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A Study on Electric Cars Using Bertopic Topic Modeling Technique

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ABSTRACT

Today, with the rapid development of technology, the use of environmentally friendly and innovative automobiles continues to increase. Among these automobiles, there is a growing interest in electric vehicles, but it is of great importance for the acceptance of these vehicles to quickly resolve the issues that consumers find inadequate. The rapid increase in the number of potential customers leads to a significant expansion in the volume of data generated and necessitates the use of advanced analytical techniques to process this data effectively. In this context, artificial intelligence and natural language processing (NLP) methods play an important role in the processes of interpreting, classifying and predicting customer data. Innovative methods and applications provide significant economic advantages to businesses in solving problems. The aim of this study is to determine the expectations, concerns, criticisms and complaints of consumers towards electric cars and to provide suggestions to manufacturers and marketers to develop solutions. In the study, BERTopic topic modelling technique was used to determine around which topics customer complaints are concentrated. As a data set, the complaints made to a electric car company between 1 January 2024 and 1 January 2025 were classified and analysed. The findings obtained can contribute to businesses to better meet customer expectations for electric cars and positively influence their purchasing behaviour.

Keywords: Customer Complaint Classification, Topic Modelling, BERTopic, Innovation, Electric Cars.

JEL Classification Codes: M31, M39, C52

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INTRODUCTION

Depending on the expectations of individuals, complaints have a very important place in a wide range from ordinary events in daily life to organisation arrangements. Complaints can be made verbally, through face-to-face meetings, by e-mail or post, or by filling out applications such as consumer complaint forms (Dwivedi et al., 2007). Complaints can also be made directly or indirectly. Complaints are generally gathered on issues such as customer-employee relations, product return, product defect elimination, timely supply or delivery of products (Aşkun, 2015). While complaints are an attempt to find a way out for the customer to solve the problems, they are a bundle of responsibilities that need to be focused on, resolved and fulfilled for the companies. Complaints are not a desirable situation for businesses. Because the results of complaints are costly. However, in return for this cost, businesses get invaluable information. In essence, complaints are the 'voice' of the customer who points to a problem experienced and reflects the feelings and thoughts of the person who experiences and feels the problem. Businesses have to hear this voice. Businesses receive and evaluate customer complaints and requests through the customer relations units they establish, and implement measures that can provide solutions.

Being aware of this situation, businesses develop channels that encourage customer complaints in order to improve their goods and services and increase their performance (Yang et al., 2018). When customer complaints are systematically transformed into information, they become a valuable data source for the business. To obtain important clues from this data source, businesses need to design, build, operate and continuously improve systems to manage complaints (Bosch & Enriquez, 2005). Reviewing the data based on customer complaints in relation to the weaknesses in the internal and external operation process of the company requires a systematic operation to eliminate product-related and operation-related inadequacies (Tuertmann et al., 2016). It is not enough for businesses to handle complaint-oriented data. It requires taking measures to turn complaints into

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satisfaction and increase customer loyalty to the company (Stauss & Schoeler, 2004). Consumers' requests and expectations for the elimination of defects in goods and services can be evaluated within the scope of complaints.

It is important for businesses to know the problems that lead to customer dissatisfaction and to reach decisions that will ensure their own development with the feedback received from the customer. Especially considering the current situation of electric cars, which are still under development in our country (Zhu et al., 2022), many electric car consumers cannot reach satisfactory information about electric cars and have difficulties in accessing reliable information (Hu et al., 2023). Deficiencies in customer understanding of electric vehicles, combined with pre-established barriers in the minds of consumers, may hinder consumers' intention to purchase electric cars (Wang et al., 2012). Like every innovation, new generation automobiles have emerged as a result of a need. Meeting the requirements can ensure the widespread acceptance of new generation cars in the society.

In order to carry out the new product acceptance process effectively, automobile manufacturers must carefully identify the needs and expectations of customers. In this context, they must use customer complaints as a source of data for communication, performance, motivation and decisions to be implemented. They can only position their own performance measurements in this context. At the same time, they are expected to make the communication language they use understandable to their target audience. Thanks to the quality and complaint systems to be created by the enterprises, it is important for them to access accurate information in order to measure the loss of performance in the functioning of the existing system within and outside themselves, to evaluate the results and to make decisions that will be reflected on the customer. In this context, customer complaints are a data source for businesses to demonstrate a traceable change and contribute to new product acceptance. By using the data source, they can plan the design, production, purchasing, after-sales service processes of the new generation automobiles they will develop in a way to meet customer expectations. When services for customer complaints are not followed up within reasonable periods of time and information is not provided for the solution of the problem, the perception of customers towards products and services becomes negative and spreads rapidly among the target audience through word of mouth and social media. In today's world where the internet and communication are gaining speed, businesses can offer complaint platforms and online feedback to customers.

Customer complaints, practices that contribute to service areas such as design, purchasing, incentives and practices, product quality, product maintenance, product performance and safety, product maintenance cost, after-sales warranty period in accordance with expectations are expected to facilitate the general acceptance of new generation products in society.

