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RESEARCH ARTICLE

Decoding Customer Experience: A Comparative Analysis of Electric and Internal Combustion Vehicles in the U.S. Market Through Structured Topic Modeling

NINA RIZUN[1] **AND BARTOSZ DUZINKEWICZ**[2]
[1]Department of Informatics in Management, Gdańsk University of Technology, Fahrenheit Universities, 80-233 Gdańsk, Poland
[2]EPAM Systems, 31-553 Kraków, Poland
Corresponding author: Nina Rizun (nina.rizun@pg.edu.pl)

ABSTRACT Amid global environmental challenges, the transition from internal combustion vehicles (ICVs) to electric vehicles (EVs) is a priority for governments and automobile manufacturers. This shift requires a deep understanding of consumer preferences and evolving adoption trends. Existing research highlights critical gaps, such as the lack of comparative studies analyzing EVs and ICVs' consumer-perceived value and their evolution over time, and the limitations of static survey methods – currently predominant but constrained in capturing comprehensive consumer insights. To address these gaps, our study utilizes computational text analytics to analyze 13 years of online customer reviews from two major U.S. automotive websites. Using Structured Topic Modeling (STM), we identified 30 factors (in 14 subcategories) influencing EV customer experiences and 40 factors (in 12 subcategories) for ICV customers. By integrating metadata contexts such as satisfaction levels (rating), review timelines, and predicted author gender, we uncovered patterns in functional and non-functional values driving consumer perceptions. This research advances computational text analytics by 1) introducing enhanced methods for STM quality control, 2) developing a comprehensive framework of factors driving EV and ICV consumer perceptions, and 3) presenting longitudinal insights into these evolving preferences. The findings provide actionable insights for policymakers and industry stakeholders. For the EV market, prioritizing affordability, charging infrastructure, and environmental benefits can accelerate adoption. For ICVs, enhancing highway fuel efficiency, reliability, and advanced safety features can enhance customer loyalty. This study lays the groundwork for customer-focused automotive solutions, bridging theoretical understanding with practical application.

INDEX TERMS Electric vehicles, internal combustion vehicles, text analytics, structural topic modeling.

I. INTRODUCTION

Governments worldwide actively pursue strategies to reduce humanity's carbon footprint and combat environmental pollution. Despite its contribution to air pollution, one indispensable aspect of modern life remains the need for efficient transportation to locations such as schools and workplaces. In this regard, automobiles play a pivotal role. To usher in a cleaner and more sustainable future, automobile manufacturers have embarked on a quest to power vehicles without the detrimental emissions traditionally associated with internal combustion engines. This endeavor has led to the development of innovative vehicle types, including Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs), and Fuel Cell Electric Vehicles (FCEVs) [1], [2].

Since Electric Vehicles (EVs) have begun penetrating the wider market, a significant body of research has primarily

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focused on *highlighting and improving their inherent values*, such as optimization of energy consumption [3], [4], [5], positive health and environmental impact [6], [7], [8], and the adoption of cutting-edge technology [9], [10], [11], [12], [13]. Furthermore, overcoming infrastructural barriers, such as the lack of public charging stations [14], [15], [16], [17] and the ability to recycle EV batteries [18], is becoming increasingly critical. Current research increasingly emphasizes the need for supportive policies, such as subsidies and incentives [19], [20], [21], [22], to facilitate a smooth transition from internal combustion vehicles (ICVs) to EVs, given the high purchase costs [22], [23], [24].

Further research is focused on identifying EVs' main strengths and weaknesses that have emerged from their operation by consumers. Key advantages of EVs, such as high performance and power [25], driving range and comfortability [26], [27], shorter charging times and low maintenance cost [10], [28], [29], higher maximum speeds and lower fuel costs [30], [31], are highlighted. However, high purchase prices and battery lifespan [26], [32] are already noted as significant barriers to future consumer EV adoption. Moreover, the predominant data sources for this type of research are structured questionnaires and interviews [32], [33], [34], which are carried out in specific regions or targeted towards particular groups of individuals and in a limited period [2], [35], making the *discovery of new and actionable insights less probable*.

In consumer experience research, there is a growing shift toward using free-text responses and reviews from social media and online platforms, where consumers share their experiences freely [36]. Recent advances have highlighted the effectiveness of semi-automatic, unsupervised machine learning techniques, such as topic modeling with Latent Dirichlet Allocation (LDA) and Structural Topic Models (STM), for extracting themes from textual data, especially in customer experience research [37], [38], [39], [40]. However, many studies *lack a rigorous approach to involving human experts* to evaluate topic quality and label accuracy. Additionally, existing methods often rely on single metrics (e.g., word frequency or sentiment scores) to identify consumer priorities [11], [12], [17], [18], [19], [20], [21], [23], which may not capture the full range of consumer needs [141]. While recent studies have focused on customer experiences with specific EV brands [35], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], a *gap* remains for *comparative analysis* that explores the main factors influencing satisfaction for *both EVs and ICVs*, thus providing deeper insights into drivers of the transition to EVs.

Thus, the *motivation* behind the primary *objective* of this study is to deepen our comprehension of the factors and patterns shaping consumer perception of EVs and ICVs. To this end, the study aims to address the following five *research questions*: (RQ1) What common and unique factors of EVs and ICVs consumption define the customers' experience? (RQ2) How do factors of the customer experience align with the overall satisfaction with the EVs and ICVs purchase and consumption? (RQ3) How do patterns in identified EVs and ICVs customer experience factors vary across review dates? (RQ4) How do patterns in identified EVs and ICVs customer experience factors vary across predicted author gender? (RQ5) Which customer service quality factors shape the image of electric vehicles conquering the automotive market?

To answer the research questions, we selected the American automotive market and analysed 2,753 online reviews regarding 12 EVs and (ii) 2,899 online reviews regarding 21 ICVs, completive to selected EVs. These reviews were published from 2010 to 2022 and from 2013 to 2022, respectively, on U.S. automotive websites – edmunds.com and cars.com. To our knowledge, this is one of the largest-scale social media discussion corpora for ICVs and EVs over 13 years.

Our research advances computational text analytics by demonstrating the *potential* of these methods to uncover drivers of consumer perception. Specifically, we (1) introduce instruments for control and quality assurance in analyzing consumer opinions on vehicles via STM, (2) build a framework of factors influencing consumer perception of EVs and ICVs, and (3) develop an approach to distinguish consumer perception patterns between EVs and ICVs. Our findings enrich *theoretical insights* into internal combustion vehicle customer preferences during the *EV transition*, addressing both functional and non-functional values and evolving trends over time.

Our findings offer valuable *technical* and *policy implications*. *Technically*, they can enhance predictive modeling, customer feedback systems, and sentiment analysis by: (1) identifying patterns in customer experience changes over time, aiding predictive ML algorithms; (2) prioritizing key factors based on importance and satisfaction levels, which strengthens real-time sentiment analysis and customer feedback; (3) using overall ratings as sentiment proxies to improve ML predictions when text data is ambiguous or limited; and (4) employing a multi-step validation approach to ensure quality and reliability in STM-generated topics and labels, reducing bias. On the *policy* side, our research highlights key factors that shape consumer experiences for both EVs and ICVs, helping identify areas for improvement to sustain and increase consumer satisfaction.

The rest of the paper is organized as follows. The Section II reviews the relevant literature. Section III describes the data used in the analysis and the methodology employed. In Section IV, we present our findings. Section V discusses our study results. We conclude in Section VI and briefly delineate future directions for our research.

II. THEORETICAL BACKGROUND

A. PRODUCT VALUE IN THE CONTEXT OF VEHICLE PURCHASES

Consumers tend to make purchase decisions when products deliver clear tangible and intangible values that align with their needs and aspirations [55], [56]. Value is often defined as a comparison between what is received (e.g., performance) and the acquisition costs (e.g., financial, psychological, or effort) [57], [58]. Importantly, consumer value arises not solely from product features but also from the experience and process of using the product [37].

In the research [59], six key benefits consumers seek in products were identified: performance (how well the product fulfils its function), durability (longevity in providing desired benefits), economy (value for money), comfort (physical and mental convenience), appearance (product aesthetics and its effect on the buyer's image), and safety (protection from physical or mental harm). Additionally, value is often associated with a product's cost or price [56], [60], [61], [62]. Study [63] categorizes value into four types: functional/instrumental (product usefulness and performance), experiential/hedonic (emotional and experiential benefits), symbolic/expressive (psychological meaning attached to the product), and cost/sacrifice value (expenses related to purchase, ownership, and usage).

In the context of vehicles, consumer intentions to purchase an EV can be categorized into two value types: functional values, such as savings, performance, and convenience, and non-functional values, including emotional, social, and epistemic aspects [64]. This classification aligns with theories linking purchase decisions to recreational purposes, deal-proneness, and functional values [65]. Consumer choices are often multidimensional, involving social, emotional, functional, conditional, and epistemic values [55]. For vehicles, functional values relate to tangible attributes like technology and driving experience, while non-functional values include design appeal and the "fun factor" of driving [66], [67], [68].

In our study, we define *vehicle value as the consumer's judgment that shapes their buying intention, reflects their needs, requirements, and aspirations, and emerges from their knowledge of the product and experience of vehicle purchase and use*. The two types of vehicle values – *functional* and *non-functional* – were chosen to (i) categorize factors (judgments) mentioned by customers in their reviews for both EVs and ICVs, and (ii) unify their further comparisons from a customer/consumer experience perspective. Table 1 outlines the definitions of these vehicle value types used in our research.

TABLE 1. Definitions of vehicle' functional and non-functional values from the perspective of customers.

Value Type	Description	Value/Source
Functional	Values originated from tangible, real, utilitarian characteristics or attributes of vehicles	- Functional/instrumental [63] - Functional [55], [64], [66], [68] - Performance, durability, economy [59] - Cost/sacrifice [63]
Non-functional	Values originated from customers' experiences, emotions and feelings during vehicle-consuming	- Non-functional [55], [64], [66] - Experiential/hedonic and Symbolic/expressive [63] - Comfort, Appearance, Safety [59] - Emotional [68]

B. RESEARCH OF INTEGRATION OF ELECTRIC VEHICLES

In examining the integration of EVs into the automotive market by reviewing the extant literature over the period 2020 to 2024[1] (see Appendix A), this study determined five distinct categories of research that address the functional aspects and suitability of both conventional and electric vehicles for effectively meeting consumer needs These categories include: (1) *Energy Management*, which investigates strategies for optimizing energy consumption and grid interactions; (2) *Health and Environmental Impact*, which assesses the ecological and health implications of shifting from internal combustion vehicles to EVs; (3) *Technological Advancements*, which reviews the latest innovations in vehicle technology that facilitate EV adoption; (4) *Development of Infrastructure and Policies*, which focuses on the necessary infrastructure and supportive policies required to ensure a seamless transition to EVs; and (5) *Consumer Experience and Market Potential*, which explores consumer attitudes, preferences, and the potential for market growth in the EV sector.

1) ENERGY MANAGEMENT

Recent publications on Energy Management can be broadly classified into two streams: (1) managing energy within electric vehicles [3], [4], [5], [13], [5], [69], [70]; and (2) optimizing energy generation, charging, and utilization within integrated systems involving energy sources, the grid, and EVs [71], [72].

The first stream addresses improving energy management in EVs under various conditions like acceleration and steady-state operation. Notable studies include using neural networks to enhance energy strategies [3] and text mining for identifying optimal solutions [4]. Additionally, a comparative analysis of fuel cells and batteries highlights their pros and cons as EV energy storage options [5]. Recent advancements, such as integrating thermal safety and degradation awareness into energy management strategies for hydrogen fuel cell hybrid electric vehicles, have demonstrated reductions in battery aging and operational costs, highlighting significant progress in in-vehicle energy optimization [69].

The second stream focuses on optimizing energy consumption within integrated ecosystems. The research employs Mixed Integer Programming (MIP) models to minimize energy costs for EV users, considering diverse scenarios and user behaviors [71], [72]. Innovations like self-learning stochastic Markov predictors enhance prediction accuracy and improve energy efficiency across source-grid-EV systems, balancing durability and resource use effectively [70].

[1]The following search terms in English were applied to paper titles, abstracts, and keywords: "*electric AND vehicle AND perception*", "*electric AND vehicle AND acceptance*", "*electric AND vehicle AND adoption*", "*electric AND vehicle AND integration*" for four electronic databases: Scopus, Web of Science, ACM Digital Library, and IEEE.

These findings underscore the transformative role of modern IT in boosting EV efficiency and optimizing integrated energy ecosystems.

2) HEALTH AND ENVIRONMENTAL IMPACT

In recent years, discussions on the health and environmental impact of electric vehicles (EVs) have gained prominence among governments and the public. Automotive manufacturers have responded to these concerns, resulting in EVs that are more environmentally friendly than ever – a feature heavily emphasized in marketing campaigns. Existing literature extensively explores these aspects, addressing topics such as the general environmental benefits of EVs, including carbon footprint and emission reductions [6], [7], [8], as well as specific impacts like particulate matter reduction [73], [74], [75].

Researchers highlight the health benefits of EV adoption, particularly in reducing mortality rates [76], [77], [78]. Studies consistently show that EVs and other battery-powered vehicles (BPVs) positively impact health and are significantly more environmentally friendly than internal combustion vehicles (ICVs). A key advantage is the reduction in particulate matter released into the air by ICVs – a mixture of tiny particles and liquid droplets that, when inhaled, can cause health issues. This factor alone underscores the health superiority of EVs over ICVs.

Various research methods have been employed to study air quality improvement through EV adoption, including simulation models to assess air quality benefits from the EV transition [7], [74], [79], [80], [81] and life cycle assessments of electric and conventional vehicles using the ReCiPe method [82], [83]. Other approaches include lifetime-intensity models considering annual driving intensity [8], holistic frameworks estimating environmental and social benefits of EV fleets [84], and statistical models analyzing environmental awareness in EV consumer decisions, CO2 emissions, and carbon footprint [6], [8], [85].

Most studies [73], [74], [75], [77], [79], [82], [86] focus on particulate matter pollution data, with some combining Air Quality Index and EV sales data to assess how air pollution affects EV adoption [87].These studies highlight the health and environmental advantages of transitioning from ICVs to EVs by analyzing emissions and comparing them to conventional vehicles. While these insights can guide policymaking and inform government decisions, they often overlook the role of environmental awareness in consumer choices [85], a gap that could also benefit automotive marketers in targeting their audience.

3) TECHNOLOGICAL ADVANCEMENTS

Technological advancements in electromobility are examined in two streams. The first addresses the technologies within Electric Vehicles (EVs) and charging stations [9], [10], [11], [12]. The second considers EVs as part of a broader infrastructure, including the power grid and traffic systems, emphasizing interactions that enhance performance and integration [23], [28], [88]. A subset of studies offers an overview of challenges and advancements in EV technology, including batteries, charging stations, and Battery Management Systems (BMS), while also highlighting AI's role in integrating these components [9], [29]. Other works focus on charging infrastructure [11], [12] and software for managing EV systems [10]. Research on EV infrastructure emphasizes optimizing coordination among EVs, power grids, and traffic systems, leveraging advancements in Big Data analytics [23], EV-grid interaction [88], and power grid optimization [89]. Key challenges include limited battery capacity, long charging times, insufficient charging stations, inconsistent plug-socket standards, and grid instability caused by EV integration.

4) DEVELOPMENT OF INFRASTRUCTURE AND POLICIES

Research on EV infrastructure emphasizes optimizing coordination among key stakeholders to ensure a smooth transition from ICVs to EVs. In recent years, governments, industries, and urban planners have increasingly recognized the importance of investing in charging networks, alongside policies and incentives. This shift is crucial as consumers, long accustomed to ICVs, navigate a world designed to meet the needs of traditional vehicles.

Researchers have identified barriers hindering EV adoption and provided insights for policymakers [90], [91], [92]. These include infrastructure challenges, such as insufficient public charging stations [17]; technological issues, like limited driving range [18]; environmental concerns, such as battery disposal [92]; and financial hurdles, including high purchase costs [17]. Studies on policies and incentives [19], [20], [21] found that automotive manufacturers often respond defensively to EV policies [19], optimal subsidy programs can be designed [21] and financial incentives are frequently paired with non-financial ones like road priority for EVs [93]. Enablers such as skill centers for EV advancement [94] and strategies for integrating charging infrastructure [14], [15], [16] have also been analyzed, offering practical solutions to boost EV adoption

The primary methods for this category of studies include a literature review [28], [91], [92], [93], surveys or focus group analysis [94], [95] and simulations for charge pricing, EV demand, and infrastructure placement [16], [96], [97]. While policymakers strive to accelerate EV adoption, their efforts could benefit from enhanced infrastructure [20]. The emphasis on infrastructure highlights its critical role in facilitating a smoother transition to EVs.

5) CONSUMER EXPERIENCE AND MARKET POTENTIAL

Studies in this category, predominantly based on survey data, explore consumer preferences and behaviors regarding EV adoption. Key factors include price sensitivity [22], [98], [99], operating costs [24], government subsidies, charging capabilities [100], [101], driving range [34], vehicle cost [23], [36], performance and power [6], battery range [9],

[102], positive environmental impact [32], [95], shorter charging time, faster maximum speeds, lower pollution emissions, and reduced fuel costs [10]. Research also highlights demographic and regional variations [103] psychological and social influences [99], and factors like social status and peer influence [100], shaping EV adoption and market potential.

To explore consumer behavior and market potential, various methods are employed, including Structural Equation Modeling [34], [100], [104], [105], [106], regression analysis [32], [98], [107], clustering algorithms [18], [108], [109], and optimization modeling [24]. These techniques offer insights into how perceptions of social value and environmental consciousness influence decision-making. However, reliance on structured questionnaires and interviews [98], [108] may restrict the ability to uncover dynamic and emerging consumer preferences.

Despite recent momentum [110], applying text analytics to analyze EVs customer opinions remains relatively novel. Research predominantly focuses on online opinions of car buyers in Asia (China, South Korea) [30], [48], [110], [111], [112], [113], [114], reflecting the region's dominance in the EV market since 2015 [115]. China, in particular, leads in global car production and battery component supply for EVs [116]. Recently, studies have increasingly examined the US EV market [49], [50], [110], [117], [118].

The majority of extant studies are focused on analyzing vehicle consumer experience and tend to center around *research objectives* that involve identifying: (1) consumer *attitude* (sentiment) towards EVs [35], [48], [111], [112], [114], [119], [120]; (2) *factors* shaping consumer's perception [38], [50], [120], [121] and their *evolution* over time [2], [35], [47], [122], [123]; (3) consumers' *preferences* for specific *cars* [54], [124], [125], [126] or car *aspects* – infrastructure [127], sound [128], charging prices [129]; (4) public *sentiment/factors evolution* in social media – Twitter [42], [43], [44], [45], [46], [52], [118], [123], Reddit [2], [49], [130], national social media platforms [35], [114]; (6) patterns in *specific* EVs-related *discourse*– crash and non-crash-related complaints [131], electric vehicle failures [54], reactions on EVs Policy [19], EV promotion in rural areas [50], trust [122] and equity-related discussions [49], start-arrival travel satisfaction [114]; awareness and intention to purchase [47].

As for *research methods*, the most popular text analytics techniques are Latent Dirichlet Allocation (LDA) [2], [35], [38], [45], [47], [49], [50], [112], [113], [118], [123], [130]; Structural Topic Modelling (STM) [122]; Association Rules [126]; word frequency analysis [115], [126]; Unsupervised Machine Learning (k-means clustering) [132], [133], Principal Component Analysis (PCA) [118], convergence of iterated corrections (CONCOR) analysis [47] and Deep Learning Networks [54] for topics or vehicles categorization; and supervised (Support Vector Machine, Logistic Regression, Naive Baye's Classifier, Random Forest, Gradient Boosting Algorithm, Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long short-term memory (LSTM) RNN, Decision Tree, Generalized Linear Models, Hierarchical Linear Models, and Geographically Weighted Regression) machine learning [35], [48], [50], [52], [111], [118], [120], [134] for sentiment analysis.

