarla yönetilmelidir (Cooper, 1999).

Bu çalışmanın amacı, yıllar içinde Türkiye ve ABD'nin M113 adlı, dünya tarihine damgasını vurmuş bir paletli muharebe aracının envanterlerinin sayısal karşılaştırmalarını yapmaktır. M113'ü değiştirecek araç ve kullanılan tasarım stratejilerine dayalı karşılaştırmalı bir analiz deneysel bir şekilde gerçekleştirilecektir. Bu süreçte, her yıl için veri kümeleri oluşturmak için ülkelerin envanterlerine ilişkin açık kaynaklar incelenecek ve bu veri kümelerine ARIMA analizi uygulanacaktır. Bu analizdeki bağımlı değişken araç sayısı olacaktır. M113'ün yerini alacak aracın üretilene kadar geçen süre, M113 yerine sürdürülebilir tasarımla üretilen aracın üretilmesine kadar geçen süre ve verilerin toplandığı yıllar için ülkelerin savunma bütçeleri bağımsız değişkenler olarak atanacaktır. Daha sonra, ilişkileri ortaya çıkarmak ve deneysel çalışma sonuçlarına ulaşmak için Pearson korelasyon analizleri yapılacaktır.

Endüstriyel tasarım, bir ürünün özelliklerini belirlemekten, konsept tasarımına, malzeme seçiminden, üretim yöntemine, prototip üretiminden ürün geri bildirimine kadar birçok konuyla ilgilenen çok disiplinli bir alandır. Bu sorumluluklar, bu bilim dalının bir ürün fikrinden somut bir ürüne dönüşüm sürecinde aktif bir rol oynadığını göstermektedir (Xia, 2011). Ancak 1970'lerden bu yana olgunlaşmaya başlayan "sürdürülebilirlik ve sürdürülebilir tasarım" kavramları, günümüzde endüstriyel tasarımın ürün yaşam döngüsü çerçevesinde ve endüstriyel tasarımcılar tarafından gelecek nesillerin dünyasına zarar vermeden daha uzun süre dayanacak ürünler oluşturma hedefiyle eşleşmektedir (Bhamra ve Lofhouse, 2007). Ancak, küresel teknoloji geliştirme sürecinin önde gelen projelerinin ve en fazla yatırım yapılan ürünlerin savunma endüstrisiyle ilgili olduğu göz önüne alındığında, sürdürülebilirlik kavramının savunma endüstrisi alanında bilimsel ve etkili bir şekilde kullanılması gerektiği anlaşılmaktadır (Hellyer, 2018). Özellikle, ürün maliyetlerinin oldukça yüksek olduğu savunma ürünlerinin maliyet etkin bir şekilde tasarlanması ve kullanılması gerektiği anlaşılmaktadır. Dünya çapında 80000'den fazla M113 zırhlı aracın üretildiği ve 50'den fazla ülkenin bunları operasyonel olarak kullandığı göz önüne alındığında (ORYX, 2022), gelişmiş ülkeler ile diğerleri arasındaki fark (ürün stratejisi) net bir şekilde görülecektir (Nuckols ve Cameron, 2016).

1970'ler ve 1980'lerden bu yana aktif olarak karşılaşılan sürdürülebilir tasarım kavramı, çeşitli savaşlar ve endüstriyel üretimin artışı ile kuvvetlenmiştir. Sera gazı emisyonları (karbondioksit (CO_2), azot oksit (N_2O), metan (CH_4) ve ozon (O_3)), endüstri devriminden sonra daha da artmış ve bu dönemde endüstri ve savaş faaliyetleri gelişmiş teknoloji ile gerçekleştiği için çevresel felaketler ciddi bir sorun hâline gelmiştir (Didenko et al., 2017). Ürünlerin daha az karbon emisyonu oluşturmasını sağlamak için eco design (ürün yaşam döngüsü çerçevesinde çevre dostu bir yaklaşım, doğada kolayca yok olabilen ürünler) ve yeşil tasarım (ürünlerde doğaya daha az zarar veren malzemelerin kullanımı) gibi tasarım stratejileri uygulanmıştır. Süreç ilerledikçe sürdürülebilir tasarım stratejileri de günümüze kadar geliştirilmiştir (Tischner, 2001). Birçok ürünü tek bir üründe toplamak, çok daha az enerji ve malzeme gerektirdiğinden, sürdürülebilir tasarım stratejisi kapsamına alınmıştır. Ürünleri uzun ömürlü ve dayanıklı hâle getirmek ve bakım maliyetlerini azaltmak hem ekonomik hem de çevresel açıdan sürdürülebilir ürün stratejileridir (European Commission, 2022).