LITERATURE

When the literature is examined, there are many studies on the acceptance of new product automobiles with different modelling. Değirmenci and Breitner (2017) examined the purchase intentions of consumers and concluded that the positive contribution of electric vehicles to the environment is a strong determinant of customers' purchase intention, valuation behaviour and attitudes. Featherman et al. (2021) state that in the adoption of innovative products, concerns about future gains and losses, social impacts, as well as beliefs about the expertise and reliability of manufacturers are determinant. The perception that electric vehicles are useful contributes significantly to increasing the value of technological products (Ray et al., 2019). Consumers' cognitive knowledge levels and expectations regarding the positive and negative consequences of electric cars in the future lead them to express their perceived risk as complaints. Complaints are concrete manifestations of these concerns and expectations. The risk perceived by consumers "in the face of uncertainty" (Schiffman & Kanuk, 2014, p.153) is their predictions about the consequences of their purchasing decisions. In cases where there is not enough attitude towards new products, extracting and classifying the implicit meanings in the complaint statements about the product may facilitate the measures that can be taken against the product.

Obtaining the energy that people need to meet their needs, increasing costs in energy, environmental pollution, health problems, researches to solve problems lead to the emergence of new technological developments and products. Electric cars are a very reasonable and logical project developed to solve the energy crisis and environmental problems. This situation attracts people and makes the future of electric cars bright. Therefore, efforts to develop electric vehicles (EV) are encouraged and are increasing rapidly in many countries to solve the energy crisis and environmental problems. However, current EVs battery technology has some challenges, such as its use in heavier vehicles, limited range and high cost. In order to overcome these challenges, new generation technologies developed in laboratory environments, such as lithium-air, metal-air

and solid-state batteries, have the potential to radically solve these problems. Intensive battery research and development is expected to contribute to the development of electric vehicles in a way that will appeal to a wider audience. However, as a result of the increasing interest in electric vehicles, it is predicted that electric vehicles will increase annual electricity consumption by 30 per cent. Because, the use of electric power supply connected to the charging of electric cars at the same time increases electricity consumption. According to calculations, electricity consumption is expected to reach 200 terawatt hours in the world by 2030 (Cerruti et al., 2023). Therefore, the establishment of smart grids in electricity distribution requires making energy grids more efficient (Alam & Krishnamurthy, 2021), regulating electricity supply, commissioning supply systems, and protecting consumers against uncontrolled electricity surges (Heinisch et al., 2021). This requires strong co-operation between vehicle manufacturers and e-mobility service providers; rapid development of charging infrastructure and widespread use of electric vehicles; and co-operation between local authorities and electricity distribution operators (Corradi et al., 2023). As with many new products, consumers have significant concerns about the acceptance of electric cars. Therefore, in order for the early majority, which constitutes an important mass in terms of new products, to start purchasing, both the evaluations of the immediate environment and the communication, evaluation and sharing carried out through relevant websites and social media platforms are becoming increasingly important. In addition, comments on websites and social platforms provide users with the opportunity to share, comment, evaluate and form public opinion on different issues (Dagoula, 2019). Naturally, in this process, the perceptions, concerns, experiences and complaints of customers who purchase and use new products inevitably arise. Systematic collection and categorical classification of customer complaints facilitates the prioritisation of measures to be taken, efficient use of the product and planning. In this study, the content on the acceptance of new products where customer complaints are collected and categorised using the BERTopic technique developed to reveal the hidden meaning in customer complaints will be discussed.

ANALYSIS and CLASSIFICATION of CUSTOMER COMPLAINTS

In order for businesses to survive, it is possible for them to receive and analyse customer complaints about the goods and services they produce and to take appropriate measures in a timely manner and to eliminate inadequacies in their goods and services. They should receive customer complaints completely, categorise the complaints categorically and interpret them in a meaningful way. The data that customers express and reflect their emotions can be analysed by text mining and sentiment analysis methods. In general, when customer complaints are analysed, it is seen that there are complaints containing negative emotions. When complaints are analysed correctly, the feedback to be given to customers can be transformed into strategies that will increase customer satisfaction (Medhat et al., 2014).

In the rapidly growing electric car market, customer complaints are also increasing rapidly. In this process, Consumers have expectations that the next generation of cars should solve problems related to fuel consumption, safety system, charging (Alkan & Köksal, 2024).

Manual categorisation of customer complaints leads to time-consuming and high error rate results. It is predicted that it will be useful to effectively examine customer complaints with automatic classification and subject modelling techniques in order to make the results with less error.

CUSTOMER COMPLAINTS and BERTOPIC APPLICATIONS in the ELECTRIC CAR SECTOR

The electric vehicle sector is expanding rapidly and users' desire for environmentally friendly cars is increasing. The shortage of chips in the electric car industry, supply chain disruptions, fluctuations in energy prices, energy prices, increase in the cost of use of electric vehicles, decrease in the value of electric vehicles, price in the second-hand market, risk of electric shock and fire during maintenance and repair of electric vehicles, intensification of competition in the electric vehicle market and geopolitical rivalries also threaten the profitability of the sector.