Certain research gaps can be drawn in summarising the existing literature. *First*, despite the growing body of research on Electric Vehicles, there is still a lack of comparative studies analyzing the EVs and ICVs' consumer-perceived *value*, including how these perceptions have evolved. *Second*, recent studies that seek to (1) highlight and improve the values of EVs inherent in their development by default (such as optimization of energy consumption, positive impact on health and the environment, and use of the latest technological advances categories); and (2) identify the current advantages and disadvantages of EVs or ICVs as a result of conducting surveys (pre-prepared that are limited by both the respondents' representativeness and surveys static nature [98], [108]) are *not able to build a complete picture* of patterns that define the consumer perceptions and factors that influence the smoothest possible integration of EVs into the automotive market [35]. In this regard, studying the *free-text customer reviews of two types of vehicles expressed on online platforms over the past 13 years will further deepen the understanding of the evolving patterns in ICV consumers'* experiences, prioritizing their preferences in the transition to EVs. *Third*, regarding the *research methods*, applied to free-text reviews, there has been a noticeable growth in research over recent years that showcases the efficacy of topic modeling algorithms (e.g., LDA) as prominent semi-automatic unsupervised machine learning techniques capable of extracting latent themes from textual data. Experience in recent years highlights the successful use of the *Structural Topic Model* (STM) in investigating customer experience [37], [122]. This approach would allow for consideration of diverse *metadata* contexts, such as satisfaction levels associated with car purchase and usage, years of review publication, and the predicted gender of the author, to more accurately identify patterns in customer experience factors [135]. *Fourth*, most studies using topic modeling *still do not include* a rigorous procedure for involving human experts to validate the quality of the generated STM models and ensure the accuracy of the labels assigned to latent topics, which can cause additional biases of subjectivity in human best STM model choice and topic labeling. *Fifth*, research on customers' opinions regarding EVs and ICVs is constrained by methods prioritising factors determining consumer satisfaction. Existing approaches mainly rely on single indicators such as word/entity frequency, topic proportion, or sentiment scores [11], [12], [17], [18], [19], [20], [21], [23]. These methods fail to provide the actionable insights necessary for practitioners and policymakers to improve the market for both vehicle types [136]. Therefore, it is essential to develop rigorous, data-driven approaches based on computational text modeling methods to provide robust evidence on the prioritization of consumer needs.

III. METHODOLOGY

A. RESEARCH QUESTIONS

To address the gaps identified, the primary *objective* of this study is to enhance the understanding of factors and patterns that shape the customer experience for Electric Vehicles and Internal Combustion Vehicles. To this end, the study aims to address the following research questions:

(RQ1) *What common and unique factors of EVs and ICVs consumption define the customers' experience?*

(RQ2) *How do EVs and ICVs customer experience factors align with the overall satisfaction with the vehicle's purchase and consumption?*

(RQ3) *How do patterns in identified EVs and ICVs customer experience factors vary across review dates?*

(RQ4) *How do patterns in identified EVs and ICVs customer experience factors vary across predicted author gender?*

(RQ5) *Which customer service quality factors shape the image of electric vehicles conquering the automotive market?*

This will be achieved by (i) employing a comprehensive research approach that showcases the benefits of *computational text analytics* in extracting actionable insights from free-text feedback; (ii) investigating the impact of *metadata* variables like review dates, author gender, and quantitative measures of customer satisfaction (ratings) on disparities in consumer experience for the two vehicle types; (iii) leveraging both qualitative and quantitative approaches to identify distinct *electric vehicles image* from the consumer's perspective.

B. DATA COLLECTION AND PREPARATION

Two main American automotive websites – edmunds.com and cars.com – were selected as data sources. We employed the BeautifulSoup[2] and Pandas[3] Python packages for the web scraping process. The data selection process adhered to the following steps: (1) For electric vehicles, we collected free-text feedback from edmunds.com and cars.com websites if the number of opinions about a particular car model exceeded a certain threshold N = 50. (2) We collected a total of 5,664 free-text feedback about ICVs models that compete with selected EVs through the research of EV and ICV counterparts.[4] The year of comments publishing was selected for EVs from 2010 to 2022 and for ICVs from 2013 to 2022. (3) To construct the final dataset, 12 EVs and 21 ICVs were assigned to its appropriate car segments. Car categorization by segments utilised three similar methodologies: Euro Car, Euro NCAP, and US EPA Size.[5] The outcomes of the car segmentation selected for our study are outlined in the provided Appendix B.

The data collected contains two distinct datasets: (1) 2,760 customer opinions on EVs and (2) 2,904 customer opinions on ICVs. Each dataset containing customer opinions encompasses the following information: (i) vehicle model name; (ii) model year; (iii) author's name; (iv) publication date; (v) overall vehicle rating (average rating from ratings by categories[6]) in the range from 1 to 5, assigned by the customer; and (vi) free-text feedback merged with its corresponding title.

The data *preparation* stage to produce a data subset with the level of data quality required for further analysis consists of three major steps. *First*, duplicate free-text feedback was removed. *Second*, we generated the additional metadata for our dataset required for further analysis. Each customer opinions dataset is augmented with (i) the predicted gender of the reviewer, determined using the gender_guesser Python package based on the author's name.[7] Only the results of males and females, mostly males and mostly females, were accepted as valid results of gender prediction[8]; and (ii) sentiment score determined using six sentiment tools.[9] *Third*, text preprocessing, including (1) word normalization to standardize the text by converting all characters to lowercase, to reduce redundancy and improve the STM model's consistency; (2) word stemming, which involves reducing words to their root forms and helps enhance the efficiency of the model by focusing on the core meaning of words rather than their various inflections; (3) removal of stop words, punctuations, and numbers to reduce dimensionality and noise in the data, which can otherwise dilute the model's effectiveness; and (4) converting the dataset into the STM Corpus format is performed. Corpus format comprises three elements: the document term matrix, vocabulary character vector and the metadata matrix containing document covariates. This step resulted in a final sample of 5,652 opinions (2,753 on the EVs dataset and 2,899 on the ICVs dataset).

The summary of the final sample comprising the distribution of the Number of comments and percentage (%) are given in Table 2. Summaries by vehicle models are presented in Appendix C.

[2]https://pypi.org/project/beautifulsoup4/

[3]https://pandas.pydata.org/

[4]https://www.businessinsider.com/tesla-model-3-gasoline-competitors-2016-4?IR=T#theres-tech-which-is-nice-5; https://www.autoweek.com/car-life/g35645393/10-evs-and-gas-alternatives/?slide=20

https://www.thecarconnection.com/compare/tesla_model-x_2020_choices

[5]https://en.wikipedia.org/wiki/Car_classification

[6]Comfort, Interior design, Performance, Value for money, Exterior styling, Reliability for cars.com, Safety, Performance, Comfort, Value, Technology, Interior, Reliability for edmunds.com.

[7]https://pypi.org/project/gender-guesser/

[8]*gender_guesser* relies on a database of names associated with likely gendered usage, which may introduce errors due to unisex names, international naming variations, and cultural differences. The tool does not predict gender identities but rather binary gender associations (male/female), and may misclassify names that are rare or ambiguous. We estimate that a small percentage of names in our dataset fall into the "unknown" or "androgynous" category, and these were excluded from gender-based comparisons to minimize potential bias. The results should be interpreted as indicative trends rather than definitive conclusions, with validation efforts presented in Section V. Discussion / A. Research findings validation and detailed further in Appendix L.

[9]Jeff Gentry's Twitter package; NRC Emotion Lexicon; Syuzhet Package; Bing lexicon; AFINN lexicon; VADER sentiment analysis library (Hutto & Gilbert, 2014).

TABLE 2. Final samples summary.

		EVs		ICVs	
		Number	%	Number	%
Total		2753		2899	
Predicted gender	Male	800	85.56	1426	72.98
	Female	135	14.44	528	27.02
Overall rating scale for electric vehicles	[1,2)	146	5.30	126	4.35
	[2-3)	114	4.14	112	3.86
	[3-4)	166	6.03	171	5.90
	[4-5)	945	34.33	723	24.94
	5	1382	50.20	1767	60.95

C. DATA ANALYSIS

1) EXTRACTING LATENT TOPICS

We employed the STM to extract latent topics (factors) from the free-text responses. STM is an extended version of the LDA (Latent Dirichlet Allocation) known for its unsupervised learning-based text analysis framework [137], which is commonly adopted in customer experience studies [37], [136], [138]. In STM models, the prevalence of topic prevalence is formulated using generalized linear models parameterized by document-specific covariates X(Y), which include information "about the text" (metadata) [139].

In this process, we took the four steps. *First*, the basic STM models were set up. The STM model's *internal parameters* were initialized using the spectral method and subsequently fine-tuned through 200 expectation-maximization iterations. STM requires a predefined number of topics, the selection of which often involves a trade-off between model simplicity and interpretability [138], [140]. A grid search was performed over STM models ranging from 20 to 100 topics for each of the two datasets to determine the optimal number of topics. No precise criteria exist for selecting the best number of topics to represent the textual data [122]. We adopted the approach [138], [140] to identify the best STM model by *selecting the model with a combination of normalized average semantic coherence*[10] *and exclusivity*[11] *metrics closest to a theoretically optimal one* (with coherence and exclusivity scores of 1). The best number of topics for the EVs dataset is 30, and for ICVs, it is 40. The best number of topics for both datasets is characterized by the highest semantic coherence and exclusivity scores, which were above the average of all analyzed models (the details of model selection see Appendix D).

Second, for each sample dataset (EVs and ICVs) the STM_1 model was created to generate the distribution of topic-words (η), document-topic prevalence (θ), lists of keywords based on Highest Probability, FREX, Lift, and Score methods, and the set of opinions primarily associated with each topic. Topical prevalence (θ) in STM_1 model in the STM_1 model indicates the extent to which a document (opinion) is associated with a specific topic relative to the presence of other topics within the same document [135]. This process yielded latent topics defined by (i) top-weighted keywords and (ii) top-20 opinions mostly associated with each topic based on the highest document-topic prevalence.

Third, the process of labeling topics was executed iteratively by three domain experts from the automobile market, text analytics, and big data: (1) experts independently labeled topics based on top-weighted keywords and deep reading of 20 of the most representative opinions for each topic from the STM model. The inter-rater agreement was identified between 0.58 (for the EVs) and 0.62 (for the ICVs); (2) as this value indicates only a moderate level of agreement, we implemented a pseudo-Delphi iterative procedure [141] wherein: (i) experts identified the topics where disagreements occurred; (ii) they jointly reviewed the representative opinions for those topics to better understand the semantic context; and

(iii) they engaged in structured discussions to clarify the topic boundaries and refine the labels; (3) as a result of this process, consensus was reached, and the finalized topic labels and descriptions were aligned across experts [140]. Cohen's Kappa indicator was used to measure inter-coder reliability for the topic labelling procedure. The identified Cohen's Kappa values varied: for the EVs-related topic labelling from 0.61 to 0.74; for the ICVs-related topic labelling from 0.65 to 0.76.

Fourth, during the topic labeling, experts also were asked to validate *topic semantic coherence* based on the degree of human interpretability of the topics identified by the selected STM model. This validation process was conducted by measuring the degree of topic coherence, which was expressed on a scale of 0 to 1 and indicates the extent to which keywords describing a topic are associated with a single semantic meaning [142]. The topic semantic coherence degrees were categorized as follows: (1) High coherence (0.8 to 1) – there were sufficient keywords to formulate the topic label clearly, and in each of the top 20 opinions, these keywords were prominently present. (2) Moderate coherence (0.5 to 0.7) å here were not enough keywords to formulate the topic label solely from them, and reading the top 20 opinions provided clarification of the topic's meaning, with some keywords present in each opinion. (3) Low coherence (0.2 to 0.4) – insufficient keywords to formulate the topic label and reading the top 20 opinions clarified the topic's meaning, but only in some opinions were individual keywords found. (4) Poor coherence (0 to 0.1) – Insufficient keywords to formulate the topic label and reading the top 20 opinions did not clarify the topic's meaning, as opinions were devoted to various unrelated issues. The average human-validated topic *semantic coherence* was identified as follows: (1) for 30 EVs-related topics, it is 0.678 (moderate), with a correlation of 0.867 between human- and STM model-provided measures; (2) for 40 ICVs-related topics, it is 0.650 (moderate), with a correlation of 0.919 between human- and STM model-provided measures. Then, experts were asked to validate *topic exclusivity* based on the assigned labels of the topics. The validation criteria were as follows: (1) High *exclusivity*(0.8 to

[10] *Semantic coherence* is a measure of the internal coherence of topics and highly correlates with human judgments of topic quality [135].

[11] *Exclusivity* measures the distinctness of topics by comparing the similarity of word distributions of different topics [138].

1) – Topics with a unique, exclusive meaning that do not need to be combined with others; (2) Moderate *exclusivity* (0.4 to 0.7) – topics that potentially can be grouped with other topics having close meanings taking into account the problem domain context. The topics with this level of exclusivity are prime candidates for categorization in the next step of our analysis (see the section below); (3) Low *exclusivity* (0 to 0.3) – topics that can be merged with another topic(s) with similar meaning. The average human-validated *topic exclusivity* was identified as follows (1) for 30 EVs-related topics, it is 0.752 (high), with a correlation of 0.871 between human- and STM model-provided measures; (2) for 40 ICVs-related topics, it is 0.668 (moderate), with a correlation of 0.841 between human- and STM model-provided measures. In both datasets, no topics that would be recommended for merging (with low exclusivity) were identified. Detailed information about the results of human validation for topic semantic coherence and exclusivity can be found in Appendix E. The general agreement, measured by the correlation coefficient, between human- and STM-generated topic exclusivity and semantic coherence is higher for the ICVs-related dataset. Conversely, the average values for both measures, as determined by human validation and STM-generated results, are higher for the EVs-related dataset.

Finally, for each latent topic, the *total topic prevalence* was determined as a metric reflecting the extent to which the factors contributing to the vehicle customers' experience are discussed in the collected free-text responses.

2) LATENT TOPICS CATEGORIZATION

At this step, we have achieved two tiers of categorization for the identified topics for both EVs and ICVs datasets separately.

First, we manually mapped the underlying topics with the subcategories outlined in the extant literature on vehicle features and categories of customer experience. Three independent experts carried out this mapping process. To accomplish this, we undertook the following steps: (1) A comprehensive review of research literature pertaining to vehicle customer experience subcategories was conducted. This involved systematically documenting existing subcategories, with a summarized compilation presented in Appendix F. (2) The labels, descriptions, and the 20 most representative opinions for each topic were meticulously examined and compared against the subcategories list and description. The results from the topic exclusivity validation step were incorporated into the analysis. The resulting assigning was performed based on similarities between hidden topics and established subcategories. (3) In cases where a topic couldn't be directly linked to existing subcategories, new subcategories were established. (4) Adopting a quasi-Delphi approach, experts collaborated to reach a consensus on the categorization of topics based on the refined mapping process. The identified Cohen's Kappa values to measure inter-coder reliability varied: (1) for the EVs-related topic categorization from 0.63 to 0.71; for the ICVs-related topic categorization from 0.68 to 0.74. Table 3 presents the final list and description of subcategories accepted in our research.

TABLE 3. The final list of vehicle customer experience subcategories.

Subcategory	Subcategory description	Source
Comfort	Factors that influence how comfortable the vehicle is	[143], Edmunds.com, Cars.com, consumerreports.org, statista.com
Communication technology	Factors that allow for smartphone connectivity, sound system, GPS	[143], Edmunds.com, statista.com
Value for money	All factors connected with financial factors of the vehicle	Edmunds.com, Cars.com, whatcar.com, topgear.com, statista.com, [144], [145]
Reliability	Factors connected with the maintenance and how reliable the vehicle is including specific issues with engine, transmission or battery	[143], [144], Edmunds.com, Cars.com
Safety	Factors connected to safety of the driver and passengers	[143], Edmunds.com, tesla.com, statista.com, [144], consumerreports.org
Environmental impact	Factors that influence the environment like gas mileage or emissions	[143], consumerreports.org, statista.com
Performance	Factors that influence or describe performance of the vehicle like speed or driving modes of the car	Edmunds.com, Cars.com, consumerreports.org, tesla.com, [145]
Design	All factors connected with the design, interior and exterior	[143], Edmunds.com, Cars.com, whatcar.com, topgear.com, tesla.com, statista.com
Driving experience	All the factors that comprise the driving experience like whether the car is fun to drive, handling of the vehicle or its sportiness	[143], Edmunds.com, Cars.com, consumerreports.org, whatcar.com, topgear.com, statista.com
Specifications	Specifications of the vehicle like its size, different package types or range	Topgear.com, tesla.com, whatcar.com
Quality	Factors that are connected with the quality of the vehicle	[63], [146]
Charging factors	Factors that are connected with charging of the vehicle like the battery capacity, charging or charger availability	Proposed in the study
Post purchase experience	Feelings that customers experience after purchasing the vehicle, which include the worthiness of the purchase or whether the car has met the expectations	Proposed in the study
Buying experience	All factors that comprise the process of buying a vehicle. This can be the customer service in dealerships or ways of purchasing a vehicle	Proposed in the study
General subjective opinion	Factors that present a general and subjective opinion about the vehicle, with no specifics	Proposed in the study

Second, We manually mapped the underlying topics with two vehicle *value* categories from the customer/consumer experience perspective – *functional* and *non-functional* – introduced in Section II-B. This mapping procedure comprised four sequential steps applied in the previous categorization step. Cohen's Kappa values to measure inter-coder reliability varied: (1) for the EVs-related topic categorization from 0.65 to 0.70; for the ICVs-related topic categorization from 0.66 to 0.69. Illustrative rules for assigning identified topics to the two value types are provided in Table 4.

3) IDENTIFYING PATTERNS IN CUSTOMER EXPERIENCE

To demonstrate the advantages of computational text analytics in extracting actionable insights from free-text feedback and to build a comprehensive picture of the factors and their patterns that influence consumer perceptions of EVs and ICVs, *four* types of *customer experience patterns* (CEP) will be explored. *First,* we leveraged the STM model to incorporate metadata as *covariates* affecting topic prevalence. This method enabled us to uncover patterns in the *importance* of customer experience factors (*topic prevalence* or discussion volume) across different levels of the following selected covariates: customer *satisfaction* related to car purchase and usage (CEP_1), *years* of review publication (CEP_2), and the predicted *gender* of the author (CEP_3). *Second*, we applied Principal Component Analysis to identify the core factors that shape the consumer's image of electric vehicles (CEP_4).

a: CUSTOMER EXPERIENCE FACTORS IMPORTANCE AND CUSTOMER SATISFACTION ALIGNMENT

To understand the CEPs in alignment between *customer experience* factors' importance (measured by *topic prevalence*) and *customer satisfaction* (measured by sentiment scores/overall reviewer ratings) in the context of car purchase and usage to build *practical recommendations for strengthening advantageous factors while addressing areas needing urgent improvement*. For this, the following approach was adopted:

First, the sentiment score obtained for each opinion during the preparation phase was normalized from 0 (most positive) to 1 (most negative). The reviewer's rating, which initially ranged from 1 to 5, was also normalized from 0 (highest) to 1 (lowest). Then, the correlation coefficient between the normalized sentiment scores and rating indicators was calculated separately for opinions within the EVs and ICVs datasets, yielding a coefficient of 0.97 in both cases.[12] This high consistency validates the reviewers' quantitative satisfaction assessment, reflecting their experience and emotions. As a result, the customer experience indicated by the *Rating* was considered a representative measure of *overall customer satisfaction.* To define the *Average Rating* for each topic, the calculation involved averaging ratings from opinions where the prevalence of that specific topic exceeded the overall dataset's average topic prevalence for the same topic. These average ratings were also normalized from 0 to 1, where 1 represented the highest and zero the lowest average rating.

Second, for each dataset (EVs and ICVs), we designed STM_2 models with Overall vehicle rating (1 to 5) as a covariate. Including such a covariate in the STM_2 model enables to estimate[13] how the topic prevalence θ^{Rating} in each document (opinion) varies under the influence of the vehicle rating assigned by the author of this opinion. The following equation shows the relationship between the topic prevalence and Overall vehicle rating covariate: $Prevalence\_2 = g\ (Overall\ vehicle\ rating)$, where the function $g()$ is a generalized linear function. For each latent topic, the *Total Topic Prevalence* TP^{Rating} across all opinions was normalized from 0 to 1, with 1 representing the maximum topic prevalence.

Third, the *Average Rating* and the *Total Topic Prevalence* for each topic were mapped on the plot, revealing *four* primary alignment patterns between the customer experience factors' *importance* (volume of discussion) and the level of overall customer *satisfaction* in car purchase and usage: (1) *Advantages* – topics showed a relatively high average rating of the reviewed vehicle with a significant volume of discussion; (2) *Disadvantages* – topics showed a relatively low average reviewed vehicle rating with a significant volume of discussion; (3) *Opportunities* – topics showed a relatively high average reviewed vehicle rating, but a relatively low volume of discussion; (4) *Minor Issues* – topics exhibited a relatively low average reviewed vehicle rating but relatively low discussion volume. The *thresholds* for the average rating

[12] Correlation coefficients Rating vs Sentiment (EVs and ICVs).
[13] https://www.rdocumentation.org/packages/stm/versions/1.3.6/topics/estimateEffect

TABLE 4. Illustrative examples for assigning identified topics to the two value categories.