M113 Paletli Zırhlı Araçları ve Modernizasyonları

M113 paletli zırhlı aracı, 1960'larda Amerika Birleşik Devletleri tarafından sahaya sürülmüş olup Vietnam Savaşı'nda önemli bir avantaj sağlamıştır (Defense News, 2016). Alüminyum kullanımı sayesinde yüksek hareketlilik kabiliyeti sağlamış ve Birinci ve İkinci Dünya savaşlarında kullanılan savunma ürünlerinin teknolojik gelişimine bağlı olarak tasarımında büyük değişiklikler yaşanmıştır (Carter, 2015; Willey ve Hudson, 2017). M113'ün tasarım özellikleri arasında, lojistik açıdan kolay üretim ve taşınabilirlik ön plana çıkmaktadır (Robinson ve Kosmatka, 2011). Zamanla yapılan yenilikler ve varyantlar aracılığıyla, güç aktarma sistemlerinin geliştirilmesi, operasyonel menzilin artırılması ve mobil yeteneklerin iyileştirilmesi sağlanmıştır (Webster, 1981; Army Technology, 2004). M113'ün dünya genelinde geniş bir kullanım alanı bulunmakta olup birçok ülke kendi ihtiyaçları doğrultusunda modernizasyonlar gerçekleştirmektedir (BAE Systems, 2011). Örneğin, Türkiye'de FNSS şirketinin M113A4 varyantı ve Avustralya'da BAE Systems tarafından tasarlanan M113A S4 varyantı bulunmaktadır. M113 zırhlı aracı, tarihsel olarak önemli bir rol oynamış ve farklı varyantlarıyla dünya genelinde yaygın olarak kullanılan bir ürün olmuştur. Türkiye'nin de envanterinde aktif olarak kullandığı bu araç, sürekli olarak yenilenmekte ve modern savaş ihtiyaçlarına cevap verecek şekilde geliştirilmektedir (ASFAT, 2020).

Yöntem ve Analizler

ARIMA Modelleme yaklaşımı, iki örnek ülkenin araç sayılarını zaman içinde karşılaştırmalı olarak analiz etmek için uygulanacaktır. Örnekleme ülkelerin sürdürülebilir tasarım stratejilerini anlamak için M113 sonrası altermatif araç geliştirme süreleri, tasarım bütünlüğü içinde alternatif araç geliştirme süreleri ve ekonomik seviyelerin etkileri bağımsız değişkenler olarak uygulanacak, yıllara göre araç sayıları ise bağımlı değişkenler olarak uygulanacaktır. Bu parametreler üzerinde doğrusal korelasyon analizi yapılacak ve bağımlı ve bağımsız değişkenler arasındaki doğrudan veya negatif ilişkiler ortaya çıkarılacaktır. ARIMA modeli, genellikle ARIMA (p, d, q) olarak gösterilir, 'p' otoregresif bileşenin sırası, 'd' fark derecesi ve 'q' hareketli ortalama bileşenin sırasıdır (Shumway ve Stoffer, 2006). ARIMA modelleri, zaman serisi verilerinde farklı standart zamansal yapıları yakalama yeteneğine sahiptir ve özellikle durağan olmayan davranış sergileyen zaman serisi verilerini modellemede kullanışlıdır. ARIMA analiz sonuçlarına göre bir sonraki adım Pearson korelasyon katsayısı olacaktır. Bu, iki değişken arasındaki doğrusal ilişkinin gücünü ve yönünü ölçmek için kullanılmakta ve genellikle 'r' olarak gösterilmektedir (Field, 2017). Sürdürülebilir tasarım stratejilerinin çalışmadaki araçlara ve politikalara tanımlanmasında izlenecek resmi direktifler ise Avrupa Komisyonu’nun EcoDesign direktifleri olmuştur. Buna göre, enerji ve kaynak verimliliğini, yeniden kullanılabilirliği, geliştirilebilir tasarımı, tamir edilebilirliği, döngüsel malzeme kullanımını ve geri dönüştürülmüş malzemelerin kullanımını sağlamak amaçlanmıştır (European Commission, 2022). Çalışmada yapılan analizlerle, Türkiye Cumhuriyeti ve Amerika Birleşik Devletleri'nin envanterlerindeki M113 araçlarının adetleri üzerinde nicel bir analiz yapılması gerekmektedir. Bu analiz ile ülkeler arasındaki tasarım ve askerî stratejilerin farklılıkları anlaşılacaktır.

Bulgular

Türkiye ve ABD'nin envanterindeki M113 zırhlı araç sayıları üzerine ARIMA analizleri ve doğrusal korelasyon analizleri gerçekleştirilmiştir. ABD'deki M113'lerin envanterden çıkarılma süreci ve Türkiye'deki M113 sayılarının analizi yapılmıştır. ABD'de daha karmaşık bir modelin ortaya çıkması, daha fazla veri toplanmasından kaynaklanırken Türkiye'deki sonuçlar sınırlı verilere dayanmaktadır. Analiz sonuçlarına göre Türkiye verilerinin daha güçlü tahmin değerine sahip olduğu görülmektedir. Türkiye ve ABD verileri üzerinde yapılan doğrusal korelasyon analizleri, ülkelerin M113 kullanımını etkileyen faktörleri göstermiştir. Özellikle, tasarım bütünlüğü içinde araç geliştirilmesi süresi ile M113’lerin yıllara göre sayısı arasında güçlü bir ilişki olduğu ortaya çıkmıştır. Bununla birlikte, ekonomik seviye değerinin artmasıyla M113 sayısında azalma görülmüştür. Bu durum, diğer araçların geliştirilmesine veya kullanımına bir geçiş olarak yorumlanabilmektedir. M113'lerin envanterdeki durumunu anlamak için yapılmış bu emprik çalışma izlenen politika, araç sayıları ve ekonomik yönden ilişkilendirilerek ülkelere özgü çeşitli sonuçlar ortaya koymuştur.