In addition to the risks involved in all these processes, electric car users often complain about battery efficiency, charging times and range (Wang et al., 2023). It is seen that customers who use electric cars complain about charging stations, service services, technological software and hardware problems, and delivery times of the vehicles. Research using BERTopic shows that it helps to understand customer complaints and requests more quickly. Despite the difficulty of understanding and correcting biases in data, complaints can be automatically categorized into different categories with the BERToping natural language processing (NLP) approach (Supriyono

et al., 2024). In addition, BERT-based models can make more accurate content classifications by analysing the context of the texts in more depth.

APPLICATION AREAS OF BERTOPIC and FUTURE RESEARCH

BERTopic, developed as a topic modelling tool, combines all documents belonging to each class and formulates the conversion process into a single document for multiple classes. Highly dense clusters are formed, word correlations are analysed and different meanings and perspectives based on the meanings are determined (Grootendorst, 2022). In particular, the texts are analysed, sorted, reduced, cleaned of unnecessary data and broken down into the smallest parts to be analysed. For the first time, Wang et al. used BERTopic to determine the novelty level of articles and to identify possible topics in scientific article texts. Later, Meng et al. (2024) also used BERTopic for semantic analysis and topic modelling of research trends related to demand-driven energy management.

It is predicted that advanced topic modelling methods such as BERTopic used today can be used in the future not only to classify customer complaints but also to develop proactive improvement strategies. The findings obtained with BERTopic in this research suggest that electric vehicle manufacturers can make changes in product design and improve the user experience by using the results of analysing trends in customer complaints. At the same time, innovative approaches such as the BERTopic topic modelling technique have the potential to provide deeper insights to researchers in the industry.

METHOD

Topic Modelling and BERTopic

Customers' expectations and complaints about new products are formed according to the meaning they attribute to the physical characteristics, design, size, performance, comfort, range, fuel usage, charging and infrastructure and usefulness of the product. It is possible to reduce the complaints of the customers about the purchase intention, purchase and post-purchase processes into two categories. Purchase intention can be divided into various groups including social, cultural, economic, personal psychological and individual differences as well as environmental influences (Kotler & Armstrong, 2018). Complaints during the purchase process are focussed on the economic value of the product, product variety, operating cost (Olsen et al., 2021), payment methods and security, warranty, maintenance and repair services, and product lifetime. Post-purchase, complaints based on the customer's experience come to the fore: ease of charging, overall performance satisfaction, fuel/durability efficiency compared to conventional products. Understanding consumer perception at each stage of the decision-making process can help manufacturers improve product offerings while addressing concerns or dispelling misconceptions about electric car ownership. This stage plays an important role in determining consumer behaviour towards electric vehicles. In this study, the aim of this research is to determine the effect of the feedback given to consumers 'complaints about the new product on customers' acceptance of the new product.

Topic modeling technique and BERTopic word embedding techniques are used in the research. BERTopic word embedding technique was used in this research. According to Grootendorst (2020), the word embedding technique converts texts into vector representations and creates more accurate and meaningful topic headings by grouping these vectors. Especially in data sets with a high density of short texts, BERTopic produces more effective results.

With the transition to electric cars, solutions have been developed to meet some of the automobile-related needs of consumers. These include increasing the number of charging stations, developing the possibility of charging with all kinds of sockets, increasing the prevalence and number of charging stations (Brescia et al., 2023), shortening charging times depending on the type of vehicle, ensuring driving comfort and safety in vehicles, launching longer range vehicles, and establishing a comfort cost balance (Cerruti et al., 2023).

In this research, BERTopic topic modelling technique was used. BERTopic is used as a statistical text mining method to identify hidden topics in text data (Altıntaş et al., 2021). In the study, customer complaint data of TOGG, which is interested in the electric vehicle sector, for the year 2024 were analysed with BERTopic. The method (or parameters) preferred in the study was optimised to obtain the most accurate and effective output based on the results of the researcher's previous experience.

The data used in the research were obtained by data scraping method from sikayetvar.com, one of the complaint platforms. The complaint data of TOGG covers the complaints between 1 January 2024 and 1 January 2025. These data consist of Complaint Subject, Date, Time and Complaint content, and only complaints and date information were used in the study.