Value category	Latent topic assigning procedure examples
Functional	*Charging* – topic indicates an aspect that is tangible and can be measured e.g. time it takes to charge a vehicle *Overall performance* – topic has real characteristics which can be measured e.g. horsepower, torque, time 0-100 km/h, time on a race track *Range* – topic describes real characteristics that can be easily measured by determining how many kilometers a car can drive on one charge
Non-functional	*Overall driving experience* – topic originates from consumer emotions, subjective opinion, can not be measured *Fun-factor* – topic is entirely subjective and originates from consumer experience and feel *Handling* – topic is subjective and originates from the opinion of the consumer, different people feel that handling the vehicle in a different way

Source: Own elaboration

and average topic prevalence for each of the *four patterns* (dimensions in the scatterplot) were determined as follows: (1) The average rating and total topic prevalence (the result of the STM model with overall vehicle rating as a covariate) for each topic were plotted on a scatterplot; (2) Critical factors with borderline values in average rating and total topic prevalence were identified and eliminated from the chart; (3) The minimal and maximal values of average rating and total topic prevalence of the remaining factors were used to determine the *middle* border to build four dimensions in the scatterplot.

b: LONGITUDINAL CUSTOMER EXPERIENCE FACTORS IMPORTANCE AND CUSTOMER SATISFACTION ALIGNMENT

To understand the CEPs in longitudinal alignment between customer experience factors *importance* (measured by *topic prevalence*) and customer *satisfaction* (measured by overall reviewer ratings), and to emphasize evidence-based insights that encourage decision-makers to be vigilant in investigating the reasons behind the *escalating customer dissatisfaction* with certain factors, while also reinforcing *best practices* related to aspects that lead to a progressive increase in customer satisfaction over time. For this, the following approach was implemented:

First, rating data was coded by assigning two main categories – Low (rating values from 0 to 3) and High (rating values above 3).

Second, for each dataset (EVs and ICVs) the STM_3 models were designed, incorporating the customer's Overall vehicle rating and the Year of the comment as covariates. The estimated effect[14] of these two covariates was computed to determine how the topic prevalence θ^{R_Y} in each document (opinion) varies under the influence of the vehicle rating assigned by the author of the opinion and the publication year for this opinion. The following equation shows the relationship between the topic prevalence and Overall vehicle rating covariate: $Prevalence\_3 = g\ (Overall\ vehicle\ rating,\ Year)$. For each latent topic, the *Total Topic Prevalence* TP^{R_Y} across all opinions was normalized from 0 to 1, with 1 representing the maximum topic prevalence.

Third, four alignment patterns between customer experience factors' year of publishing and the level of overall customer satisfaction with car purchase and usage were identified [147]: (1) *Growth in Customer Satisfaction* – topics showed a prevalence of opinions with high car ratings as opposed to reviews with low car ratings, and there was a positive trend in the volume of discussions related to these topics over time; (2) *Recession in Customer Satisfaction* – topics showed a prevalence of reviews with high car ratings as opposed to reviews with low car ratings, and there was a negative trend in the volume of discussions related to these topics over time; (3) *Growth in Customer Dissatisfaction* – topics showed a prevalence of reviews with low car ratings as opposed to reviews with high car ratings, and there was a positive trend in the volume of discussions related to these topics over time; (4) *Recession in Customer Dissatisfaction* – topics showed a prevalence of reviews with low car ratings as opposed to reviews with high car ratings, and there was a negative trend in the volume of discussions related to these topics over time.

The slope of the regression, representing the ratio of estimated topic prevalences between the final $\theta^{R\_Y}(i+1)$ and initial time θ^{R_Y} (i) periods was used as a measure to unveil the *direction* (less than or equal to 0 – recession, greater than 0 – growth) and *rate of change* (the higher – the faster). For recession, we reversed the rate of change numbers to indicate that an initial lower value means a faster recession in the topic volume of discussion. The year of opinion publishing spans from 2010 to 2022 for EVs, and from 2013 to 2022 for ICVs.

c: PREDICTED GENDER OF THE AUTHOR'S IMPACT ON CUSTOMER EXPERIENCE FACTORS IMPORTANCE

To understand the CEPs in alignment between customer experience factors *importance* (measured by *topic prevalence*) and customer *gender* (*male* and *female*) and to encourage the advancement of a more *user-centric* approach in vehicle manufacturing and customer service, the following approach was utilized: for each dataset (EVs and ICVs) the STM_4 models were designed. Including Predicted Gender as a covariate in the STM_4 model enables to estimate how the topic prevalence θ^{Gender} in each document (opinion) varies under the influence of the vehicle reviewer's Predicted Gender. The following equation shows the relationship between the topic prevalence and Overall vehicle rating covariate: $Prevalence\ \_4 = g\ (Predicted\ Gender)$. For each latent topic, the *Total Topic Prevalence* (TP^{Gender}) across all opinions was normalized from 0 to 1, with 1 representing the maximum topic prevalence. Factors that are more prevalent in females' experiences than males', and vice versa, were identified by calculating the predicted *Gender Prevalence Score* as a difference between estimated topic prevalence for covariate value Male TP^{M} and Female TP^{F}.

d: COMPUTATIONAL RESOURCE MANAGEMENT

Efficient resource management was critical for handling the iterative computations and large document-term matrices required by STM. In the context of our study, dataset sizes across models for electric vehicle customer opinions remained consistent, with approximately 7.4 MB used for document preprocessing and 238–251 MB required for STM fitting, depending on model complexity. During STM fitting, *memory usage* increased depending on model complexity: STM_1: 238 MB; STM_2: 243 MB; STM_3: 247 MB; STM_4: 251 MB. *Processing times* varied as well: STM_1: 57.60 seconds; STM_2: 56.05 seconds; STM_3: 54.56 seconds; STM_4: 58.40 seconds

To optimize resource usage during STM computations, we utilized built-in parallel processing features in R, such

[14] https://www.rdocumentation.org/packages/stm/versions/1.3.6/topics/estimateEffect

as options(mc.cores = detectCores()),[15] which detects the number of available cores and adjusts the modeling process accordingly. Additionally, memory monitoring was performed using object.size(out),[16] which reports the memory size of data objects in R. These measures ensured efficient resource allocation without requiring external optimization techniques, such as LEOA [148], [149] or AEFA [150].

e: SHAPING THE CONSUMER'S IMAGE OF ELECTRIC VEHICLES

To indicate the CEPs in customer experience factors shaping the EVs image, Principal Component Analysis (PCA) was employed. The notion of "brand image" is linked to the attributes, features, and usage situations of a product/brand that influence customers' purchase intentions. In our case, we utilized PCA to reduce the linear dimensionality of customer experience factor datasets, allowing us to extract the most significant features. PCA is also used in brand image analysis to create a perceptual map, graphically depicting the positioning of competing brands in the market based on key parameters [151].

To implement the identification of the EVs image, the following steps were undertaken:

First, we use 30 variables (latent topics – factors of EVs customer experience), represented by the topic prevalence values for 2,753 free-text opinions. Each opinion was complemented by metadata, specifying one of eight vehicle models (BMW, Chevrolet, FIAT, Hyundai, KIA, Nissan, Tesla, and Volkswagen) for which the review was written. To build the final input dataset, we calculated the geometric average value of the topic prevalence for each vehicle model.

Second, we tested the *PCA procedure's feasibility* by calculating the correlation coefficient between the consumer experience factor variables. High positive correlations were observed for several variables[17] (e.g., Maintenance/Overall driving experience, Overall performance/Pricing, Superchargers/Safety features). Therefore, PCA was justified to address potential multicollinearity.

Third, PCA tools from R studio[18] were applied to the final input dataset, followed by an analysis of the prevalence of variance explained by each component. The relative importance of the first four principal components (PC) derived from the PCA, retaining 82.10% of the data variance, with the first two components alone explaining 49.6%.[19] Samuels [204] recommends retaining at least 50% of the explained variance with the chosen number of components. In this study, we retained the first two principal components for further interpretation of customer experience factors shaping the EVs image.

A summary of the overall approach used in our research is presented in Figure 1.

IV. FINDINGS

A. EMERGENT FACTORS (TOPICS) OF VEHICLES CUSTOMERS PERCEPTIONS

This section answers RQ1: "*What common and unique factors (topics) of EVs and ICVs consumption define the customer experience?*".

[15] detectCores.
[16] object.size.
[17] Correlation Coefficients.
[18] https://cran.r-project.org/web/packages/factoextra/index.html
[19] Relative importance.

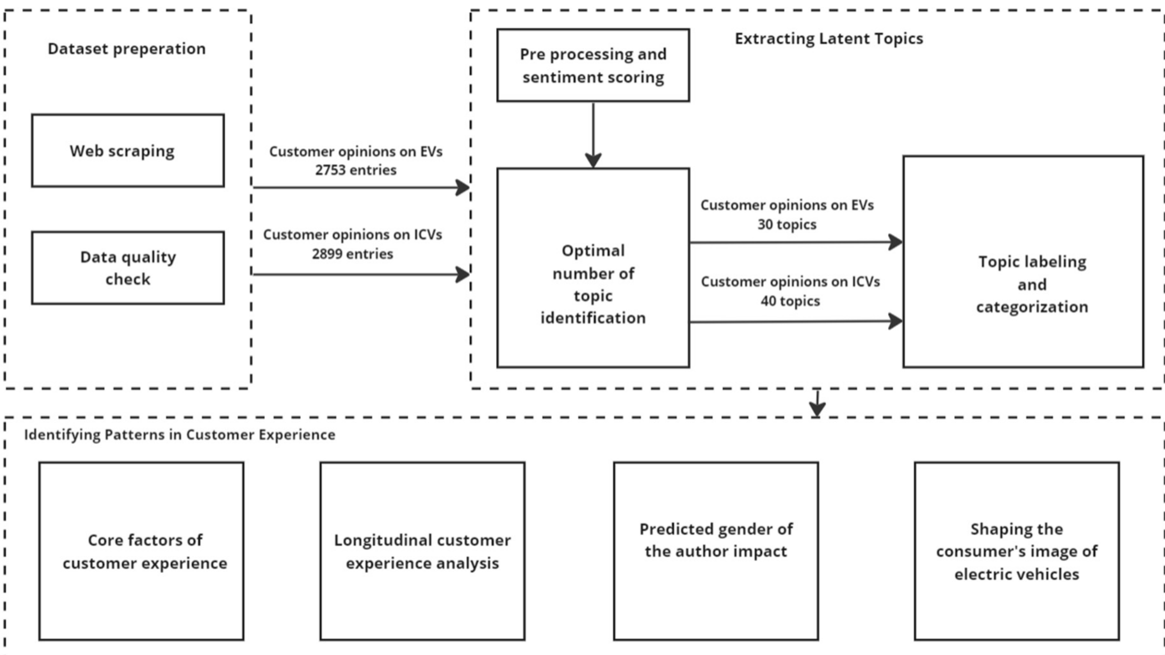


FIGURE 1. Summary of our overall research approach.

TABLE 5. Topics labelling results summary (EVs customer opinions).

Topic/ Subcategory	Topic Label	Topic/Subcategory prevalence (%)	Exclusivity	Semantic Coherence	Category
Charging infrastructure		14.9			
Topic 9	Battery capacity	5.9	9.51	-91.76	Functional
Topic 7	Charging	5.6	10.05	-64.60	Functional
Topic 19	Superchargers	3.5	9.46	-73.12	Functional
Driving experience		12.6			
Topic 10	Overall driving experience	12.6	9.76	-54.61	Non-functional
Value for the money		12.0			
Topic 11	Fuel-cost savings	5.9	10.39	-74.93	Functional
Topic 1	Pricing	3.6	9.67	-68.92	Functional
Topic 12	Financing	2.5	10.61	-85.09	Functional
Performance		8.8			
Topic 4	Speed	4.9	10.24	-105.12	Functional
Topic 23	Overall performance	2.6	9.16	-102.90	Functional
Topic 29	Traffic performance	1.3	8.81	-74.99	Non-functional
Specification		8.4			
Topic 15	Size	6.6	9.72	-71.59	Functional
Topic 20	Range (driving)	1.9	9.80	-86.79	Functional
Buying experience		7.8			
Topic 6	Technical Service	4.0	9.84	-77.72	Non-functional
Topic 13	Transition experience (ICV -> EV)	2.0	10.15	-87.53	Non-functional
Topic 22	Customer service	1.8	9.40	-88.46	Non-functional
Reliability		6.8			
Topic 26	Maintenance	3.7	10.99	-91.03	Non-functional
Topic 8	Manufacturing defects	1.8	10.53	-81.34	Non-functional
Topic 27	Dead battery	1.3	9.86	-64.20	Non-functional
General subjective opinion		5.9			
Topic 5	Comparisons	3.1	9.59	-101.21	Non-functional
Topic 28	General opinion	1.5	8.86	-70.72	Non-functional
Topic 2	Presentation	1.4	9.95	-139.52	Non-functional
Quality		5.5			
Topic 25	Overall quality	3.6	9.91	-71.99	Non-functional
Topic 21	Build quality	1.9	9.33	-68.94	Non-functional
Communication technology		5.0			
Topic 14	Software updates	2.8	9.72	-65.91	Functional
Topic 24	Steering wheel functionalities	2.2	9.41	-69.86	Functional
Comfort		4.7			
Topic 18	Spaciousness	4.7	10.47	-76.19	Functional
Safety		3.0			
Topic 3	Safety features	3.0	10.24	-105.12	Functional
Environmental impact		2.8			
Topic 17	Ecology (zero-emission)	2.0	10.29	-79.72	Functional
Topic 30	Quietness	0.8	9.62	-65.41	Non-functional
Design		1.8			
Topic 16	Overall design	1.8	9.96	-69.00	Non-functional

Source: Own elaboration

1) ELECTRIC VEHICLES

During the analysis of the EVs customer opinions dataset, 30 topics were identified.[20] Then these topics were grouped into 14 subcategories (according to the categories introduced in Table 4) and mapped into functional and non-functional categories of vehicle values from a customer/consumer experience perspective. The Top-5 factors with the highest topic prevalence (TP) are (1) *Overall driving experience*(TP = 12.6%). This factor focuses on how the driver feels when driving the car; it answers the question of how the car operates, whether it feels good to drive and whether the control of the vehicle's movement is adequate and responsive. (2) *Size* factor (TP = 6.6%) indicates the car's property is small, making it easy to fit into small parking spaces. It is followed by both (3) *Fuel-cost savings* and (4) *Battery capacity* (both by TP = 5.9%), which focus on the amount of money saved on gas and issues with low battery capacity, respectively; and (5) *Charging* issues (TP = 5.6%) related to charging stations accessibility issues. Top-3 subcategories of EVs consumption are *Charging infrastructure* (TP = 14.9%), *Driving experience* (TP = 12.6%) and *Value for money* (TP = 12.0%). A summary of the latent topics, characterised by (i) topic label; (ii) topic prevalence (%); (iii) topic exclusivity and semantic coherence; (iv) topic subcategory; and (v) topic category (functional and non-functional vehicle values) are presented in Table 5. Description of identified factors of EVs customer experience and exam-

[20]The topics' keywords wordclouds are presented in the supplemental material: WordClouds_EV.

ples of the most representative opinions are provided in Appendix G.

Regarding EVs values from a customer experience perspective, *Functional* values factors are mentioned more frequently (TP = 57.70%) than *Non-functional* ones (TP = 42.60%). At the same time, the category Functional and Non-functional values categories are represented equally by 15 factors. The most popular Functional values are *Size*(TP = 6.60%) and *Battery capacity*(TP = 5.90%), while the most popular Non-functional values are *Overall driving experience* (TP = 12.60%) and *Technical Service*(TP = 4.00%). Surprisingly, factors related to sustainable electric mobility and *Environmental impact* [152], [153], such as *Ecology*, associated with zero-emission or zero tailpipe emission, and *Quietness*, contributing to reducing noise pollution, are ranked low among the most frequently mentioned factors, with a total proportion (TP) of only 2.80%. This may suggest that consumers inherently view EV vehicles as sustainable and environmentally friendly "by design" [154]. A comparison of the distribution (%) of the prevalence of factors (topics) relating to the functional and non-functional values of EVs is presented in Appendix H.1.

2) INTERNAL COMBUSTED VEHICLES

As a result of the analysis of the ICVs customer opinions dataset, 40 topics were identified.[21] Then these topics were grouped into 12 subcategories and mapped into functional and non-functional categories of vehicle values from a customer/consumer experience perspective. Top-3 factors mentioned in free-text feedback are (1) *Gas mileage*(TP = 10.10%); (2) *Looks*(TP = 9.30%); and (3) *Overall driving experience* (TP = 7.10%). Top-3 subcategories of ICVs consumption are *Driving experience* (TP = 16.80%), *Design*(TP = 13.60%) and *Reliability*(TP = 12.40%). Figure 2 compares the distribution of topic prevalence (TP, %) for factors related to customer experience subcategories between EV and ICV vehicles.

Regarding ICVs values from a customer/consumer experience perspective, *Functional* values take up 43.00%, while *Non-functional* ones 56.9%, which emphasizes the opposite trend identified for EVs (see Appendix H.2). At the same time, the Functional values category is represented by 17 factors (42.50% of factors number), while Non-functional values category – by 23 factors (57.50% of factors number). The most popular Functional values are *Gas mileage* (TP = 10.10%) and *Electronics*(TP = 3.50%), while the most popular Non-functional values are *Looks*(TP = 9.30%) and *Overall driving experience* (TP = 7.10%). Factors related to *Environmental impact*, such as *Gas mileage* and *Highway gas mileage*, rank fourth among the most frequently mentioned considerations (12.10%), occurring four times more often than mentions of electric vehicles. Although these factors are often associated with smooth driving and economical opera-

[21]The topics' keywords wordclouds are presented in the supplemental material: WordClouds _ICVs.

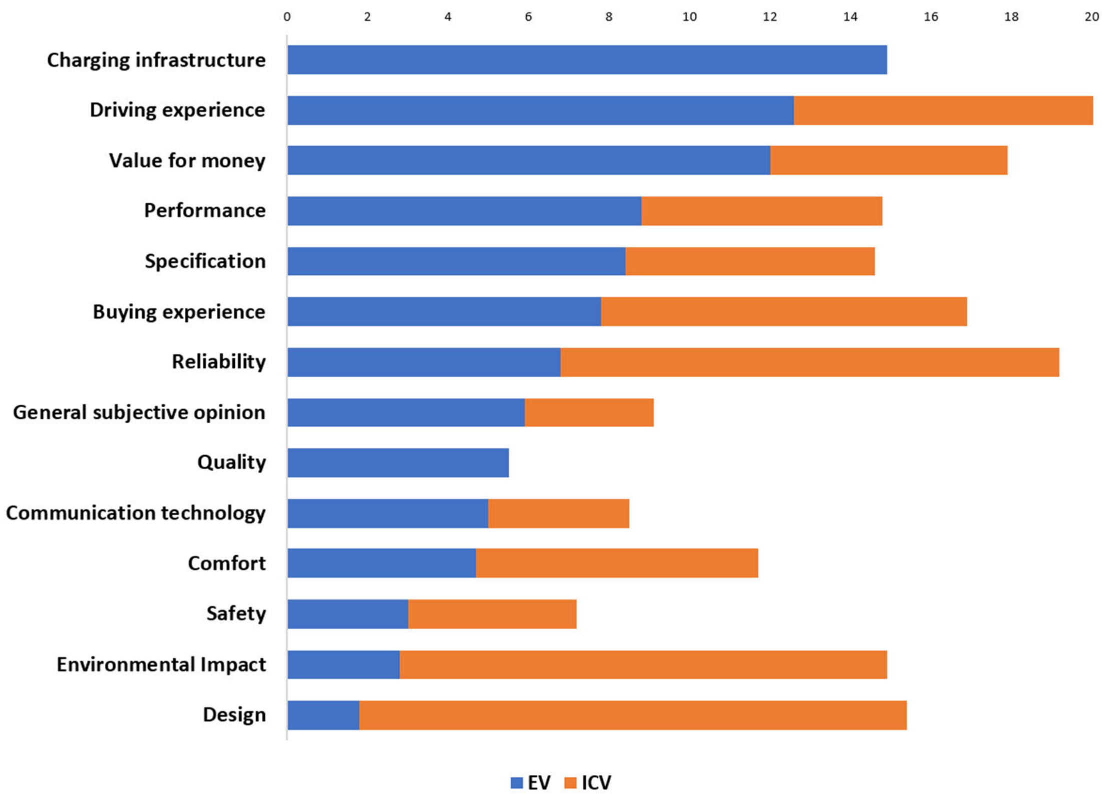


FIGURE 2. Distribution of customers' experience subcategories prevalence (%) for EVs and ICVs.

tion experience, these consumer preferences underscore the importance of enhancing fuel efficiency and enacting robust policies to support reducing emissions and sustainable road transportation [155], [156].