Sonuç ve Öneriler

Bu emprik çalışmada, sınırlı veri ve kaynaklarla gerçekleştirilen ARIMA analizi ve Pearson korelasyon analizi ile bağımlı ve bağımsız değişkenler arasındaki ilişki ortaya çıkarılmıştır. Sınırlı veriye rağmen, örnek ülkelerin envanterleri için gerçekleştirilen ARIMA analizleri güvenilir sayısal değerlendirme katsayılarını korumayı başarmıştır. Ülkelerin kendi stratejileri için yaptıkları savunma çalışmalarının sürdürülebilir tasarım stratejileri ile gerçekleştirilmesi durumunda ülke ekonomisi ve ihtiyaçları açısından avantaj oluşturabileceği görülmekle birlikte literatürde çeşitli ürünlerde de bu durum doğrulanmıştır.

Analiz sonuçlarına göre, Vietnam Savaşı gibi olaylar nedeniyle ABD envanterinde M113'lerin yüksek üretimine ihtiyaç duyulduğu açıkça ortaya çıkmıştır. Geri bildirimler sonucunda, 1981'de tasarım bütünlüğü çerçevesinde Bradley aracının sahaya sürüldüğü görülmüştür. Bu sebeple de M113'lerin envanterdeki azalışı analiz sonuçlarında ortaya çıkmıştır. M113 ve Bradley arasındaki doğrusal korelasyon ilişkisi bu durumu desteklemiştir. Bradley araçlarının sayısındaki artışa rağmen M113'lerin azalışıyla, doğrusal korelasyonun önemi, sürdürülebilir tasarımı temel alan bir aracın üretilmesi durumunda M113'lerin aşamalı olarak kullanımdan kaldırılacağı hipotezini desteklemiştir. Türkiye envanterindeki M113'lerin durumu incelendiğinde ise tasarım bütünlüğüne sahip bir araç geliştirememenin yani Altay tankı gibi temel araçlarla doğrudan hareketi veya korumayı ilgilendiren ana parça ilişkisine sahip bir aracın olmaması ve M113'lerin sayısı arasında kesin bir doğrusal ilişki olduğu görülmektedir. M113 modernizasyon stratejilerinin kısa zamanda fazla operasyonel araç elde etmek için uygun olduğu ancak uzun vadede hiç de verimli olmayan bir strateji olduğu görülmüştür. Türkiye'nin bayrak gemisi projesi olan Altay tankı ile birlikte, 61 yıllık süreçte tasarım bütünlüğüne sahip paletli personel taşıyıcı araca sahip olmadığı anlaşılmıştır. 1980'lerde sürdürülebilir tasarım kavramının popülerleşmesi ve ABD ordusunun Abrams tankını ve Bradley personel taşıyıcısını tasarım bütünlüğü çerçevesinde üretmesi, 1980'lerde sürdürülebilir tasarım olarak adlandırmasalar da tasarım bütünlüğünün bugün sürdürülebilir tasarım altında tanımlanmasını etkilemiştir. Bu, o dönemin koşullarında bakım, onarım ve personel eğitimi üzerindeki harcamaları azaltan tasarım bütünlüğünün, bugün çeşitli sürdürülebilir tasarım stratejileri altında yer aldığı görülmektedir.

Çalışma ile savunma sektöründe tasarım stratejilerini belirlemek için ülkelerin daha büyük ve gelişmiş veri kümeleri hazırlaması gerektiği ortaya çıkmıştır. Paletli personel taşıyıcı ve ana muharebe tankı tasarımı bütünlükle yapılmasının önemi ve kullanıcı orduların sahadan geri bildirim alabilecek, raporlayabilecek ve işleyebilecek kapsamlı birimlere sahip olmasının ekonomi ve sürdürülebilirlik açısından avantajlar sağlayacağı ortaya çıkmıştır. Literatürde teknoloji, tasarım ve endüstrinin tasarım kısıtlamaları ve sayısal ürün miktarları analiz edilerek izlenen politikalar arasındaki ilişkiler politikalara rasyonel değer kazandıran bir yöntem uygulamalı olarak sunulmuştur. Böylece teknoloji, tasarım ve endüstri kapsamındaki kurum, kuruluş veya bireylerin bu alanda kullanabileceği teorik bir yaklaşım önerilmiştir.