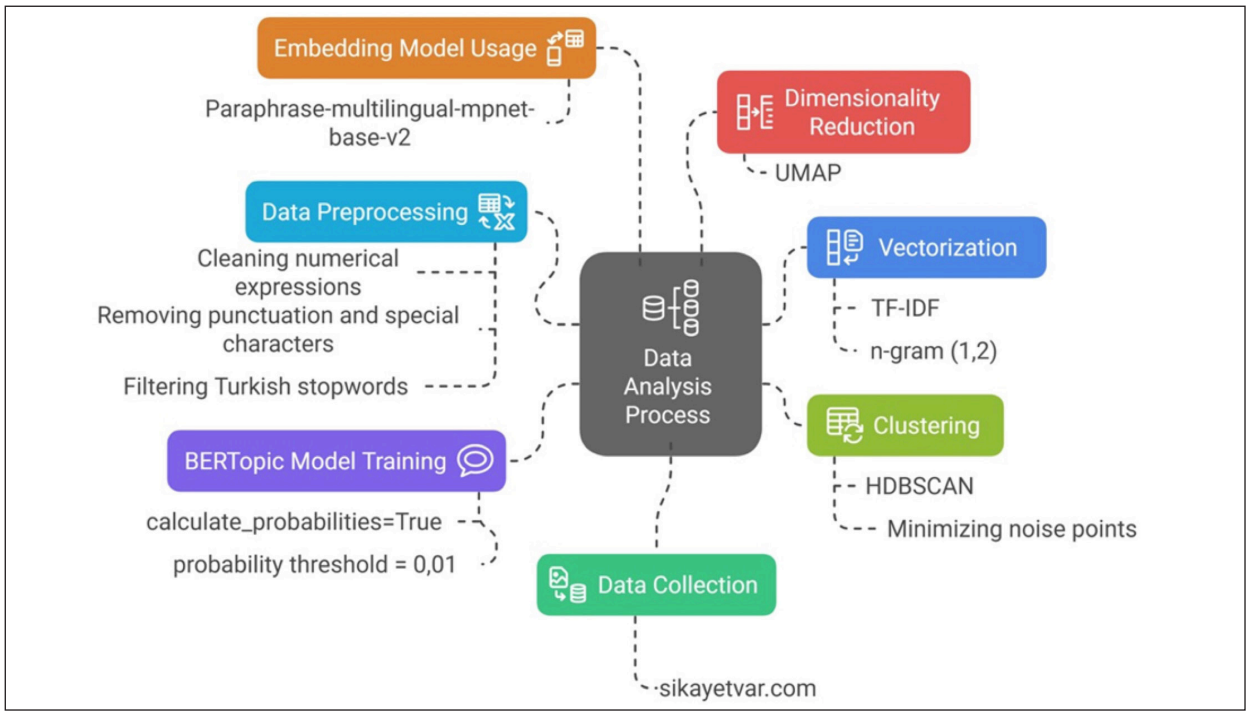

Figure 1. Data Analysis Process

In the process of topic modelling analysis on text-based complaint data, the paraphrase-multilingual-mpnet-base-v2 embedding model suitable for Turkish language was used (Mehak et al., 2023). This model was pre-trained for more than fifty languages and showed an effective performance in generating vector representations of texts.

Data preprocessing steps are very important to improve the quality of data used in natural language processing applications and to facilitate the analysis process (Khanbhai et al., 2021). Accordingly, various preprocessing steps were applied to clean and standardise the data. Firstly, numerical expressions in the text were removed. Then, punctuation marks and special characters were removed. Single-letter words that were unlikely to carry a significant meaning were eliminated. Excess spaces were normalised to make the text more consistent. In addition, Turkish stop words were filtered. These steps made the text cleaner and more suitable for analysis.

The TF-IDF vectorisation method was used for topic modelling and the n-gram interval was set to (1,2). This parameter was chosen to capture noun phrases that are commonly used in Turkish (Koruyan, 2022). UMAP algorithm was used for dimensionality reduction and clustering was performed using HDBSCAN. HDBSCAN parameters were optimised to minimise noise points and define the minimum cluster size. The BERTopic model was trained with the parameter calculate_probabilities=True and a probability threshold of 0.01 was set to reduce outliers (-1).

Once the model was trained, the reduce_outliers function was used to minimise noisy issues (outliers). This was done using both c-tf-idf and embeddings strategies. According to the results of the analysis, the embeddings strategy was chosen for further processing. Since the number of topics changes each time the algorithm is run, the model was run multiple times and the parameters were fine-tuned to determine the optimum number of topics and their distribution.

As a result of this iterative process, the number of noisy topics has significantly decreased and the topic distributions have become more balanced. As a result, the number of updated -1 complaints has significantly decreased and the topic distributions have become more balanced.

RESULTS

In this study, experiments were conducted using BERTopic to extract meaningful themes from complaint texts. In each experiment, the approximate number of topics varied between 20 and 30 and the parameters specified in the Methodology section were fine-tuned. As a result of these experiments, the optimal number of topics was determined as 20.

Outlier results that did not belong to any topic were assigned -1 and accounted for 3.48 per cent of all topics. Table 1 shows the frequency of complaint topics, their ratio to the total number of topics and the related markers/n-grams.