A summary of the latent topics is presented in Table 6. A description of identified factors of ICVs customer experience and examples of the most representative opinions are provided in Appendix I.

B. ALIGNING CUSTOMER EXPERIENCE WITH CUSTOMER SATISFACTION

To explore: *"How do factors of the customer experience align with the overall satisfaction with the EVs and ICVs purchase*

TABLE 6. Topics labelling results summary (ICVs customer opinions).

Topic/ Subcategory	TOPIC LABEL	Topic/Category prevalence (%)	Exclusivity	Semantic Coherence	Category
Driving experience		16.8			
Topic 2	Overall driving experience	7.1	10.20	-82.28	Non-functional
Topic 29	Handling	5.0	10.10	-91.51	Non-functional
Topic 5	Fun-factor	2.5	9.96	-88.18	Non-functional
Topic 15	Test drive	2.2	9.52	-101.40	Non-functional
Design		13.6			
Topic 28	Looks	9.3	10.10	-91.78	Non-functional
Topic 35	Sports Utility Vehicle (SUVs)	1.9	9.68	-95.79	Non-functional
Topic 37	Colour	1.3	9.40	-109.45	Non-functional
Topic 18	Overall design	1.1	9.02	-98.28	Non-functional
Reliability		12.4			
Topic 10	Overall reliability	3.7	10.21	-115.41	Non-functional
Topic 9	Electronics	3.5	9.93	-71.73	Functional
Topic 11	Engine	2.1	9.36	-86.39	Functional
Topic 32	Transmission	2.1	9.82	-91.64	Functional
Topic 24	Parts needed service	1.0	9.24	-83.33	Functional
Environmental Impact		12.1			
Topic 22	Gas mileage (fuel efficiency)	10.1	10.30	-73.99	Functional
Topic 21	Highway gas mileage	2.0	9.71	-107.92	Functional
Buying experience		9.1			
Topic 17	Purchase experience	2.2	9.65	-113.73	Non-functional
Topic 4	After-purchase experience	1.9	9.59	-94.53	Non-functional
Topic 26	Expectations	1.8	10.00	-126.82	Non-functional
Topic 19	Comparison shopping engines	1.4	9.91	-99.77	Non-functional
Topic 36	Dealerships' service	1.2	9.32	-119.15	Non-functional
Topic 40	After-purchase opinion	0.6	10.48	-97.70	Non-functional
Comfort		7.0			
Topic 14	Seats	2.7	9.45	-95.18	Functional
Topic 13	Legroom	2.5	9.71	-93.96	Functional
Topic 12	Trunk	1.8	9.54	-101.80	Functional
Specification		6.2			
Topic 7	Size	3.4	9.65	-104.57	Functional
Topic 8	Package types	2.8	10.91	-112.14	Functional
Performance		6.0			
Topic 23	Driving modes	2.2	9.71	-85.69	Functional
Topic 16	City/Highway performance	1.6	9.56	-92.88	Non-functional
Topic 30	Speed	1.3	9.76	-98.60	Functional
Topic 27	Performance in different conditions	0.8	9.95	-79.65	Non-functional
Value for money		5.9			
Topic 3	Overall value for the money	2.7	10.52	-112.41	Non-functional
Topic 1	Purchase worthiness	2.1	10.62	-115.95	Non-functional
Topic 25	Pricing	1.1	9.54	-89.90	Functional
Safety		4.2			
Topic 34	Safety features	1.6	9.58	-83.04	Functional
Topic 20	Lighting	1.4	9.53	-101.90	Functional
Topic 31	General safety	1.2	9.85	-91.20	Non-functional
Communication technology		3.5			
Topic 6	Sound system	2.1	10.30	-82.60	Non-functional
Topic 38	Phone integration	1.4	10.57	-81.92	Functional
General subjective opinion		3.2			
Topic 33	General	1.8	9.92	-115.50	Non-functional
Topic 39	Brand opinion	1.4	9.40	-109.57	Non-functional

Source: Own elaboration

and consumption?"(RQ2), the *Average Rating* and *Total Topic Prevalence* for each identified factor were analyzed and visualized using scatterplots. This approach enabled the identification of patterns (CEP_1) in customer experience factors across varying levels of satisfaction, providing insights into consumer priorities and concerns.

For EVs, two critical factors (outliers) were observed.[22] The first pertains to the *Overall Driving Experience* factor, which can be categorized under the main *Advantages* pattern and refers to customer feeling when driving a EVs. This factor is represented by opinions featuring a high average rating for the reviewed vehicle and a substantial volume of discussion. The second critical factor concerns the *Technical service* aspect, marked by a notably negative opinion (low average rating). However, this aspect is not as frequently mentioned in customer opinions and primarily encompasses individual instances of critical customer service situations at dealerships. This could be classified within the *Minor Issues* pattern.

Figure 3 presents the conclusive outcomes of aligning the remaining EVs customer experience factors importance (measured by *Total Topic Prevalence*) with customer satisfaction (measured by *Average Rating*). The scatterplot visualizes non-functional categories of factors with dots and functional categories with squared markers.

Customers most appreciate such *advantages* EVs as vehicle *Size*, *Speed*, *Spaciousness*, and the potential for *Fuel-cost savings*. *Battery* capacity issues for long road trips, in combination with "spotty *charging infrastructure*", are prominently discussed as a key *disadvantage*. Customers perceive *opportunities* for success in the vehicle market through aspects including car *Maintenance*, *Quality*, *Pricing* policy, *Supercharges*, *Comparisons* with other care handling, *Safety* features, and *Software* updates. It is positive news that Environmental impact factors, such as *Ecology* and *Quietness*, aim to support the transition toward sustainable electric mobility [157], [158] are also perceived as EVs opportunities. The *minor* issues encompass *Manufacturing defects*, *Customer service*, *Design*, *Steering wheel* functionalities, *Build quality*, *Dead Battery* and General concerns.

The results of mapping the average rating and total topic prevalence, which characterize the experience of ICVs customers, are presented in Figure 4. Factors identified as outliers based on discussion volume and user satisfaction levels are as follows[23]: primarily, high *Gas mileage* related to improving energy efficiency and environmental impact, along with car aesthetics (*Looks*), *Driving experience*, and *Handling*. These factors are perceived by customers as the *primary advantages* of ICVs. Most *Minor ICVs issues* encompass the *Electronics*, *Transmission*, and *Engine factors*. These aspects are characterized by both a low frequency of mention in customer opinions and the lowest levels of customer satisfaction. Upon examining the patterns within the remaining factors, the following insights emerged. Customers

[22]Patterns in customer experience (CEP_1) with outliers.

[23]The details of mapping the average rating and total topic prevalence with outliers are presented in the Patterns in customer experience (CEP_1) with outliers.

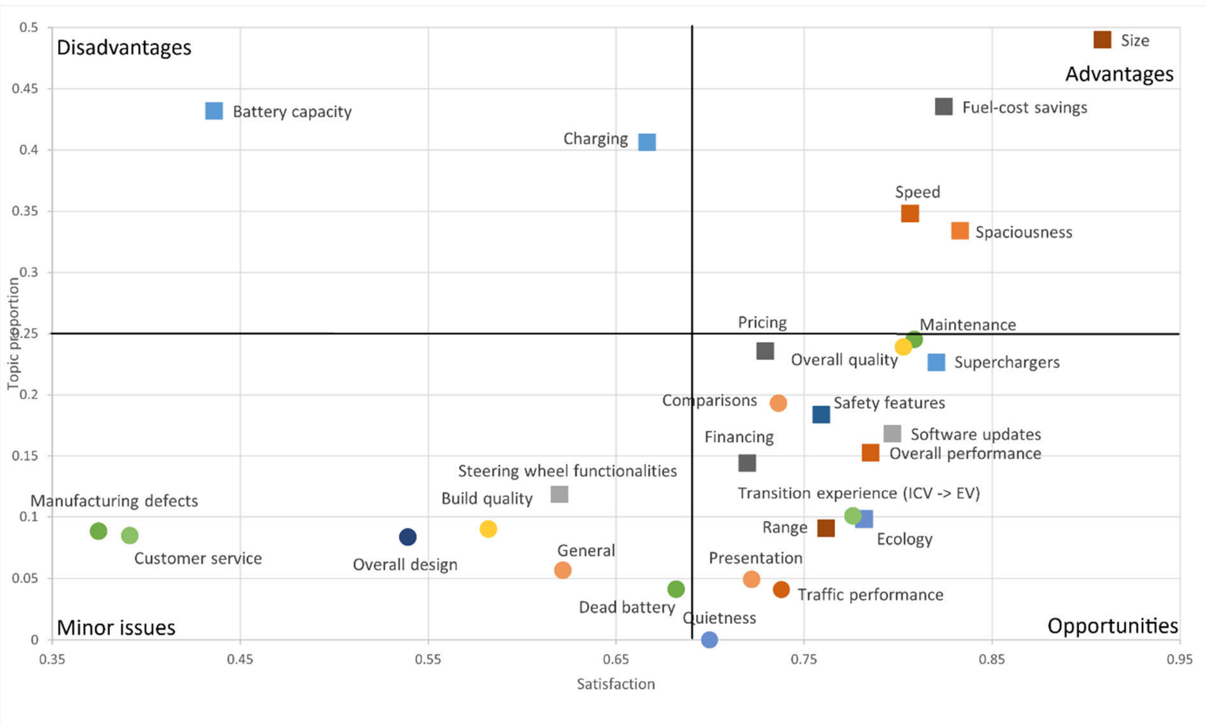


FIGURE 3. Alignment between EVs customer experience factors and customer satisfaction.

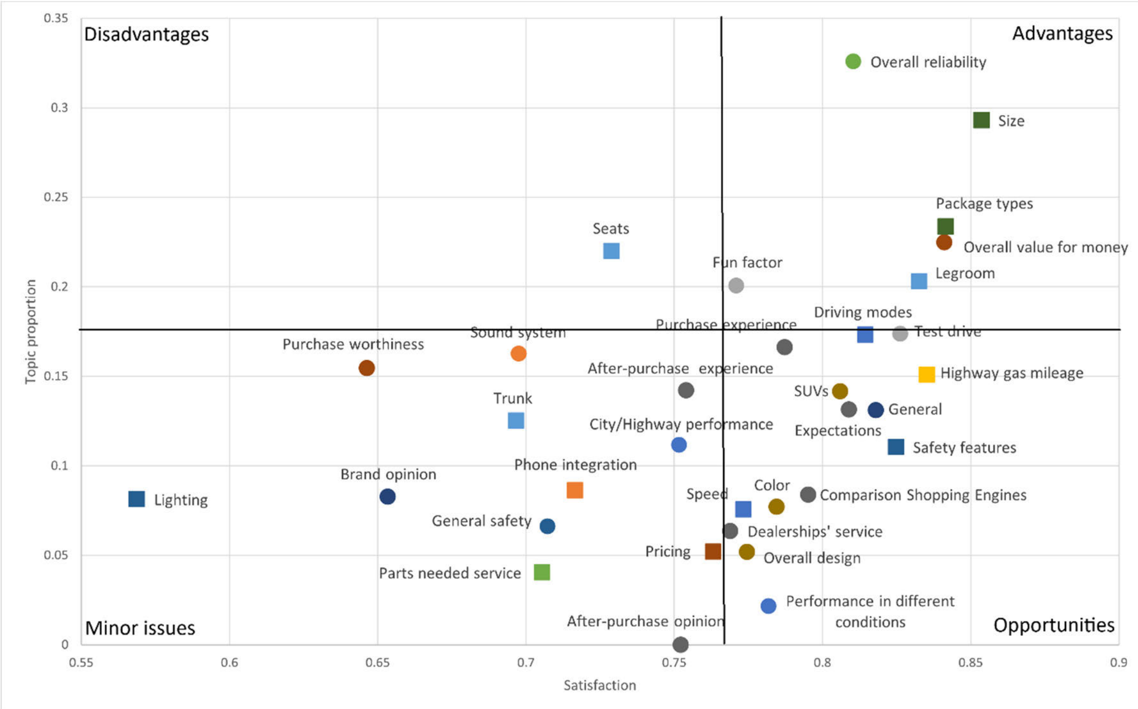


FIGURE 4. **Alignment between ICVs customer experience factors and customer satisfaction.**

highly value the *advantages* associated with ICVs, such as *Reliability*, *Size*, *Package types*, *Value for the money*, and *Legroom*. *Seat* features are the primary *disadvantage*, while the *Fun* factor of the driving process may lean more towards being a neutral factor. Customers recognize the *potential* for success in the vehicle market through aspects including *Test drives*, *Highway gas mileage*, *Purchase experiences*, and *SUVs*. The most populated category is *minor* issues, which encompasses factors like *Lighting*, *Brand* opinion, *Purchase worthiness*, *Trunk*, and *Sound system*.

C. LONGITUDINAL ALIGNMENT OF CUSTOMER EXPERIENCE FACTORS & CUSTOMER SATISFACTION

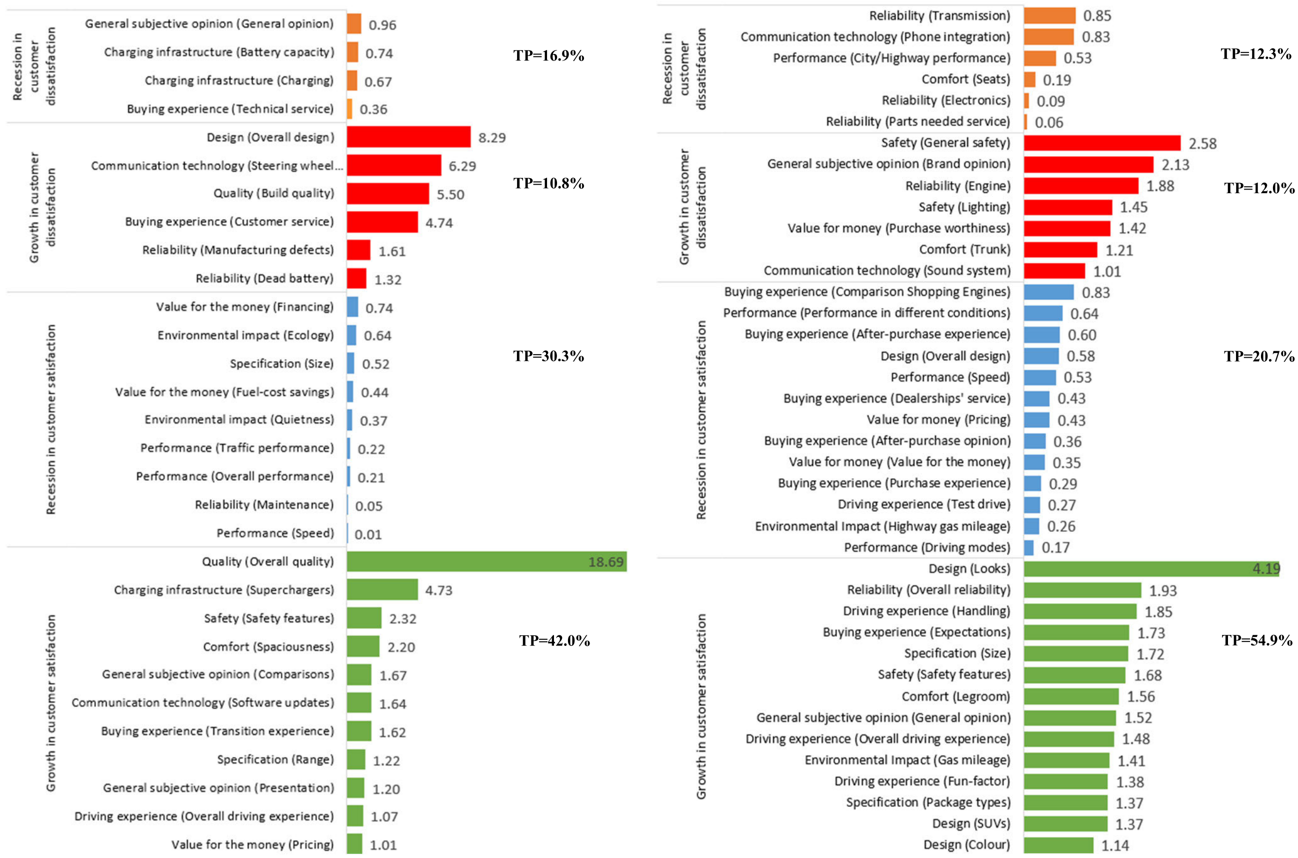
The results of identifying patterns in customer experience over time (CEP_2) are presented in Figure 5.[24] These findings shed light on the longitudinal alignment between EVs and ICVs customer experience factors' importance and customer satisfaction, addressing RQ3: "*How do patterns in identified EVs and ICVs customer experience factors vary across review dates*?"

According to our methodology, the regression slope allows us to estimate the relative *Rate of change* in the importance of a topic over time, indicating a *recession* (less than or equal to 0) or *growth* (greater than 0) in customer interest in this topic. Additionally, groups of factors associated with low ratings (below 3) and high ratings (above 3) are categorized as factors associated with customer *dissatisfaction* or *satisfaction*, respectively.

[24]The details of longitudinal analysis of the relationship between EVs/ICVs and customer experience factors and customer satisfaction (rating) are presented in the Longitudinal analysis.

The largest proportion of the discussion is occupied by the alignment pattern of *growth in customer satisfaction* (TP = 42.0% for EVs and TP = 54.9% for ICVs). The greatest growth in this category is observed for the topic of categories *Quality* (*Overall quality*), followed by a large margin for *Charging infrastructure*(*Superchargers*) and *Safety* (*Safety features*) for EVs. Respectively, for ICVs, *Design* (*Looks*), *Reliability*(*Overall reliability*), and *Driving experience* (*Handling*) are characterized by the highest growth in the positive interest of users. The most frequent categories in the *growth in customer satisfaction* pattern group for ICVs are *Driving experience, Design* and *Specification*. In contrast, electric vehicle categories display uniform distribution within the customer satisfaction growth group on the other hand highlighting the diverse and evolving priorities of consumers toward emerging technologies.

However, a significant proportion of customer experience is also associated with some *recession* in interest in factors inherently associated with *customer satisfaction*. For EVs, the TP of such factors is 30.3%, and for ICVs, it is 20.7%. The most rapid decline in satisfaction among EV-related categories is observed in *Value for Money (Financing)*. This category contains various aspects such as leasing options, credit availability, incentives, and government rebates, all of which influence the affordability of purchasing electric vehicles. The *Environmental impact* (*Ecology*) category is also on this list. This can be attributed to initial optimism related to zero-emission and the positive impact of electric vehicles on climate change culture and sustainable electric mobility, which in recent years has given way to concerns over socio-environmental issues related to lithium-ion battery



a) EVs b) ICVs

FIGURE 5. **The rate of change in customer experience factors over the review's dates of publishing.**

production, social equity challenges, and the increased strain on grid infrastructure energy [156], [157], [159]. For ICVs, the positive acceptance of such categories of consumer experience as *Buying experience* (*Comparison Shopping Engines* and *After-purchase experience*), and *Performance* (*Performance in different conditions)* also cease to be as relevant. The primary categories showing a decline in customer satisfaction for EVs are *Performance, Environmental impact* and *Value of money*. For ICVs, the prevalent categories also include *Performance* and *Value for Money*, with *Buying Experience* additionally highlighted.

Regarding factors related to customers *dissatisfaction*, the share of such factors with a *recession* in the degree of discussion (TP = 16.9%) for EVs is higher than the share of issues in which user interest is still *increasing*(TP = 10.8%). Key areas raising concern among EV customers include *Desing* (*Overall design*), *Communication technologies* (*Steering wheel functionalities*), and *Quality* (*Build quality*). For ICVs, rising concerns focus on *Safety* (*General safety* and *Lighting*), *Reliability* (*Engine issues*), and *Value of money* (*Purchase worthiness*) with a share of 12.0%.

Meanwhile, issues primarily related to *Charging infrastructure* (*Battery capacity* and *Charging*) and *Buying Experience* (*Technical Service*) for EVs appear to have seen improvement, supporting a smoother adoption of EVs. Similarly, concerns around *Reliability*, *Communication technologies*, and *Performance* for ICVs have shown a decrease in customer dissatisfaction over time.