Table 1. Frequency of Complaint Threads

Topic	Count	Token/n-gram	Frequency	Rate(%)
-1	28	['voice', 'december date', 'key', 'right', 'lived', 'suddenly', 'seven', 'herd', 'a lot', 'said to be needed']	28	3,48
0	141	['energy', 'failure', 'energy system', 'system failure', 'update', 'error', 'my vehicle', 'energy system', 'battery', 'system']	141	17,52
1	106	['order', 'delivery', 'payment', 'I gave', 'registration', 'order', 'credit', 'bank', 'transactions', 'to be delivered']	106	13,17
2	102	['km', 'right', 'damage', 'on the road', 'to the right', 'accident', 'substitution', 'day later', 'difference', 'front']	102	12,67
3	77	['appointment', 'update', 'wrote', 'update', 'make an appointment', 'smart', 'problem', 'software', 'software-based', 'pull']	77	9,57
4	40	['credit', 'january', 'order', 'payment', 'invoice', 'month', 'campaign', 'campaign', 'campaign', 'month']	40	4,97
5	38	['replacement vehicle', 'substitution', 'part', 'damage', 'change', 'my vehicle', 'hour', 'appointment', 'right', 'in service']	38	4,72
6	33	['atatürk', 'istanbul', 'service', 'delivery', 'test', 'information about', 'monday', 'day later', 'stopped', 'far']	33	4,1
7	30	['clock', 'said', 'battery', 'failure', 'key', 'failure', 'called', 'ending', 'system failure', 'service']	30	3,73
8	29	['error', 'energy', 'km', 'etc', 'in service', 'we received', 'piece', 'standard', 'we received', 'in vehicle']	29	3,6
9	27	['our vehicle', 'employees', 'calling', 'need', 'these', 'from the service', 'saying', 'behind', 'someone is calling', 'someone']	27	3,35
10	26	['refund', 'my money', 'application', 'not done', 'call center', 'payment', 'center', 'number', 'call', 'my order']	26	3,23
11	24	['people', 'chassis', 'without taking', 'nothing', 'regret', 'irrelevant', 'wrong', 'you are doing', 'they did', 'obvious']	24	2,98
12	21	['fee', 'I will receive', 'paying', 'almost', 'shame on you', 'shame on you', 'lady', 'available', 'let it be', 'our pride']	21	2,61
13	17	['accident', 'I can't reach', 'söğütözü', 'ankara', 'glass', 'for days', 'with my vehicle', 'after', 'my vehicle', 'to your service']	17	2,11
14	15	['credit', 'thousand tl', 'campaign', 'campaign', 'credit campaign', 'payment', 'applied', 'wanted', 'to the bank', 'ongoing']	15	1,86
15	14	['appointment', 'izmir', 'trying to get', 'they don't give', 'I'm working', 'I'm complaining', 'in the car', 'my complaint', 'making an appointment', 'call']	14	1,74
16	13	['by me', 'they don't', 'cancel', 'charger', 'customer representative', 'representative', 'return', 'device', 'year', 'created']	13	1,61
17	12	['increase', 'gift', 'as of', 'type', 'credit', 'price', 'to take', 'spare', 'mart', 'insurance']	12	1,49
18	12	['stays', 'in between', 'closes', 'sometimes', 'faults', 'opens', 'went to service', 'comes', 'full', 'front']	12	1,49
Sum			805	100

The algorithm categorised 17.52% (141) of the texts related to the energy system as Topic 0. Similarly, 13.17% (106) of the texts related to ordering and payment processes were labelled as Topic 1. 12.67% (102) of the texts related to road condition and damage were categorised as Topic 2. 9.57% (77) of the texts about appointments and software updates are labelled as Topic 3. 4.97% (40) of the texts about payment and campaign information were assigned to Topic 4. 4.72% (38) of the texts about damage and replacement vehicles are labelled as Topic 5. 4.1% (33) of the texts related to Istanbul and service processes were categorised as Topic 6. In order to assess the distribution of text content, BERTopic provides a classification probability for each text, allowing the topic reliability to be analysed. In this context, texts about the energy system and faults are strongly associated with Topic 0, while payment and ordering processes are concentrated in Topic 1. Less represented groups, such as Topic 6, may have lower certainty in topic separation.

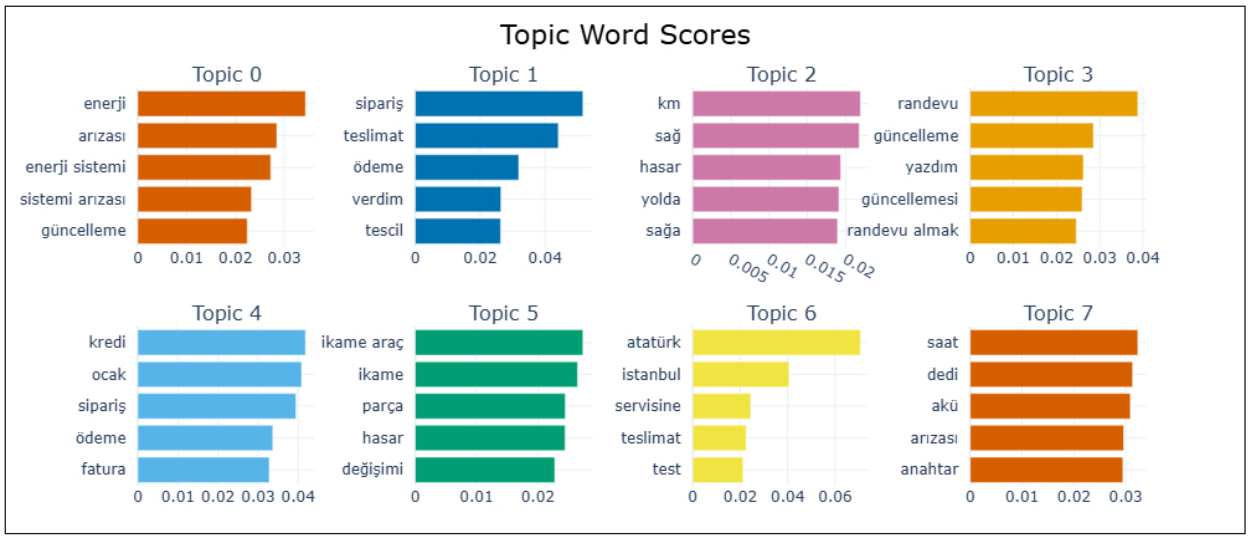

Figure 2. Distribution According to the Prominent Keywords of the Topics

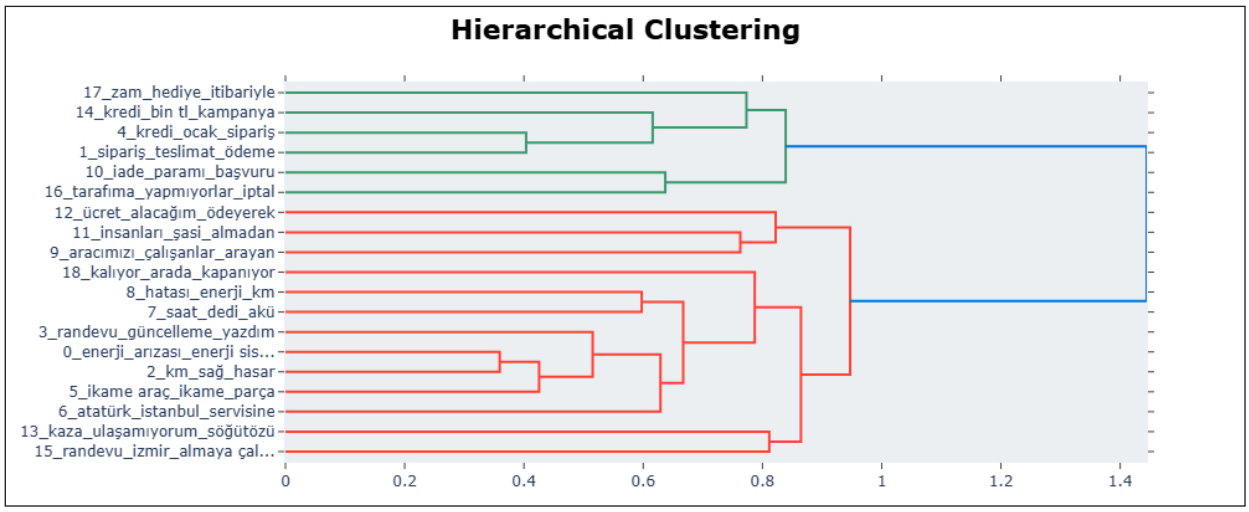

Figure 3. Hierarchical Clustering Dendrogramme

Thanks to its dynamic topic modelling feature, BERTopic combines word embedding and hierarchical clustering techniques to group complaint texts and identify prominent topics (Vermulst et al., 2024). As a result, eight different meaningful topics were identified from the unstructured text. Texts assigned a value of -1 by the model were considered outliers and were excluded from the analysis.

Figure 2 shows the distribution of topics according to their prominent keywords. Accordingly, Topic 0 is associated with energy failures and updates, while Topic 1 focuses on ordering and delivery processes. Topic 2 refers to vehicle damages and road problems, while Topic 3 is related to appointment and update processes. Topic 4 represents credit and payment transactions, while Topic 5 corresponds to spare vehicle and parts replacement processes. Topic 6 is related to service procedures and Topic 7 is linked to battery and energy systems.

The hierarchical clustering dendrogram shown in Figure 3 visualises the relationships between the identified topics. It is observed that Topic 3 (appointment and update processes) has a high similarity with Topic 0 (energy failures). Similarly, a close relationship was found between Topic 5 (replacement vehicle and parts replacement) and Topic 6 (service processes). This finding shows that users perceive vehicle maintenance and repair processes holistically and that there is a strong connection between these issues.

The time series analysis in Figure 4 shows the evolution of the topics over time. For example, while complaints about energy faults increase in certain periods, complaints about appointment and update processes tend to peak at different times of the year. This shows that customer complaints are affected by seasonal factors and tend to be concentrated in certain time periods.