D. PREVALENT CUSTOMER EXPERIENCE FACTORS AMONG CUSTOMER'S GENDER

Answering RQ4: "*How do patterns in identified EVs and ICVs customer experience factors vary across predicted author gender*?", the study revealed significant diversity in the experience patterns of customers of different genders (CEP_3). Figure 6 shows the predicted *Gender Prevalence Score* of factors (topics) in the experience of males and females depending on the identified (predicted) gender of the reviewer (by name).

For EVs, it appears that *male* customers primarily engage in discussions around *Charging infrastructure* (particularly *Supercharger* aspects specific to Tesla vehicles). They also show heightened interest in *Reliability* factors (such as *Maintenance* and *Manufacturing defects*) and focus significantly on *Design*, *Quality*, and *Communication technologies*. *Environmental impact* aspects of EVs also tend to be a male-dominated discussion topic.

Females are more likely to focus on EV-related aspects around *Comfort* (e.g., *Spaciousness*) and concerns regarding *Charging infrastructure*(e.g., *Charging* and *Battery capacity*). Other relevant factors for women include discussions on *Value for money* (e.g., *Financing* and *Fuel-cost savings*) and *Safety features* (Figure 6, a).

In the case of ICVs customer experience, *female* reviewers express a strong interest in the vehicle's *Design* (*Looks*), with this factor significantly outweighing all others in importance. After excluding this outlier, other frequently mentioned factors among female consumers include *Reliability* and, specific to EV female customers, *Comfort* (e.g., *Legroom* and *Seats*), *Specifications* (*Size*), and additional aspects of *Design* (e.g., *Colour*).

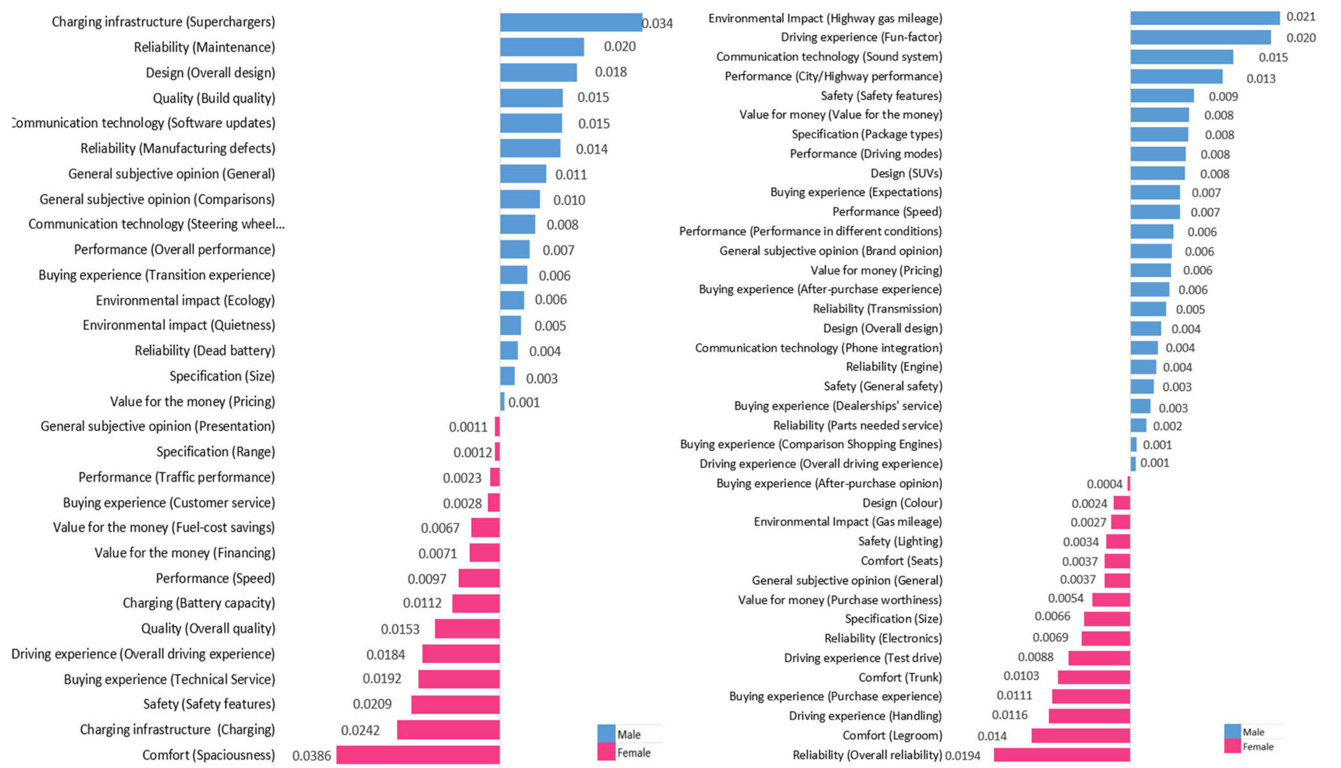
Notably, the *Environmental impact* factor related to *Highway gas mileage* also tends to be a *male*-dominated discussion topic for ICVs. Additionally, males are more inclined to discuss *Driving experience* (e.g., *Fun* factor), *Communication technologies* (e.g., *Sound* system), Performance (e.g., *City/highway performance*, *Speed*, and *Performance in various conditions*), and *Specifications* (e.g., *Package* types) (Figure 6, b).

E. SHAPING THE CONSUMER'S IMAGE OF ELECTRIC VEHICLES

To find the answer to RQ5: "*Which customer service quality factors shape the image of electric vehicles conquering the automotive market*?", a perceptual map was constructed illustrating the image structure of each of the eight selected electric vehicle models, as derived from customer experience expressed in free-text opinions (Figure 7).

Appendix J provides the factor loadings of customer experience topics for the two principle dimensions, aiding in understanding the significance and impact of each variable within each main component, while the vehicle models are plotted according to the loadings shown in Appendix K. For interpretative purposes, the principle components have been named based on the topic labels with the highest load values. Accordingly, PC1 was designated "*Capacity & Size*" and PC2 was labelled "*Financing & Size*"

Perceptual map shows that consumers strongly associate the brand *Tesla* with eight main factors Speed, Ecology, Presentation, Overall performance, Superchargers, Manufacturing defects, Technical service and Overall driving experience. The image of *BMW* is highly associated only with Quietness, while *Chevrolet* is associated with the driving Range factor. *FIAT* in customer experience has strong associations with Financing, Maintenance, Size, Fuel-cost savings and Traffic performance. *Nissan* is positioned as a brand associated with Transition experience, Fuel-cost



a) EVs b) ICVs

FIGURE 6. **Alignment between customer experience factors and customer's gender (predicted Gender Prevalence Score).**

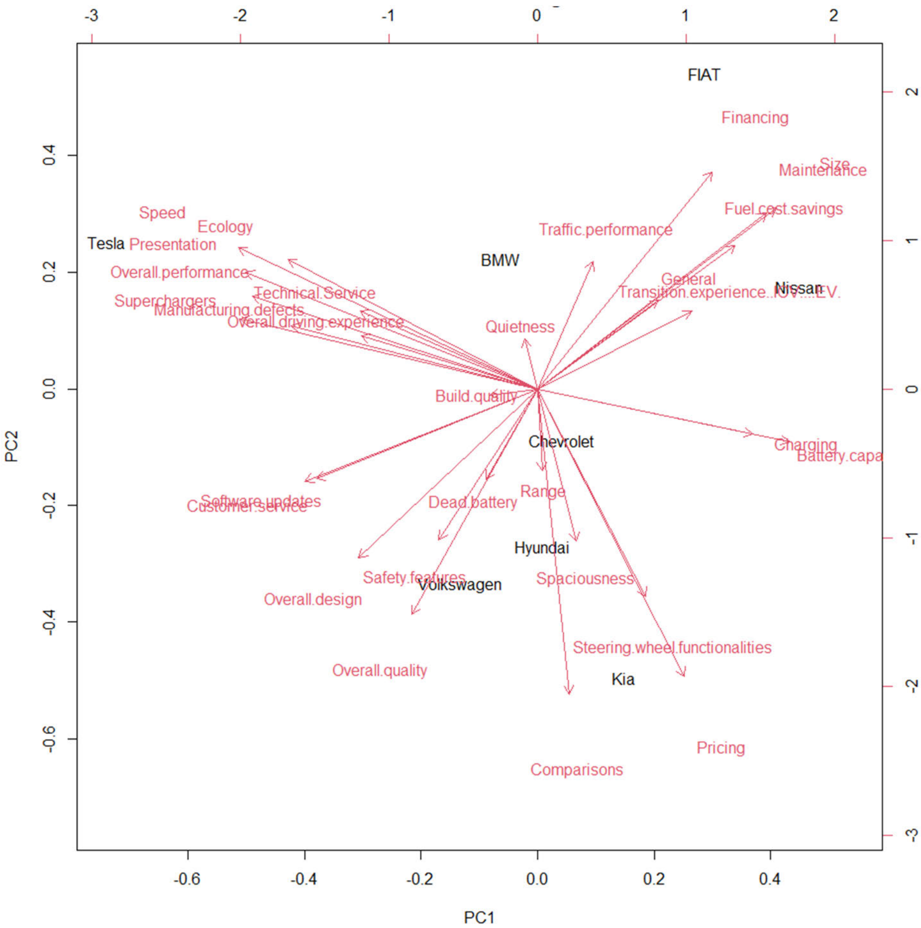


FIGURE 7. Two-dimensional perceptual map of EVs images.

savings, and Maintenance and Size. *Hyundai* is primarily associated with experience related to Spaciousness and Comparisons with other models. *KIA's* image is connected with affordable Pricing policy and Steering-wheel functionalities discussions. And *Volkswagen* model image contains Overall quality, Safety features, Overall design and Dead battery issues.

V. DISCUSSION

Our analysis identifies *several common and unique factors shaping customer experiences in EVs and ICVs*(RQ1), offering insights that both reflect and expand upon existing literature in several key ways:

- *common and unique factors*: Both EVs and ICVs share most sub-categories in consumer discussions. However, unique to EVs are factors like *Charging Infrastructure* [160], [161] and *Build Quality*, highlighting the distinct considerations brought about by EVs' technological and infrastructural demands;
- *customer focus variations*: There are notable differences in the focus of customer discussions. *Environmental impact*, *Design* and *Reliability* factors are more frequently emphasized by ICV consumers, consistent with [162]. Conversely, EV customers show a stronger focus on categories like *Driving Experience, Performance, Specifications*, and *Value for Money* [47];
- *functional vs. emotional values*: The greater importance of functional values for EV customers could stem from the relative novelty and perceived risk associated with electric vehicles. Consumers tend to scrutinize the tangible benefits and trade-offs of adopting EVs to assess alignment with their traditional driving habits. This behavior aligns with perceived value theory, which suggests that functional value is prioritized when evaluating new or less familiar products [55]. In contrast, ICV consumers – who are more familiar with the technology – are more inclined to emphasize emotional and subjective factors, such as comfort, nostalgia, and symbolic attachment, reflecting non-functional value dimensions. This contrast is consistent with existing consumer behavior literature on product maturity, emotional attachment, and risk perception [163];
- *shared functional & emotional factors*: Among the shared functional factors for both EVs and ICVs, *Safety Features*, *Size*, *Speed*, and *Pricing Policy* [123] were consistently identified. However, the emotional factors differ more markedly between the two vehicle types, with commonalities limited to Over-

all Driving Experience, *Overall Design*, and *General Opinion*;

- *environmental impact comparisons*: Discussions around environmental impact differ significantly between EVs and ICVs. EV-related sustainability features such as zero-emissions (Ecology) and noise reduction (Quietness) are less frequently discussed, potentially reflecting consumer assumptions that these attributes are inherent to EVs [158]. On the other hand, ICV consumers prioritize fuel efficiency-related factors like *Gas Mileage* and *Highway Gas Mileage*. This finding points to an opportunity for policymakers to enhance awareness of EVs' unique environmental benefits while reinforcing support for low-emission transportation policies, as emphasized in prior studies.

Our study reveals several *patterns in customer experience factors that align with the overall satisfaction of EV and ICV consumers*(RQ2), expanding upon the findings of previous studies:

- *understanding primary advantages*: ICV customers demonstrate a more established understanding of key benefits, including improved *fuel efficiency* (*gas mileage)*, *car appearance*, *driving experience*, and *handling*. These factors consistently emerge as the most positively perceived attributes. Conversely, EV customers are most engaged and satisfied with the *overall driving experience*. However, other aspects of EVs do not garner unanimous positive consensus, reflecting a nuanced evaluation process;
- *identifying significant disadvantages*: EV customers predominantly highlight *Charging Infrastructure* issues, such as low *battery* capacity and limited accessibility to *charging* stations, as significant drawbacks [2], [47], [130], [161]. Meanwhile, ICV customers focus their criticism on seat comfort issues, particularly seat heating, which stands out as the most frequently and negatively discussed topic;
- *functional and non-functional values*: EV customers value *functional advantages* such as *speed*, *spaciousness* [43], and *fuel-cost savings*. In contrast, ICV customers prioritize *basic functional* features like vehicle size (especially for urban settings), *packaging* options, and *legroom*. Furthermore, *non-functional* aspects such as *reliability*, subjective perceptions of *value* for *money*, and *driving f*un are emphasized by ICV customers as key advantages;
- *market success opportunities*: For EVs, promising factors include the perception of "*zero maintenance*" requirements, high interior quality, luxurious designs, and functional features such as *equalization* of *prices* [159] across dealers, access to *superchargers* (not limited to Tesla owners), enhanced safety features (e.g., lane-keeping/line assist), and regular *software updates*. For ICVs, market success is more tied to improving non-functional customer experiences, such as *test-drive* satisfaction (comfort and handling) and *purchase experience* (perceived value regardless of cost). Optimizing functional features like highway *gas mileage* and *safety* features (lane-keeping and cruise control) can further solidify ICVs' appeal.

Our research explores *how customer experience patterns for EVs and ICVs evolve over time* (RQ3), offering critical insights into changing perceptions and priorities. For EVs, longitudinal patterns reveal several trends:

- *disadvantages*: *Battery capacity* remains a notable concern, but the frequency of dissatisfaction expressed by customers has shown a gradual decline over time. This suggests that industry efforts to address this issue, such as improving battery technology, yield results;
- *advantages*: While *Spaciousness* is the only factor with a notable increase in customer interest and satisfaction over time, other well-regarded factors such as *Size*, *Fuel-cost* savings [164], and *Speed* have experienced a relative decline in positive evaluation or customer attention in recent years;
- *opportunities*: Factors categorized as opportunities, such as *Overall Quality*, *Pricing*, *Supercharges*, *Safety*, and Software updates, are being increasingly discussed over time. This upward trend indicates that decision-makers should prioritize enhancing and sustaining these features to meet customer expectations.

For ICVs, the longitudinal patterns display similar and divergent trends:

- *advantages***:** most factors, except *Value for money*, that are associated with positive qualities distinguishing cars in the eyes of customers, maintain their positive reputation throughout the analyzed years and are characterized by increasing attention and approval from customers;
- *disadvantages***:** While *Seats* remain the most negatively discussed factor, the frequency of these complaints has been gradually decreasing, reflecting improvements in addressing this issue;
- *opportunities***:** Promising attributes such as *Test Drives, Highway Gas Mileage, and Purchase Experiences* are facing a reduction in customer focus, which may imply missed opportunities for enhancing satisfaction.
- *minor issues***:** Issues such as *Engine, Brand, Purchase Worthiness, Lighting, Sound System*, and *Trunk* have seen an increase in negative discussions. Addressing these aspects may be critical to maintaining customer satisfaction and brand reputation.

These evolving patterns underscore the dynamic nature of customer expectations and provide actionable insights for the automotive industry to improve customer satisfaction and competitive positioning.

The summary of the identified patterns (CEP_1 - CEP_3) is visually represented in Figure 8, capturing the longitudinal trends across the EV and ICV segments.

Our analysis highlights *how customer experience patterns for EVs and ICVs differ across predicted author genders*

(RQ4), revealing gender-specific preferences and priorities that shape discussions. For *EVs*, gender differences are pronounced:

- *male customers*: Discussions among male reviewers frequently emphasize factors such as *Superchargers, Design elements, Maintenance, Build Quality, and Manufacturing Defects*. Male reviewers also show a notable interest in *Environmental impact*, often expressing satisfaction with the sustainability benefits of EVs. Comments highlight the appeal of zero emissions, clean air, and the quiet driving experience, reinforcing that men are likelier to associate their purchase decisions with environmental motivations. This aligns with prior research indicating that men self-report greater knowledge about ultra-low emission vehicles and public charging points [165];
- *female customers***:** Female reviewers are more likely to prioritize factors such as *Spaciousness*, *Charging* infrastructure, *Safety features*, *Battery capacity*. These preferences suggest a focus on practical, safety-oriented, and functional aspects of EV ownership, complementing and reinforcing previous findings [35].

For ICVs, the gender-specific patterns diverge further:

- *female customers***:** Female reviewers emphasise aesthetic factors as vehicle *Looks* alongside practical considerations such as *Reliability* and *Legroom*. These preferences highlight the importance of comfort and visual appeal in shaping their overall customer experience;
- *male customers*: Male reviewers frequently discuss aspects such *as Fun Factor, Sound System, and City/Highway Performance.* Their focus on these factors

Pattern	*EVs Factors*				*ICVs Factors*			
	Advantages	*Disdvantages*	*Opportunities*	*Minor Issues*	*Advantages*	*Disdvantages*	*Opportunities*	*Minor Issues*
Growth in customer satisfaction	Overall driving experience **Spaciousness**		**Safety features** **Range** Presentation Quality **Software updates** **Pricing** Comparisons Superchargers Transition experience		**Gas mileage** Looks Handling Reliability **Size** **Package types** Driving experience Fun factor **Legroom**		General Color **Safety features** Expectations SUVs	
Recession in customer satisfaction	**Fuel-cost savings** **Speed** **Size**		**Financing** Traffic performance **Overall performance** **Ecology** Quietness Maintenance		Value for money		Purchase experience Test drive **Speed** **Highway gas mileage** **Driving modes** Comparison Shopping Engines Performance in different conditions Overall design Dealerships' service	After-purchase opinion **Pricing** After-purchase experience
Growth in customer dissatisfaction				Customer service **Steering wheel functionalities** Build quality Overall design Dead battery Manufacturing defects				**Lighting** **Trunk** Purchase worthiness **Engine** General safety Brand opinion Sound system
Recession in customer dissatisfaction		**Battery capacity** Charging		Technical service General		**Seats**		**Electronics** **Phone integration** **Transmission** **Parts needed service** City/Highway performance

Female preferences		Male preferences		Functional Values	**Bold**

FIGURE 8. Summary of patterns in EVs and ICVs customer experience.

TABLE 7. Literature review of EVs integration.