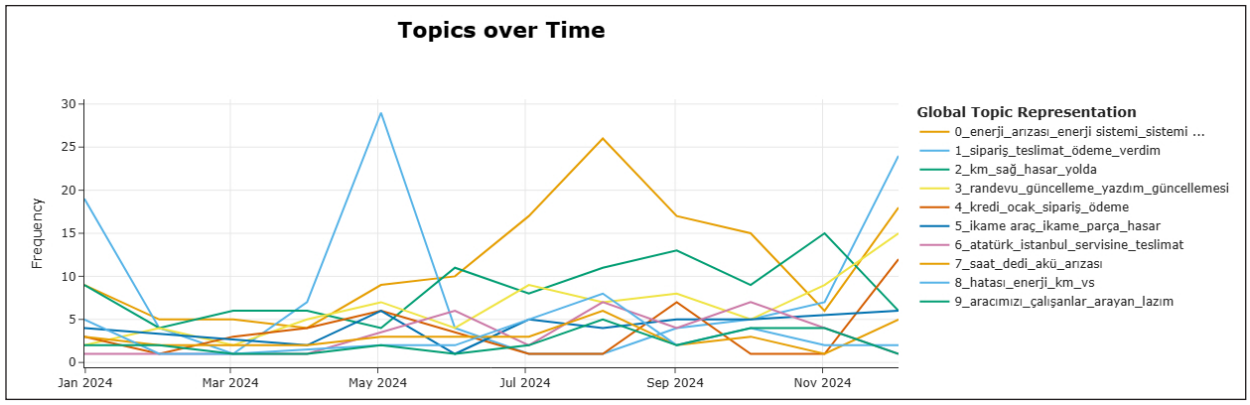

Figure 4. Time Series Analysis

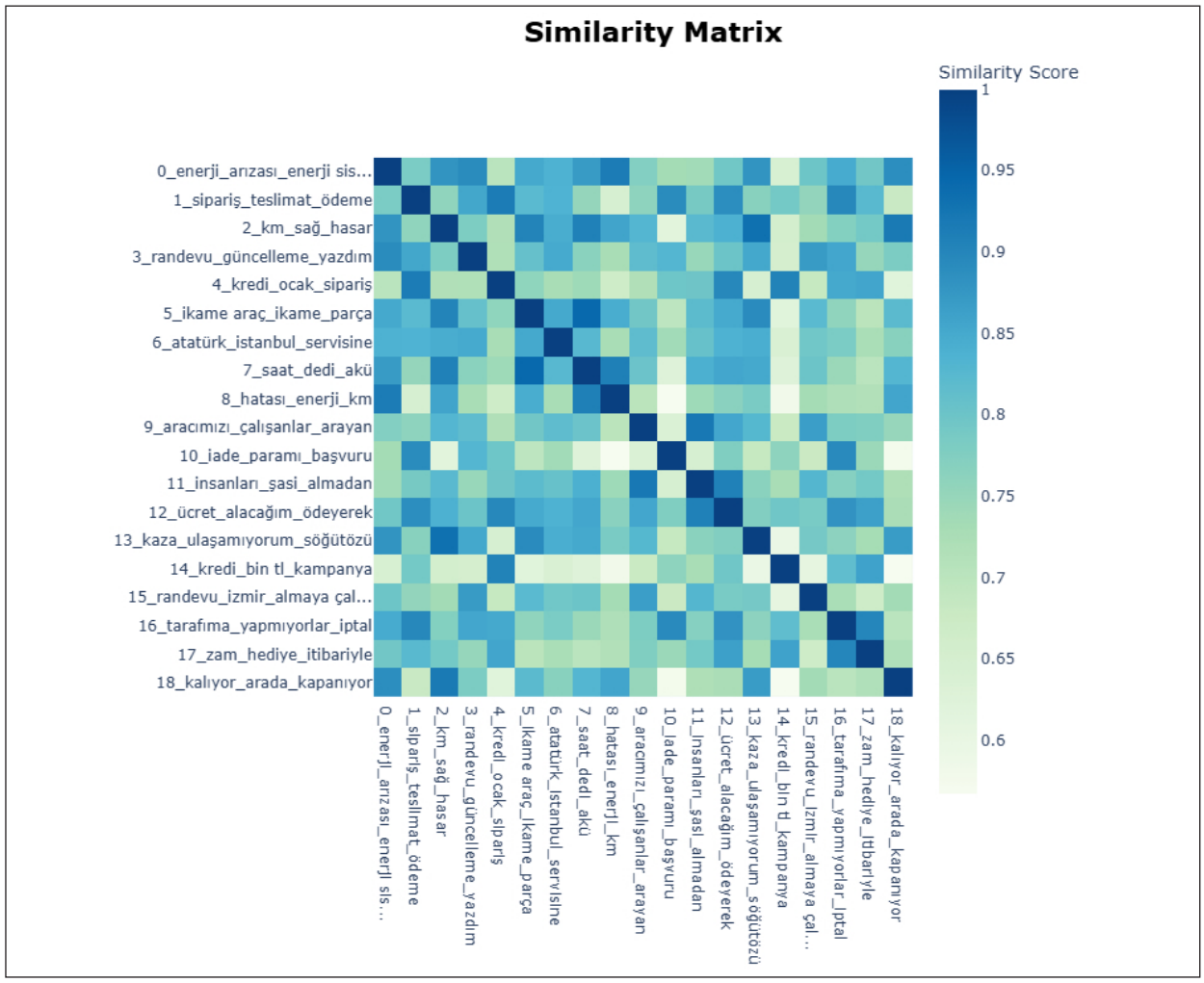

Figure 5. Similarity Matrix

The similarity matrix presented in Figure 5 quantifies the degree of relationships between the identified topics. In particular, the high correlation between energy failures (Topic 0) and battery and energy systems (Topic 7) reveals that topics related to vehicle power systems are interconnected.

As a result, the analysis obtained with BERTopic has enabled a systematic categorisation of customer complaints and revealed the relationships between different themes. This information provides valuable insights for increasing customer satisfaction and improving service processes. Future work could focus on modelling the temporal changes of the identified themes in more detail and performing a deeper analysis of customer feedback.

CONCLUSION

In this study, customer complaints are analysed and described. This situation, which affects the car acceptance process, also affects the diffusion of electric cars. As a result, the study has shed light on the following issues by revealing the critical areas and complaint patterns that concern customers: Customer complaints were categorised in 7 different areas such as 1-battery, malfunction, usage time key; 2-battery, order, payment, delivery, registration, energy failure system failure and energy systems; 3-damage, being on the road, robustness 4-making an appointment, appointment update, software update 5-credit, order, payment and invoice and 6-parts replacement, replacement vehicle, damage and replacement; 7- Istanbul, Atatürk airport, delivery test and service services. In the time-dependent analysis of the complaints; it is observed that orders increased in May, credit utilisation increased in September and October, and orders and deliveries took place in November. It is observed that other complaints continue with small changes throughout the year according to their characteristics.

The information generated through techniques such as BERTopic can help businesses monitor current improvements, identify gaps and optimise financial flows. Time-varying complaints, especially in a new and emerging electric car sector, can lead to the use of data mining and big data, accurate insights and better decision-making. Policy makers and financial institutions can support financing instruments with local inputs. It may offer investment and financing opportunities at regional and country level according to the developments in the electric automotive sector.

Especially for underdeveloped and emerging technologies, artificial intelligence transparency and efficiency seem to increase customer satisfaction and play a more effective role in the technological acceptance process. With the rapid growth of the electric car industry, accurately classifying and analysing customer complaints gains great importance. BERTopic and similar advanced topic modelling techniques stand out as an important tool in this process. Accurate categorisation of complaints not only contributes to product development, but also plays a critical role in creating strategies to increase customer satisfaction. For this reason, the use of BERTopic to analyse customer complaints in the electric car sector offers an important research topic and application opportunity in the future.

DISCUSSION

The classical methods of data collection to date are being replaced by the development of algorithmic capability, focusing on the collection of valuable information for detection-based situation monitoring and resolution. BERTopic offers a potential application for the identification of customer complaints. As the systems in the electric car sector become more complex, the type and scope of complaints will change in the future. This will lead professionals to integrate the data processed using BERTopic into AI-based data analysis. Furthermore, this process is also associated with technologies such as ML models (see e.g. Lin & Chen, 2024), DT (Urso et al., 2024), Internet of Things (Christou et al., 2022), Cyber-Physical Systems (Ulhe et al., 2024) and simulation (Darmawan & Sheu, 2021). In electric car production, collecting, verifying and analysing complaint information on issues such as order, appointment, maintenance, repair, damage, credit, financing, breakdown, energy systems and battery charging contributes to the adoption of new and innovative theoretical approaches in production, marketing and product acceptance processes. Securing complaint, maintenance and repair records as well as sensor data using a blockchain-based structure to support data analytics increases the possibility of accessing more reliable information and providing feedback. Thanks to new data analytics, it is envisaged to make significant contributions to the better diagnosis of problems as well as the production of more precise and robust, personalised solutions. It is inevitable that applications based on consumers' complaints and needs will support target-oriented efforts as well as increasing productivity of data-based and uninterrupted services in the context of artificial intelligence-supported feedback, guidance, registration, maintenance, payment, ordering, credit, etc. Services (Sala et al., 2023; Yigin & Celik, 2024).

The paradigm of the future in the automobile industry makes it possible to focus sufficiently on the development of human-machine-collaborative, human-centred, durable and sustainable infrastructure and superstructure services based on customer expectations. The use of human-collaborative systems is likely to increase maintenance operations, marketing and customer satisfaction, while increasing the demand for highly skilled personnel. Companies experience the cost and quality paradox at every level of production and marketing. They can give more space to AI-supported service processes to reduce the cost of employing skilled personnel in order to eliminate customer complaints about personnel.

Sustainability is ensured both in managing the life cycle of electric cars (maximising the lifespan of cars and components, minimising failures) and in maintenance processes (making maintenance activities more economical, reducing negative impacts on the environment and society). In this context, researchers are likely to face new challenges and opportunities in the process. The survival and development of the electric car industry is expected to be realised by integrating sustainability principles.

RECOMMENDATIONS

In order to ensure customer satisfaction in the services they offer, companies should plan time-based work intensity, personnel assignment, work flow chart and personnel requirements; this may contribute to the timely and effective realisation of information, promotion and infrastructure services to eliminate complaints.

Considering the seasonality of the complaints and the high correlation between energy failures and battery and energy systems, it can be said that regulations for power systems require coordinated efforts of both public and private sectors.

Considering the relationship between automobile appointment and update processes, replacement vehicles, parts replacement and service services, a holistic approach to vehicle maintenance and repair processes can minimise customer complaints.

The decisions taken by governments influence the development of automobile technologies. Focusing the incentives, credit and financing support on environmentally friendly technologies can contribute to the reduction of greenhouse gas emissions.

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