Source	NLP	Data source	Functionality	Public service value	Problem addressed	Benefit	Research method	Stakeholders
Technological advancements								
[22]	None	Floating Car Data, Probe Vehicle Data	Traffic and Energy Consumption Modelling for EVs	Enhanced accuracy of EV energy consumption models	Updating parameters of energy consumption models for EVs	Improved eco-driving and eco-routing applications	SCV Procedure, Weighted GLS Estimator	Transport Planners, Automotive Industry, Environmental Researchers
[29]	None	Literature Review	Reviewing advancements and challenges in EV technology	Comprehensive understanding of EV technologies and challenges	Review of battery technologies, charging methods, and market trends	Enhanced knowledge base for future EV developments	Literature Review	Industry Researchers, Policymakers, EV Manufacturers
[10]	None	Literature Review	Analyzing EV hardware and software systems	Advancing EV technology and infrastructure policies	Identifying current limitations and future developments in EV platforms	Comprehensive understanding of EV systems and advancements	Systematic Review, Analysis	EV Manufacturers, Researchers, Policy Makers
[178]	Weka	Machine learning dataset	Classification of car types using semantics	Improving car type classification accuracy	Understanding car type classification based on semantics	Enhanced accuracy in car type classification	Machine learning, Weka	Researchers, automotive industry
[88]	None	Literature Review	Reviewing advancements and future prospects of EV technologies	Informing stakeholders on future EV developments	Identifying current advancements and future prospects of EV technologies	Enhanced understanding of EV technologies and their future trends	Literature Review	Researchers, Policymakers, EV Manufacturers
[11]	None	Literature Review	Analyzing challenges and opportunities in EV charging infrastructure	Optimizing EV charging infrastructure and route planning	Identifying challenges in establishing new EV charging stations and optimizing their use	Enhanced EV charging infrastructure and route planning	Literature Review	Transport Planners, Policymakers, EV Manufacturers
[9]	None	Literature Review	Reviewing existing and future technologies for batteries of EVs	Informing future EV technology development towards batteries	Identifying current technologies and future developments in batteries of EVs	Comprehensive understanding of EV technologies and future perspectives for batteries	Literature Review	Researchers, EV Manufacturers, Policymakers
[179]	None	Questionnaire survey	Analyzing the usage intention of EV users	Informing EV manufacturers for better product development and marketing	Identifying factors influencing the usage intention of EVs	Developing a model for understanding usage intention	Exploratory factor analysis	EV Manufacturers, Researchers, Policymakers
[180]	None	Charging data from corporate fleets	Analyzing EV charging data for corporate fleets	Supporting data-driven decisions on EV charging infrastructure	Understanding the impact of electrification on corporate fleet operations	Improved planning and efficiency in EV charging	CRISP-DM methodology	Corporate Fleet Managers, Energy Planners
[110]	None	Scopus database from 2011-2023	Analyzing scientometric trends in EV research through text mining	Supporting policy and innovation in EV research	Identifying research trends and gaps in electric vehicle studies	Enhanced understanding of research directions in EV studies	Bibliometric and Sociometric Analysis	Researchers, Policymakers, EV Industry
[164]	None	Database of 123 EVs	Analyzing energy consumption parameters of EVs	Improving understanding of factors affecting EV energy consumption	Identifying correlations between energy consumption and vehicle parameters	Enhanced data analysis methodologies for EVs	Data Analytics, Python	Researchers, Automotive Industry, Policymakers
[122]	Text Mining	Consumer reviews and comments	Analyzing trust issues in self-driving vehicles	Improving trust and acceptance of autonomous vehicles	Understanding consumer perceptions and trust factors for self-driving cars	Enhanced strategies for building trust in autonomous vehicle technology	Structural Topic Modelling	Automakers, Policymakers, Researchers
[46]	Sentiment Analysis, Machine Learning	Twitter data	Analyzing public sentiment on EVs in India	Informing marketing and policy decisions for EVs	Understanding public opinions and sentiment regarding EVs	Enhanced strategies for public engagement and policy-making	Sentiment Analysis, Machine Learning	Policymakers, Automakers, Marketing Professionals
[128]	Text Mining	Qualitative think aloud data	Exploring UX issues related to EV sound	Informing EV sound design	Understanding user preferences and issues with EV sound	Improved EV sound design	Text Mining, Sentiment Analysis	Automotive Engineers, UX Designers, Researchers
[38]	Text mining	Abstracts collected from scientific article database	Development of knowledge synthesis model for e-bus literature model	Provides a comprehensive overview of e-bus research and highlights topics used in it	Addresses a need for synthesized knowledge on e-buses	Its findings help to identify critical research areas and emerging new topics	Topic modelling	Researchers, policy makers, public transport authorities
[12]	None	EV connected information's	It systematically reviews charging technologies for EVs	Comprehensive overview of current EV charging technologies	Addresses issue of charging time and complexities of developing EV charging schemes	Help in identification of knowledge gaps and guide future research efforts	Information review	Policy makers, automotive manufacturers and marketers
[133]	Text mining	Patents related to EVs	Analysis of patents for EVs to identify their key characteristics	Provides insights into development trajectory of EVs	Addresses the need to understand rapid development of EVs	It highlights technological advancements and contributions to EV industry	???	Researchers, policy makers, automotive industry manufacturers
[181]	None	Case study data	Study develops and compares metaheuristic algorithms to solve problem of optimization of EVs	Provides framework for optimization of fleet management in context of EVs	Addresses trade-offs and optimization challenges in transition to EVs	Findings offer insights for planners and policy makers to optimize integration of EVs	Development and comparison of two metaheuristic algorithms for solving a large scale non-linear optimization problem	Policy makers
[182]	None	Literature review of articles	Investigation of factors that affect customers' intention to adopt EVs	Provides comprehensive insights into customers' attitude towards EV adoption	Addresses the slow market penetration of EVs despite promotional efforts from government	Findings can help policy makers and automotive manufacturers to better understand customer needs	Literature review with categorization	Policy makers and automotive manufacturers
[183]	None	Analysis of energy systems on Island	Allows for high renewable energy scenarios evaluation	Promotes sustainable energy practices	Addresses the problem of high oil consumption and CO2 emissions	Allows for specification of reduced oil consumption and CO2 emissions	Smart Energy Systems concept, power system analysis	Policy makers, energy planners
[96]	None	Literature on EV charging stations placement	Allows for optimal placement strategies evaluation	Enhances network performance and shows environmental benefits	Addresses problem of uncoordinated surge for electric vehicles and charging stations	Prevents issues associated with integration of EVs	Review of different approaches of strategies	Policy makers, energy planners
[89]	None	Analysis of scientific data sources	Categorization and summary of data sources relevant to EV integration into power systems	Shows reference for researchers to access EV related data	Addresses low amount of necessary data for EV impact on power systems analysis	Allows for facilitation of accurate charging profiles creation	Literature overview	Researchers, policy makers
[184]	None	Media, marketing materials	Categorization and description of functions from charging-as-a-service vendors	Shows insights into emerging model to support EV adoption	Addresses problem of sparse access to EV charging infrastructure	Reduction of charging costs	Analysis of media and marketing together with scholarly publications	Researchers
[13]	None	Simulation data	Simulation and optimization of EV performance	Improvement of the efficiency and sustainability of EVs	Addresses complexity of EV performance and efficiency optimization	Improvement in EV efficiency by e.g. reducing energy consumption and overall performance enhancement	Mathematical modeling and simulation	Automotive Manudacturers

TABLE 7. ***(Continued.)*** **Literature review of EVs integration.**

Health & impact on environment								
[73]	None	Pollution data (PM)	Investigation of co-benefits from battery electric bus fleet utilization	Determining benefits of electric bus fleet	Addresses the benefits of electric bus fleet in terms of clean energy	Helps in driving the EV adoption by highlighting the climate benefits of EVs	Statistical model	Policy Makers, Environmental Researchers, Automotive Industry
[74]	None	Pollution data (PM)	Ivenstigates the health and air quality benefits of electrification of heavy-duty vehicles	Shows the health and air pollution reduction benefits of electrification of heavy-duty vehicles	Addresses the problem of not resolved air quality and health implications at equity-relevant scales	Shows the importance of EV adoption in heavy-duty vehicles as a way for air pollution reduction and health improvement	Simulation of atmospheric processes and weather conditions - Community Multi-scale Air Quality (CMAQ)	Policy Makers, Environmental Researchers, Automotive Industry
[77]	None	Pollution data (PM)	Investigation of EV air pollution health benefits	Shows the benefits of EVs in terms of air pollution reduction	Addresses the problem of scant literature on EV health impacts	Shows the health and air pollution reduction benefits that EVs provide	Health impact assessment	Policy Makers, Environmental Researchers, Automotive Industry
[86]	None	Pollution data (PM)	Examination of vehicle weight-dependence of particulate matter emissions from abrasion, and road dust	Shows the difference in PM emissions between EVs and ICVs	Addresses the assumption that battery-electric vehicle non-exhaust emissions of particles may exceed all particles generated by ICVs	Compares the particulate matter generated by EVs and ICVs	Estimation of particulate matter emissions based on vehicle weight and emission factors	Policy Makers, Environmental Researchers, Automotive Industry
[75]	None	Pollution data (PM), emission data	Evaluation of air quality and health improvements that EVs provide	Shows the benefits of EVs in terms of air quality and health	Addresses the problem of how the adoption of EVs can benefit the environment and health	EV adoption will improve air quality and health of people by reducing PM2.5 and ozone levels	Air quality impact assessment using chemical transport modeling - Community Multiscale Air Quality	Policy Makers, Environmental Researchers, Automotive Industry
[8]	None	Carbon footprint data from Swedish vehicle retirement	Assessment of how vehicle lifetime and annual driving intensity impacts the carbon footprint of shared and autonomous EVs	Shows the public how shared and autonomous EVs can be designed to minimize carbon footprint	Addresses the problem of carbon footprint levels and shows how EVs can reduce them	Shows potential for carbon footprint reduction by introducing EVs	Statistical analysis of vehicle retirement data and lifetime modeling - Swedish Vehicle Registry and Semi-Empirical Lifetime-Intensity Model	Policy Makers, Environmental Researchers, Automotive Industry
[185]	None	Pollution data (PM), emission data	Comparison of electric vehicles and hydrogen fuel vehicles	Allows the public to see the comparison of EVs and HFCVs	Addresses the problem of lack of comparison between electric vehicles and hydrogen fuel cell vehicles	Allows policy makers and the public to see the comparison of EVs and HFCVs	Comparative analysis	Policy Makers, Environmental Researchers, Automotive Industry
[78]	None	Regional transportation data	Quantification of CO2 emission reductions and air pollution together with health benefits of urban transport policies that promote EV adoption	Demonstrates how urban transport policies that promote EVs can lead to emission reduction	Addresses the problem of conventional transport as source of emissions and how to lead to reduce them through electrification	Shows how EV adoption and active transport promotion can reduce emissions	Comparative risk assessment	Policy Makers, Environmental Researchers, Automotive Industry
[82]	None	Pollution data (PM)	Investigation of life-cycle environmental impacts	Provides essential insights into how electrification can improve air quality, reduce greenhouse gas emissions and lower health risks caused by air pollution	Addresses the problem of diesel-powered public buses contribution to air pollution	Identification and quantification of environmental and health benefits that bus fleet electrification could bring	Life cycle assessment using ReCiPe method	Policy Makers, Environmental Researchers, Automotive Industry
[79]	None	Pollution data (PM)	Assessment of impact of using biofuels and EVs in Spain on air quality and health	Identification of strategies that can improve air quality and reduce emissions	Addresses environmental and health benefits that electrification can bring	Shows that increase of electrification use in transport can reduce air pollution, decrease premature mortality and help in climate change mitigation	Air quality modeling, health impact assessment, CHIMERE model	Policy Makers, Environmental Researchers, Automotive Industry
[186]	None	Bus fleets power grid related data	Explores environmental implication of EV adoption for Taiwan bus fleet	Shows the public benefits of renewable energy use for Taiwan bus fleet	Addresses problem of electric bus fleet charging patterns in Taiwan	Provides a detailed analysis on electric bus charging patterns and how the electrification of bus fleet can reduce emissions and air pollution	Bottom-up approach	Policy Makers, Environmental Researchers, Automotive Industry
[84]	None	Fleet data, urban area data, energy consumption data, emission data, health and impact data	Provides methodology which helps in estimation of environmental and social benefits of fleet electrification	Shows environmental and social benefits that go with promotion of fleet electrification	Addresses the problem of decarbonization of energy systems by electrification of fleet	Provides a comprehensive methodology for quantification of environmental benefits of fleet electrification	Holistic methodological framework	Policy Makers, Environmental Researchers, Automotive Industry
[80]	None	Pollution data (PM)	Assessment of health benefits caused by EV adoption	Shows that EV is a way to reduce pollution caused by internal combustion vehicles	Addresses the problem of health problems caused by air pollution and shows how EVs can improve them	Reduction of respiratory mortality and emissions caused by electrification of vehicles	Comparative health risk assessment, air quality modeling	Policy Makers, Environmental Researchers, Automotive Industry
[83]	None	Emission data	Compares environmental life cycle assessment of battery electric vehicles and internal combustion vehicles	Shows that ICVs are strong contributors to climate change, human toxicity and metal depletion	Addresses the problem of small amount of researches that take into consideration electricity mix scenarios to determine what fuel types have major impact on environment	Shows that EVs are much more environmental friendly than ICVs when powered by cleaner electricity sources	Life cycle assessment using ReCiPe method	Policy Makers, Environmental Researchers, Automotive Industry
[81]	None	Pollution data (PM)	Looks into changes in PM and ozone levels taking into consideration electrification	Shows how transitioning to EVs can impact and improve air quality and health in urban areas	Addresses the problem of poor air quality and how EVs can improve it in US urban areas	Electrification can improve air quality and provide economic and health benefits	Air quality modeling, health impact assessment	Policy Makers, Environmental Researchers, Automotive Industry
[6]	None	Comparative analysis with various data sources	Assessing emission reduction potential of EVs	Informed decision-making for emission reduction	Evaluating CO2 emissions of EVs vs. ICEVs under different conditions	Identifying scenarios where EVs reduce emissions effectively	Statistical model	Policy Makers, Environmental Researchers, Automotive Industry
[85]	None	Survey data from 751 EV users in China	Analyzing the role of environmental awareness in EV adoption	Informing policy and marketing strategies for EV adoption	Understanding the impact of environmental awareness on EV adoption intentions	Empirically tested value-based adoption model	Statistical model	Policy Makers, Environmental Researchers, Automotive Industry
[76]	None	Scientific article databases	Investigation of health impact of EVs	Informing the public about the EVs impact on health	Understanding how EVs impact the health	Showing the opportunities that EV create for more healthy world	Literature search	Policy Makers, Environmental Researchers,

TABLE 7. ***(Continued.)*** **Literature review of EVs integration.**

								Automotive Industry
[132]	None	Estimations based on calendar lifespan and sales trends of EVs and LiBs	Predicts trends in EV sales	Provides crucial insights for policy makers	Addresses the need for predicting and managing the future volume of waste from EVs in China	Findings help to evaluate the environmental impact and profitability of recycling industry for EVs	???	Policy Makers, Environmental Researchers, Automotive Industry
[87]	None	Air Quality Index (AQI) and EV sales data	Analyzes how air pollution impacts consumer adoption of EVs	Provides evidence-based insights for policy makers to design effective strategies that promote EV adoption	Addresses impact of air pollution on consumer approach towards EV adoption	Findings highlight the crucial role of air pollution in driving EV adoption	Multiple regression analysis	Policy Makers, Environmental Researchers, Automotive Industry
[7]	None	Mobility data	Proposes data-driven architecture which uses users attitudes towards EV adoption to help policy makers	Offers a comprehensive tool for policy makers to design policies for EV users	Addresses the need for policies for EV users	Understanding of aids and needs that EV users need for swift EV adoption	Simulations	Policy Makers, Environmental Researchers, Automotive Industry
[187]	None	Theoretical analysis and comparison of regulatory structures	Study compares effects of commitment against non-commitment in emission standards for automotive market	Provides insights into the impact of regulatory commitment on emissions	Addresses the differential impact of regulatory commitment on emissions	Helps policy makers to understand trade-offs between commitment and non-commitment to emission regulations	Theoretical comparison and Cournot competition model analysis	Policy Makers, Environmental Researchers, Automotive Industry
Energy management								
[3]	None	Simulation Data	Energy Management for Hybrid Storage System in EVs	Optimized power management in EVs	Securing required power and optimal power control strategy in EVs	Improved energy economy, increased system life	Artificial Neural Networks, Simulation	Electric Vehicle Manufacturers
[71]	None	Simulation data	Designing mechanisms for efficient EV allocation to charging stations	Improving the efficiency of EV charging station usage	Optimizing allocation of EVs to charging stations	Enhanced charging station efficiency and user experience	Mechanism design, Simulation	Charging Infrastructure Operators, EV Users
[24]	None	Simulation data	Optimizing utilization of battery storage and EVs in a prosumer power system	Enhancing energy efficiency and reliability in prosumer systems	Identifying optimal strategies for battery storage and EV integration	Improved energy management and system performance	Optimization modeling	Prosumer System Operators, Energy Researchers
[4]	VOSviewer based bibliometric maps	Scientific article databases	Investigation of energy management strategies for hybrid electric vehicles	Help to determine the best way to find optimal solution on energy management related problems	Understanding the energy management strategies for hybrid electric vehicles	The result allows for a search of answers to energy management-related problems for hybrid electric vehicles	Bibliometric Analysis, Bibliometric maps	Automotive manufacturers
[5]	None	Industry report	Provides comprehensive comparison of EVs in the automotive sector	Offers insights into strengths and weaknesses of EVs	Addresses the debate over the viability and future potential of fuel cells and batteries in the automotive industry	The comparison between FCVs and BEVs helps to highlight conditions under which each technology excels	Qualitative analysis of existing literature	Policy Makers, automotive manufacturers and marketers
[70]	None	Simulation Data	Energy Management for Hybrid Storage System in FCHEVs	Optimized power management in hybrid systems	Balancing thermal safety, fuel cell aging, and battery degradation during operation	Reduced battery aging by 34.8%, operational cost by 12.3%	Cost-minimization framework, stochastic Markov predictors	EV Manufacturers, Fuel Cell System Designers
[65]	None	Simulation Data	Integrated Energy Management in Source-Grid-EV Systems	Optimizing energy utilization in ecosystems	Balancing energy efficiency, system durability, and cost in diverse scenarios	Improved energy efficiency and system performance	Mixed Integer Programming (MIP), Simulation	Energy Providers, EV Users, Grid Operators
Development of infrastructure and policies								
[95]	None	Large-scale public survey	Exploring equity issues in EV and charging infrastructure deployment	Advancing equitable vehicle electrification policies	Identifying socioeconomic and perceptual barriers to EV adoption and charging infrastructure	Informed policy-making for equitable vehicle electrification	Survey Analysis, Multinomial Logistic Regression	Policy Makers, Environmental Researchers, Automotive Industry
[14]	None	Literature review, Causal loop diagrams	Developing a charge pricing model for EVCI	Promoting EV adoption through profitable charging infrastructure	Identifying factors influencing profitable EVCI	Enhanced business strategies for charging infrastructure development	System dynamics modeling	Charging Infrastructure Operators, Policymakers
[19]	Text Mining	News articles and annual reports	Analyzing stakeholder reactions to India's EV policy	Informing policy adjustments based on stakeholder feedback	Understanding stakeholder responses to policy changes	Enhanced policy implementation and stakeholder engagement	Text Mining	Policymakers, Industry Stakeholders, Researchers
[33]	None	EV cost related data (purchase cost, maintenance cost etc.), EV related literature	Value creation opportunities and governing factors for EV proliferation	Informing the public of EV market opportunities	Understanding the EV proliferation factors that influence consumer to buy EV instead of ICV	Showing the future opportunities for EVs to outsell ICVs	MATLAB-based dynamic model	Automotive Marketers, Researchers
[50]	Text mining	Twitter data	Investigation of sentiment of U.S. Communities on EVs	Help to understand how rural U.S. communities view EVs and infrastructure	Determine how rural U.S. communities view electric vehicles and infrastructure connected with them	Results show the view of rural U.S. citizens on EVs and allows automotive marketers to better target them	Sentiment analysis, Generalized Linear Models, Hierarchical Linear Models, Geographically Weighted Regression	Automotive manufacturers, Automotive marketers
[15]	None	GPS trajectory extraction data	Presents model which helps in optimization of the location and size of public fast charging stations for EVs	Provides strategy to improve placement of fast charging stations for EVs	Addresses mismatch between public fast charging stations layout and the demand for charging stations from EV owners	Findings can improve charging stations placement and increase support for them	Multi-period locating and sizing optimization model using GPS data, Heuristic algorithm, k-medoids clustering	Urban planners
[20]	None	Case study of China EV industry	Study offers dynamic game approach to compute optimal subsidies for EV adoption	Offers framework which helps in designing sustainable subsidy policies which help in finding balance between EV promotion and infrastructure development	Addresses the insufficiency of current subsidy programs which helps to support long-term EV growth	Help to create policies to ensure growth in EV adoption	Dynamic game approach	Policy makers
[182]	None	Survey	Develops and validates model which shows impact of various barriers preventing from EV adoption	Provides insights into EV adoption barriers	Addresses the need for to understand EV adoption barriers	Help policy makers and automotive stakeholders in overcoming EV adoption barriers	Structural equation modelling	Policy makers, automotive manufacturers
[21]	None	Real data for model calibration	Uses bilevel model to determine optimal incentives for consumers to buy EVs	Provides framework for policymakers to design effective incentives for EV	Addresses challenges of optimizing incentives for EV purchases	Help policymakers in balancing incentives and traffic regulations to help in EV adoption	Bilevel model	Policy makers

TABLE 7. ***(Continued.)*** **Literature review of EVs integration.**

				purchase				
[91]	None	Research articles from Scopus database	It conducts a bibliometric analysis to summarize adoption of EVs and provide a overview on trends and key contributions	Provides comprehensive understanding of factors that influence EV adoption	Addresses need for an overview of research on the social acceptance of EVs	Findings help to identify critical factors and gaps in EV adoption	Bibliometric Analysis, Bibliometric maps	Researchers, policy makers, automotive industry manufacturers
[92]	None	Systematic literature review of research articles	Reviews and analyzes existing mathematical models that are used to optimize adoption of EVs	Provides insights into the effectiveness of different mathematical techniques used in adoption of EVs	Addresses need to understand and optimize transition to EVs through mathematical modelling	Findings help to identify effective modelling techniques, barriers for EV adoption and more effective EV transition strategies	Systematic literature review	Researchers, policy makers, automotive industry manufacturers
[93]	None	Published literature	Reviews existing literature to summarize policies and regulation which support EV transition	Provides insights into effective policy measures for EV transition	Addresses challenges of EV adoption in developing countries	Findings help policy makers in developing countries to create effective EV transition programs	Literature review and theoretical framework analysis	Policy makers
[94]	None	Focus Group Discussion	Identifies key enablers and evaluates their promotion of EV adoption	Provides insights for policy makers to effectively promote EVs	Identifies challenges and key enablers of EV adoption	Helps in formulating strategies for policy makers to facilitate faster EV adoption	Focus Group Discussions	Policy makers
[16]	None	Real data from metro system	Examining of the integration of EV parking lots with rails systems	Provides insights for policy makers and urban planners on how to effectively integrate EV charging infrastructure with existing rails systems	Addresses process of managing the increased load from EV charging to avoid line losses	Underlines significant reduction in line losses by proper management of EV parking lot integration	Stochastic approach, Mixed-Integer Linear Programming (MILP)	Policy makers, urban planners
[97]	None	Case study	Models energy management with EV integration for 3 type of stations: parking, charging and battery swapping	Allows for energy usage optimization for EVs	Addresses the problem of inefficient energy management	Allows for daily energy cost reduction	Simulations	Home owners
[28]	None	Review of literature of EV user charging behavior	Analysis of methods and data sources which allows to understand EV charging behavior	Enhanced planning of EV charging stations	Disconnect between user behavior and EV charging stations characterization	Promotion of dynamic planning framework for EV charging stations	Critical review of studies on EV charging	Researchers, policy makers
[188]	None	Review of existing studies	Presentation of comprehensive analysis of both positive and negative impacts of EVs on power systems	Shows insights for EV integration optimization	Shows pros and cons of EV impact on power systems	Allows energy planners for easier management of EV infrastructure	Comprehensive literature overview	Policy makers, energy planners
[17]	None	Online survey data	Investigation of barriers for EV adoption	Shows the top concerns for EV adoption that can be seen as barriers	Determine barriers that should be addressed for smooth EV adoption	Its findings determine barriers for EV adoption which are public infrastructure and vehicle performance in terms of range and life of battery	Descriptive analysis, statistical testing	Policy makers, automotive manufacturers
[18]	None	Expert interviews	Identification of barriers for EV adoption	Allows the public to see the barriers that prevent smooth EV transition	Addressing the barriers for EV adoption	Its findings determine barriers for EV adoption which are public infrastructure and vehicle performance in terms of range and life of battery	Sociotechnical approach, descriptive analysis, cluster analysis	Policy makers, automotive manufacturers
Consumer experience and market potential								
[32]	None	Survey data from NVES	Analyzing PEV discontinuance and barriers to repurchase	Guiding PEV policy designs and targeted leasing & brand loyalty programs	Identifying factors influencing PEV discontinuance	Reducing PEV discontinuance by addressing key barriers	Survey Analysis, Binary Logistic Regression	Policy Makers, Automotive Industry, Environmental Researchers
[108]	None	Survey data	Investigating EV market segments	Promoting the adoption of EVs	Identifying groups of prospective EV buyers	Useful direction for academics and policymakers	Cluster analysis, multiple discriminant analysis, Chi-square test	Academics, Policymakers
[98]	None	Big data from "Vehicle-Parts" data resource system	Studying price correlation between new energy vehicles and spare parts	Providing market analysis and decision-making reference	Understanding the pricing relationship between vehicles and spare parts	Promoting sustainable development of new energy vehicle industry	Generalized Linear Model (GLM) analysis	Industry stakeholders, policymakers
[100]	None	Survey data from 238 Macau residents	Analyzing social influence and image impact on BEV adoption	Informing strategies for promoting BEV adoption	Understanding the role of social influence and image in technology acceptance	Better strategies for technology acceptance and promotion	Structural equation modeling (SmartPLS)	Policymakers, EV Manufacturers
[24]	None	Simulation data	Comparing market models for EV utilization and renewable energy	Reducing greenhouse gases and optimizing market models	Identifying optimal utilization strategies for EVs and renewable sources	Enhanced flexibility and reduced costs in prosumer systems	Optimization modeling	policymakers, energy researchers
[189]	None	Rental company data	Segmenting customer markets for EV rental sites	Improving service system and increasing profit for EV rental sites	Identifying diverse customer needs and optimizing service strategies	Enhanced customer satisfaction and service optimization	Latent class modeling	EV rental site operators, urban planners
[104]	None	Survey data	Analyzing EV acceptance using SEM and TPB	Informing policy makers and automotive industry	Understanding factors influencing EV adoption in Indonesia	Enhanced policy and market strategies for EV adoption	Structural Equation Modeling (SEM), Theory of Planned Behavior (TPB)	Policymakers, Automotive Industry
[109]	None	Big data from a self-made survey	Identifying potential customers for EVs in China	Informing marketing and policy strategies for EVs	Understanding characteristics of potential EV customers in China	Enhanced marketing and policy strategies based on customer segmentation	K-Means Clustering	Automotive Industry, Policymakers
[117]	None	Survey data	Analyzing user perception and usage of plug-in electric hybrids	Informing policy and marketing strategies for plug-in hybrids	Understanding user behavior and perception towards plug-in hybrids	Improved policy and marketing strategies for plug-in hybrids	Survey Analysis	Policymakers, Automotive Industry
[190]	None	EV related literature	Developing a conceptual model for EV acceptance in Indonesia	Informing strategies to increase EV adoption	Understanding factors influencing user acceptance of EVs	Enhanced strategies for promoting EV adoption	Conceptual Model, Casual Loop Diagrams, System Diagram	Policymakers, Automotive Industry
[22]	None	Survey	Investigation of consumer attitudes towards EVs in terms of their pricing	Allows for a better understanding of public opinion on EV price ranges	Determine the consumer interest and understanding of EVs	Allows automotive manufacturers and marketers in creation of their pricing strategy of EVs	Price assessment methods: van Westendrop price sensitivity method (PSM) and the willingness-to-pay approach	Automotive marketers, Policy makers

TABLE 7. ***(Continued.)*** **Literature review of EVs integration.**

[99]	None	Survey	Investigation of lower tier city Chinese consumers preferences on EVs	Allows automotive marketers to widen the consumer group by including people's opinions from lower tier Chinese cities	Underutilized opinions of consumers from Chinese lower tier cities	Allows to improve the ad targeting for EVs on the market	Stated preference experiment design	Automotive marketers
[25]	None	Scientific article databases	Investigation of factors that influence public to buy an EV	Allows automotive marketers to better understand factors that influence consumers to buy an EV	Even though EVs are environment friendly the number of BEVs on the road is low	Allows for improvement of EVs which can be taken into consideration by automotive manufacturers and marketers	Systematic Review	Automotive manufacturers and marketers
[26]	None	Stated preferences UK dataset	Investigation of Uk consumer preferences that can influence the adoption of EVs	Allows the government bodies to gain more information on EVs which can in turn speed up the EV adoption	Even though EVs are environment friendly the number of BEVs on the road is low	Allows the government bodies to make the EV adoption faster	Lasso methodology, binomial logit and ordered logit regressions	Policy makers
[27]	None	Survey and vehicle registration data	Analysis of electric vehicle adoption patterns in Virginia using both individual-level and county-level data.	Provides insights that can inform more effective electric vehicle policies and initiatives.	Addresses the inconsistency between stated preferences and actual EV ownership patterns.	Findings help in identification of influential factors for EV adoption and improvement of the alignment of EV policies with real-world behaviors.	Machine learning models	Automotive manufacturers, Automotive marketers, Policy makers
[162]	None	Nation-wide web-based stated preferences discrete choice experiment (DCE)	Investigation of consumer preferences for alternative fuel vehicles	Offers insights for policy makers and other industry stakeholders to better understand and promote EV adoption	Addresses willingness-to-pay for EVs attributes which vary among different consumer segments	Helps to idenify the most promising consumer groups for EVs and enhance the ad strategies for automotive marketers	Discrete choice experiment	Policy makers, automotive industry manufacturers and marketers
[191]	None	Interviews with UK consumers	Investigation of UK consumer responses to electric vehicles based on interviews that were conducted after a week-long trial period	Offers insights into mainstream consumer perceptions and shows barriers in adoption of EVs	Addresses gap in understanding consumers opinions on EVs	Identification of barriers of EV adoption	Qualitative analysis	Policy makers, automotive industry manufacturers and marketers
[30]	None	Survey	Analysis of the attitudes of consumers towards EVs	Provides insights for developing promotion strategies for EVs	Addresses need to understand consumer preferences and willingness to pay for EVs	Findings can help automotive marketers to promote EVs to the public	Stated choice experiment, Random Parameter Logit model	Policy makers, automotive manufacturers and marketers
[192]	None	Secondary literature collection, case studies, data analysis	Provides strategic marketing plan analysis for Tesla Motors by comparing its approach to Apple's marketing model	Offers insights into effective marketing strategies for EVs	Addresses the gap in research on Tesla's marketing strategies	Findings help to understand esla's unique marketing approach when compared to other automotive industry leaders	Qualitative, exploratory research	Tesla motors, automotive manufacturers and marketers
[64]	None	Survey	Investigation of the impact of functional and non-functional values on consumers' intention to adopt electric vehicles	Provides insights that help in developing marketing strategies and informs policy decisions	Addresses need to understand how different functional and non-functional values influence consumer decisions	Help to design targeted marketing campaign to consumers	Survey-based analysis	Automotive marketers, Policy makers
[107]	None	Data on Norwegian BEV adoption and socioeconomic and climatic factors	Analyzes socioeconomic drivers and climatic conditions and how they influence patterns of EV adoption	Provides insights into factors that influence EV adoption in a mature market	Addresses lack of understanding of EV adoption in well-matured market	Help policy makers in understanding of critical factors for EV adoption	Conditional autoregressive models	Policy makers
[193]	None	State-level data on motor fuel tax reliance, fuel efficiency, EV sales growth, roadway conditions, vehicle miles traveled, political environment, and neighboring states' policies	Analysis of determinants that influence adoption of EV fees at state level	Provides insights into impact of reduced motor fuel tax revenue due to growth in EV adoption	Addresses impact of reduced motor fuel tax revenue due to EV adoption growing extensively	Help policy makers in understanding of key factors that influence EV fee adoption	Discrete-time event history analysis	Policy makers
[194]	None	Interviews and survey	Uses Behavioral Reasoning Theory framework in order to analyze motivations and barriers for EV adoption	Provides comprehensive understanding of factors that influence EV adoption	Addresses motivators and barriers to EV adoption among Indian consumers	Findings offer valuable insights into the reasoning for and against EV adoption	Mixed-method approach	Policy makers, automotive manufacturers and marketers
[105]	None	Survey	Analysis of socio-psychological factors influence on the intention to adopt EVs	Provides insights into effective policy making and promoting EVs	Addresses the problem of understanding socio-psychological factors that influence intention to purchase EV	Helps policy makers in promotion of EVs in India	Structural Equation Modelling (SEM), Theory of Planned Behavior (TPB)	Policy makers, automotive manufacturers
[195]	None	Case study of 5 firms in Stockholm	Investigation of the drivers and barriers to adopt electric freight vehicles	Provides insights into challenges and motivations of adoption of EFVs	Identification of why so little companies are adopting EFVs despite the incentives from policy makers	Helps policy makers to understand challenges that prevent companies from EFV adoption	Embedded case study	Policy makers
[196]	None	Survey	Examines factors that influence purchase intention of Chinese EVs among consumers in California	Provides insights into consumer attitudes towards Chinese brand EVs in California	Identifies key factors that influence purchase intentions of consumers	Helps EV marketers and manufacturers in improving their product and better targeting their customers	Structural Equation Modelling (SEM)	Policy makers, automotive manufacturers and marketers
[103]	None	Studies	Investigates cultural and symbolic associations with EVs and how they impact their adoption	Provides insights for policy makers and automotive marketers to understand and address gender level barriers for EV adoption	Identifies gender barriers for EV adoption	Helps to develop better targeted policies and marketing campaigns	Country-level analysis	Policy makers, automotive manufacturers and marketers
[197]	None	Survey	Identifies factors which influence consumer intentions to adopt EVs	Provides insight for policy makers for faster EV adoption based on customer opinions	Addresses problem of low adoption rates for EVs	Helps in developing targeted policies for faster EV adoption	Survey-based study analysis	Policy makers, automotive manufacturers and marketers
[106]	None	Survey	Investigates factors that influence EV adoption in Ghana	Provides insights for policy makers to improve strategies for EV adoption	Addresses low enthusiasm and interest for EV adoption in Africa	Helps to identify key factors that influence EV adoption	Structural Equation Model (SEM)	Policy makers
[34]	None	Survey	Explores adoption and	Provides insights for	Addresses hesitancy in	Helps to identify factors that	Structural Equation	Policy makers,

TABLE 7. ***(Continued.)*** **Literature review of EVs integration.**

			intention of adoption of battery swappable EVs	policy makers for promotion of BSEVs	adoption of BSEVs	influence consumers to adopt BSEVs	Model (SEM)	automotive manufacturers and marketers
[198]	None	National consultation and workshop series	Examining strategic integration of EVs in Australia	Provision of valuable insights for policy makers on how to effectively integrate EVs in Australia	Addresses the assurance of cost effective incorporation of EVs in Australia	Shows unique Australia market characteristics and innovative approach for EV integration	National consultation and workshop series	Policy makers, energy providers
[101]	None	Real-time electricity consumption data	Research integrates time-specific charging data into LCA models	Provides accurate data on the environmental impact of EV technologies	Addresses the problem where LCA models fail to account for fluctuations in carbon intensity of electricity	Result is a more precise comparison of vehicle carbon footprints	LCA models	Policy makers, environmental researchers, Automotive Industry
[199]	None	Survey	Analysis of consumer preferences for adopting alternative fuel vehicles	Provides insights for policymakers and automotive stakeholders to develop effective incentives and strategies in order to promote EVs	Addresses need to understand consumer preferences and barriers for EV adoption	Findings allow for better decision making and policy development in order to encourage transition to low carbon vehicles	Bayesian logit and hierarchical models	Policy makers, automotive manufacturers, environmental agencies
[40]	Latent Dirichlet Allocation (LDA)	Online survey data	Profiling potential EV markets	Tailored EV promotion strategies	Intertwined relationships between EV configuration and EV incentives	Creation of tailored solutions for promoting EVs	Latent Dirichlet Allocation (LDA) model	Policy Makers, Auto Industry
[36]	Accumulated Local Effects (ALE)	Online survey data	Predicting EV buying decisions	Informed policy-making for EV promotion	Determining factors influencing EV purchase decisions	High prediction accuracy of EV purchase factors	Discrete Choice model, XGBoost, Accumulated Local Effects (ALE)	Policy Makers, Environmental Researchers, Automotive Industry
[101]	Accumulated Local Effects (ALE)	Online survey data	Predicting EV purchase likelihood	Informed policy-making for EV promotion	Identifying factors influencing EV purchase decisions	High prediction accuracy and interpretability	Discrete Choice Experiment, XGBoost, LGBM, CatBoost, Accumulated Local Effects (ALE)	Policy Makers, Environmental Researchers, Automotive Industry
[200]	Machine Learning, Text Analysis	Provincial panel data from China, Consumer reviews from Autohome	Analyzing consumer sentiment and its impact on NEV sales	Improving understanding of factors influencing NEV adoption	Examining the impact of consumer sentiment on NEV sales	Enhanced strategies for NEV promotion and infrastructure development	Textual Analysis, Sentiment Index Construction	Policymakers, Automotive Industry, Environmental Researchers
[52]	Sentiment Analysis, Topic Modeling	Twitter data	Analyzing public opinion on EVs in Indonesia	Informing decision-making for EV stakeholders	Understanding public sentiment and key discussion topics on EVs	Enhanced public engagement and policy development for EVs	Sentiment Analysis, Topic Modeling	Policymakers, Automakers, Researchers
[54]	Deep Learning	Consumer reviews from online platforms	Diagnosing EV failures using deep learning techniques	Improving reliability and performance of EVs	Identifying common failures and issues in EVs based on consumer reviews	Enhanced diagnostic techniques for EVs	Deep Learning, Multi-Label Classification	Automotive Industry, Consumers, Researchers
[45]	LDA	Tweets about EVs	Identifying conversation topics on EVs in Indonesia	Informing marketing and public communication strategies for EVs	Understanding public discourse and concerns regarding EVs	Improved strategies for public engagement and information dissemination	Topic Modeling, LDA	Policymakers, Automakers, Marketing Professionals
[113]	LDA	5185 articles from CNKI	Exploring policy and development trends of NEVs in China	Supporting policy-making and strategic planning for NEVs	Tracking the evolution of NEV policy and development in China	Enhanced understanding of NEV trends and future directions	Text Mining, LDA	Policymakers, Researchers, Industry Stakeholders
[118]	NLP, Machine Learning	Survey data, Social media posts	Analyzing perceptions of EV adoption	Informing strategies to enhance EV adoption	Understanding barriers and drivers of EV adoption	Improved strategies for promoting EV adoption	Sentiment Analysis, Machine Learning	Policymakers, Automakers, Researchers
[120]	Machine Learning	Twitter data	Analyzing sentiment of tweets about EVs	Informing marketing and policy decisions	Understanding public sentiment towards EVs	Enhanced strategies for promoting EV adoption	Two-Layered Machine Learning	Policymakers, Marketers, Researchers
[53]	Sentiment Analysis, Machine Learning	Twitter data	Analyzing sentiment of tweets about automotive brands	Informing marketing strategies for automotive companies	Understanding public sentiment towards automotive brands	Enhanced marketing strategies and customer insights	Sentiment Analysis, Machine Learning	Automotive Marketers, Researchers
[49]	Text mining	Twitter and Reddit data	Investigation of equity perception of EVs	Help to understand how the public views EVs	Understanding the equity perception of EVs	Results allow to better understand the public perception of EVs	Fight'in words algorithm, sentiment analysis, sentiment clustering	Automotive manufacturers
[47]	Text mining	News articles and online postings	Investigation of factors affecting consumer awareness and purchase of EVs	Help to understand what are the factors that affect purchase of EVs	Understanding the factors and overall public approach towards EVs	Results allow to better understand public approach towards purchasing an EV	LDA method, wordclouds, CONCOR analysis	Automotive manufacturers and marketers
[114]	Text mining	Largest social network platforms in China	Creation of travel satisfaction index	User feedback is important, thus creation of travel satisfaction index will benefit the public	Scientifically creating the travel satisfaction index	Results allow to increase the interest in shared electric vehicles	Sentiment analysis, VAR model	Shared electric vehicle companies, Automotive manufacturers
[130]	Text mining	Twitter, Reddit data	Investigation of public perception of electric vehicles	Help to understand how the public views EVs	Determine topic and sentiment patterns for EVs	Results show how public views EVs which can help in their improvement	Topic modelling, sentiment analysis	Automotive manufacturers, Automotive marketers
[2]	Text mining	Reddit	Investigation of public perception of EVs	Help to understand how the public views EVs	Determine topic and sentiment patterns for EVs	Results show how public views EVs which can help in their improvement	Topic modelling, sentiment analysis	Automotive manufacturers, Automotive marketers
[48]	Text mining	Car reviews	Investigation of sentiment of the public towards EVs	Help to understand how the public views EVs	Determine topic and sentiment patterns for EVs	Results show how public views EVs which can help in their improvement	ERNIE, deep Convolutional Neural Network, Sentiment analysis	Automotive manufacturers, Automotive marketers
[35]	Text mining	Social media posts	Investigation of sentiment of Chinese public towards EVs	Help to understand how the public views EVs	Determine topic and sentiment patterns for EVs	Results show how public views EVs which can help in their improvement	Topic analysis, sentiment analysis	Automotive manufacturers, Automotive marketers
[99]	Text mining	Twitter data	Improvement of promotional strategies for EVs adoption	Help to understand the public perception of EVs	Improvement of promotional strategies for EVs adoption using scientific methods based on public reviews	Benefits the automotive markaters as they are now able to better target their ads towards the public	Sentiment analysis, Latent Dirichlet Allocation (LDA)	Automotive manufacturers, Automotive marketers
[112]	Text mining	Social media posts	Exploration of public attitudes and sentiments	Provides insights into public opinion on	Addresses lack of comprehensive studies on	Helps in identification significant concerns and	Machine learning models	Policy makers, automotive

TABLE 7. ***(Continued.)*** **Literature review of EVs integration.**

			towards EVs	EVs which can influence policy makers and other stakeholders of EV industry	public attitudes and sentiments in China on national scale	preferences of the public towards EVs		manufacturers and marketers
[35]	Text mining	Social media posts	Investigation of attention and sentiment towards EVs	Insights that are data-driven which can help in policy-making strategy creation	Addresses limitations of traditional questionnaires in public opinion analysis	Helps to understand regional, gender-based and user-type variation in EV attention and sentiment	Machine learning models	Policy makers, automotive manufacturers and marketers
[111]	Text mining	Social media posts	Analysis of consumer perception of Proton vehicles using sentiment analysis	Provision of insights on public opinion which helps to improve sales, services and marketing strategy	Addresses need to understand consumer perception on Proton vehicles	It offers insights into improvement of marketing strategy	Text mining, sentiment analysis, Support Vector Machine classification	Automotive marketers, Policy makers
[126]	Text mining	Consumer reviews from car review website	Analysis of consumer reviews using competitive car brands to determine their advantages and disadvantages	Offers detailed view on advantages and disadvantages on 3 competitors form automotive market	Addresses the need for marketers and automotive manufacturers to improve their marketing campaign and products	Findings help in improvement of product	Topic modelling	Automotive manufacturers and marketers
[134]	Sentiment analysis using logistic regression and interval type-2 fizzy sets	Customer reviews	Proposes an integrated framework which analyzes consumer sentiment	Provides detailed analysis of consumer sentiment on EV reviews	Addresses accuracy of sentiment classification and its challenges	Findings can help in accurately ranking EVs and identifying their strengths and weaknesses	Sentiment analysis using logistic regression, IT2FSs, stochastic multi-criteria acceptability analysis	Automotive industry manufacturers and marketers

TABLE 8. **Vehicle segmentation chosen for study.**

Euro Car Segment	Euro NCAP Class	US EPA Size Class	Selected EVs	Examples of ICVs
A – segment mini cars	Supermini	Minicompact	BMW i3, Fiat 500e	Fiat 500
B – segment small cars		Subcompact	Chevrolet Bolt EV, Hyundai Kona EV, KIA Niro EV	Chevrolet Spark, Hyundai Kona, Kia Rio
C – segment medium cars	Small family car	Compact	Nissan Leaf, Volkswagen e-Golf, Volkswagen ID.4	Volkswagen Golf, Volkswagen Tiguan, BMW X1, Mazda 3
D – segment large cars	Large family car	Mid - size	Tesla Model 3, Tesla Model Y	Toyota Camry, BMW 3 Series, Mercedes-Benz C-class, Audi A4, Audi Q5, BMW X3, Nissan Altima
E – segment executive cars	Executive	Large	Tesla Model S, Tesla Model X	Chrysler 300, Audi A6, BMW 5 Series, Mazda CX-9, Porsche Cayenne, Volvo CX-90

underscores a tendency to prioritize enjoyment and performance in ICV ownership.

- *common ground*: Factors like *Driving Experience, Comparison Shopping Engines*, and *After-Purchase Experience* receive similar levels of attention across genders, suggesting areas of shared interest.

Interestingly, the *Environmental impact* factor pertains to ICVs (e.g., improving gas mileage), remains predominantly discussed by male reviewers, mirroring their environmentally driven considerations for EVs. Furthermore, the proportion of issues discussed by women regarding EVs (46.67%) is significantly higher than for ICVs (38.46%), aligning with findings that highlight gender differences in automotive preferences and priorities.

Finally, our analysis reveals the *customer service quality factors shaping the perception of electric vehicle brands in the automotive market* (RQ5), providing valuable insights into brand differentiation and consumer expectations. *Tesla* is uniquely associated with eight principal factors: Speed, Ecology, Presentation, Overall Performance, Superchargers, Manufacturing Defects, Technical Service, and Overall Driving Experience. These factors align closely with Tesla's official statements,[25,26] reinforcing its brand identity as a leader in innovation and performance in the EV market.

In contrast, other brands demonstrate distinctive associations with specific factors: *BMW* is primarily linked to Quietness, emphasizing its focus on creating a serene and premium driving experience; *Chevrolet* stands out for its association with Driving Range, highlighting a critical consideration for customers prioritizing longer-distance capabilities; *FIAT* is connected with a diverse range of factors, including Financing, Maintenance, Size, Fuel-Cost Savings, and Traffic Performance, suggesting a value-oriented appeal; *Nissan* is noted for its Transition Experience, along with Maintenance, Size, and Fuel-Cost Savings, reflecting a focus on providing a smooth shift to EV ownership; *Hyundai* is recognized for Spaciousness and Model Comparisons, appealing to customers seeking versatility and informed decision-

[25]https://www.businessinsider.com/tesla-owners-reveal-cars-pros-cons-features-elon-musk-2023-2?IR=T

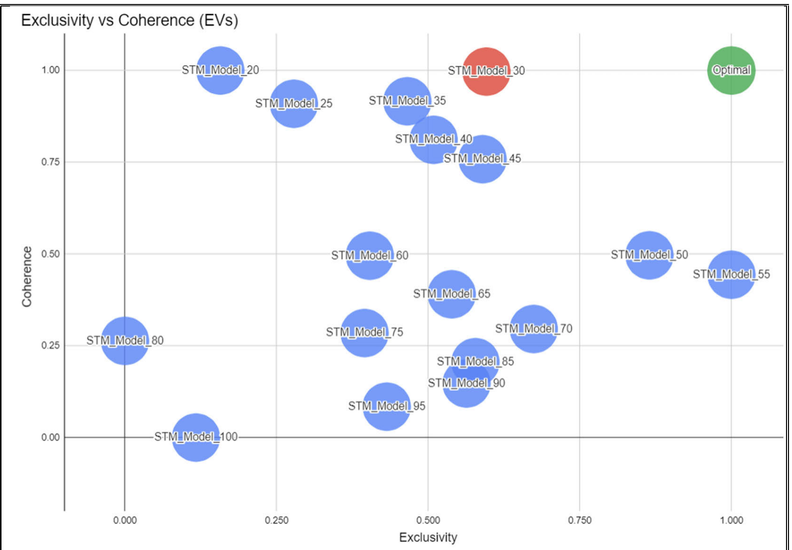
[26]https://escalent.co/blog/would-tesla-be-better-off-without-elon-musk-some-electric-vehicle-shoppers-think-so/

TABLE 9. Sample summary by models.

EVs model	Number of free-text comments	ICVs model	Number of free-text comments	ICVs model	Number of free-text comments
BMW i3	217	Audi A4	111	Mazda 3	182
Chevrolet Bolt EV	420	Audi A6	105	Mazda CX-9	159
FIAT 500e	125	Audi Q5	131	Mercedes-Benz C-Class	121
Hyundai Kona EV	65	BMW 3 Series	128	Nissan Altima	199
KIA Niro EV	66	BMW 5 Series	98	Porsche Cayenne	97
Nissan Leaf	547	BMW X1	110	Toyota Camry	242
Tesla Model 3	450	BMW X3	161	Volkswagen Golf	134
Tesla Model S	447	Chevrolet Spark	150	Volkswagen Tiguan	166
Tesla Model X	156	Chrysler 300	110	Volvo XC90	143
Tesla Model Y	97	FIAT 500	114		
Volkswagen e-Golf	82	Hyundai Kona	133		
Volkswagen ID.4	65	KIA Rio	105		

TABLE 10. Best STM model selection (EVS).

STM Model	Exclusivity	Coherence	Exclusivity (normalized)	Coherence (normalized)	Distance to Optimal Model
Model_20	9.2248	-80.4563	0.1572	1.0000	0.843
Model_25	9.3908	-82.1901	0.2785	0.9094	0.727
Model_30	9.8248	-80.5125	0.5960	0.9971	0.4040
Model_35	9.6465	-82.0582	0.4656	0.9162	0.541
Model_40	9.7058	-84.0679	0.5089	0.8112	0.526
Model_45	9.8161	-85.0775	0.5896	0.7584	0.476
Model_50	10.1923	-90.0872	0.8648	0.4965	0.521
Model_55	10.3771	-91.0968	1.0000	0.4437	0.556
Model_60	9.5619	-90.1065	0.4037	0.4955	0.781
Model_65	9.7466	-92.1161	0.5388	0.3904	0.764
Model_70	9.9314	-93.9257	0.6740	0.2958	0.776
Model_75	9.5500	-94.1354	0.3950	0.2848	0.937
Model_80	9.0100	-94.5450	0.0000	0.2634	1.242
Model_85	9.8000	-95.6547	0.5779	0.2054	0.900
Model_90	9.7800	-96.7643	0.5632	0.1474	0.958
Model_95	9.6000	-97.9740	0.4316	0.0842	1.078
Model_100	9.1700	-99.5836	0.1170	0.0000	1.334



making; *KIA* is linked to Affordable Pricing Policy and Steering-Wheel Features, emphasizing cost-effectiveness and user-friendly design; *Volkswagen* is distinguished by Overall Quality, Safety, Design, and Dead Battery Issues, showcasing a blend of premium design and practical concerns.

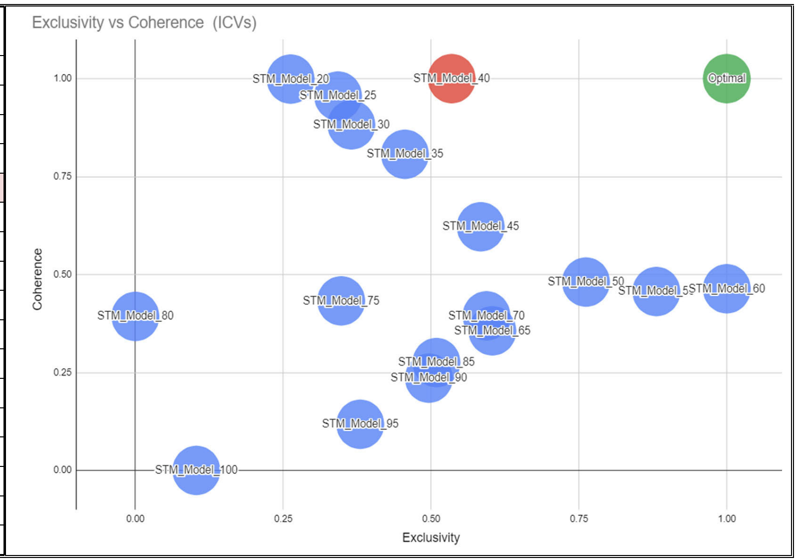
A perceptual map of consumer perceptions reveals four distinct clusters of electric vehicle brands: Tesla stands alone, distinctly separate from all other brands, reflecting its unique positioning in the EV market (*cluster* 1); FIAT and Nissan form their cluster, sharing several overlapping features such as Maintenance, Size, and Fuel-Cost Savings, indicating a competitive dynamic (*cluster* 2BMW occupies its cluster, characterized by its focus on Quietness and a distinct premium positioning (*cluster* 3); Chevrolet, Hyundai, KIA, and Volkswagen form a broader cluster, with shared attributes like affordability, practicality, and varied customer priorities (*cluster* 4).

A. RESEARCH FINDINGS VALIDATION

To validate our findings on the main drivers of customer transition to EVs, we compared the key factors identified in

TABLE 11. Best STM model selection (ICVs).

STM Model	Exclusivity	Coherence	Exclusivity (normalized)	Coherence (normalized)	Distance to Optimal Model
Model_20	9.4174	-91.2452	0.2625	0.9989	0.737
Model_25	9.5419	-91.8002	0.3427	0.9556	0.659
Model_30	9.5767	-92.7428	0.3652	0.8821	0.646
Model_35	9.7174	-93.7061	0.4558	0.8069	0.577
Model_40	9.8400	-91.2311	0.5348	1.0000	0.4652
Model_45	9.9161	-96.0775	0.5839	0.6219	0.562
Model_50	10.1923	-97.8872	0.7619	0.4808	0.571
Model_55	10.3771	-98.1968	0.8809	0.4566	0.556
Model_60	10.5619	-98.1065	1.0000	0.4637	0.536
Model_65	9.9466	-99.4828	0.6036	0.3563	0.756
Model_70	9.9314	-98.9924	0.5937	0.3946	0.729
Model_75	9.5500	-98.5021	0.3480	0.4328	0.864
Model_80	9.0100	-99.0117	0.0000	0.3931	1.170
Model_85	9.8000	-100.5213	0.5091	0.2753	0.875
Model_90	9.7800	-101.0310	0.4962	0.2355	0.916
Model_95	9.6000	-102.5406	0.3802	0.1178	1.078
Model_100	9.1700	-104.0503	0.1031	0.0000	1.343



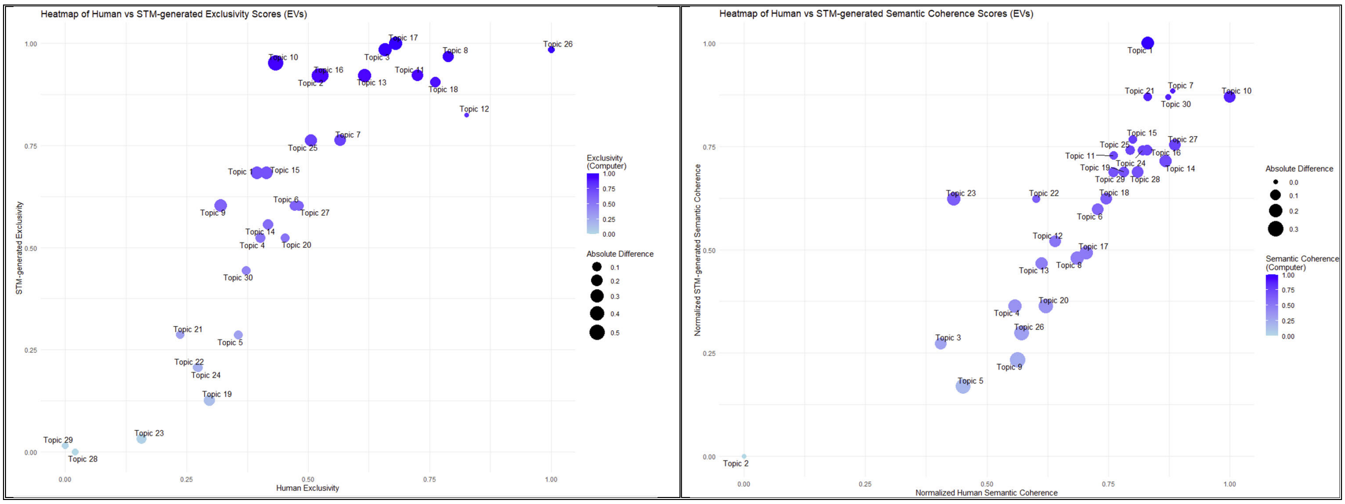


FIGURE 9. The results of topic semantic coherence and exclusivity human validation (EVS).

our study with insights from surveys and research on EV attitudes across multiple markets. This comparison aimed to confirm that our findings reflect genuine consumer concerns and are not skewed by data collection or analysis biases. Ten relevant case studies, including large-scale surveys and industry analyses, were used for this validation, and consumer concerns highlighted in each were systematically compared with our findings (see Appendix L for a summary).

In the US, sources such as the Potential Energy Coalition and Pew Research Center emphasize affordable upfront costs, driving range, climate impact, and public charging accessibility as major factors for EVs adoption [166], [167] This aligns with our Pricing, Driving Range, and Environmental Impact findings. However, factors like *local job creation* and *energy independence* highlighted in the National Travel Attitudes Study were not identified as primary concerns in our data [160], [165], [167]. In Europe, the McKinsey Mobility Consumer Pulse Survey [168] highlights battery range, purchase price, and accessible charging infrastructure as consumers' concerns, all well-matched with our factors. However, considerations like *battery decommissioning* in Europe suggest further areas of exploration. In the Polish market, where EV adoption is emerging, practical incentives like *free parking zones* are critical [169].

For Generation Z in Europe, survey data points to functionality, quietness, comfort, and futuristic technology, captured in our study under quietness, steering wheel functionalities, spaciousness, and pricing [158]. In Australia, Canada, and the US, the Compare the Market Survey [170], [171] highlights battery life, replacement costs, driving range, and charging

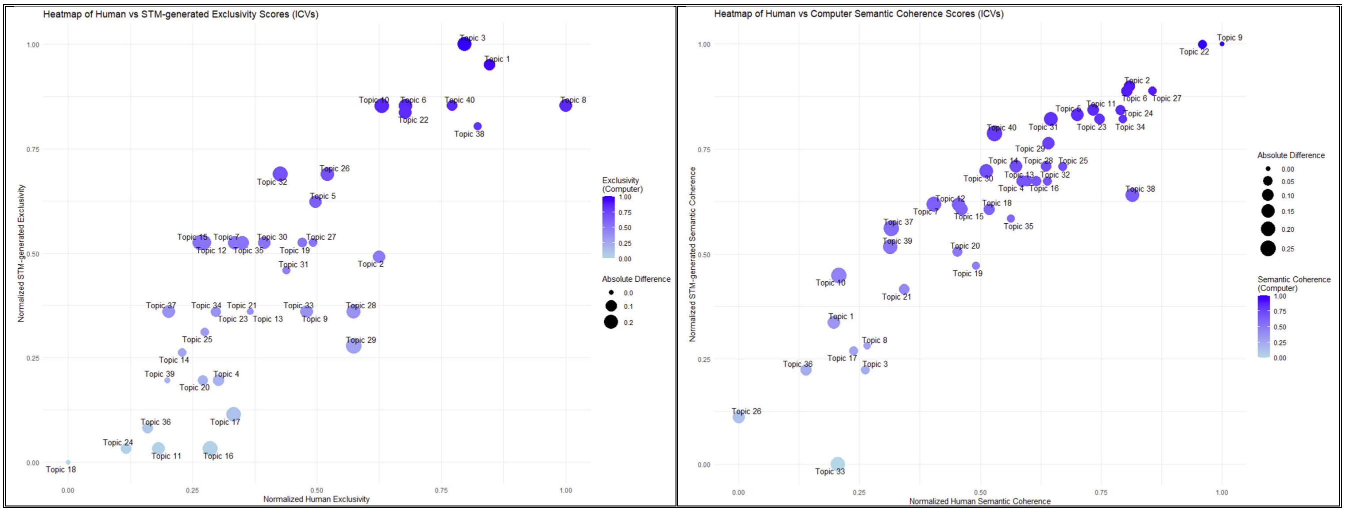


FIGURE 10. **The results of topic semantic coherence and exclusivity human validation (ICVs).**

TABLE 12. **The summary of vehicle of customers experience categories.**

Source	Categories
[143]	Driver experience, Comfort, Information and Communication, Economic efficiency, Everyday Suitability, Quality and Reliability, Safety, Environmental Compatibility, Off-Road Capability, Design
Edmunds.com	Safety, Technology, Performance, Interior, Comfort, Reliability, Value
Cars.com	Comfort, Interior design, Performance, Value for the money, Exterior styling, Reliability
consumerreports.org	Performance, Comfort and Convenience, Fuel Economy and Emissions, Driver Assistance Features and Crash Protection, Specification
whatcar.com	Driving, Interior, Practicality, Costs and verdict, Version and specs
topgear.com	Driving, Interior, Buying, Specs and Prices
tesla.com	Safety, Performance, Range, Interior, Specs,
www.statista.com[27]	Fuel efficiency, Safety, Low price, High quality, Sustainability for everyday use, High driving comfort, Good warranty and customer service, Design, Spaciousness, My preferred make, Good connectivity with smartphones and internet services, Environmental friendliness, Good driver assistance systems, Good multimedia system, Sportiness, Propulsion type
[144]	Financial factor (Interest rate, Job security, Purchasing-power), Vehicle features (Design, Safety, Technology), Maintenance factor (Fuel-consumption, Service cost, Spare part cost), Promotion offered (Insurance offer, Price discount, Service package offer, Warranty offer)
[145]	Economic factors (Price level, Economic/monetary benefit, Financial/cost factors), Technical characteristics (Driving range limit, Battery lifetime, (Re)charging time, Maximum speed, Performance), Risk and benefit factors (Perceived Usefulness and/or Ease of Use, Perceived risk, Perceived benefit, Perceived barrier, Perceived value, Environmental impacts)

times, aligning with our factors such as battery capacity, dead battery, and charging infrastructure, with an additional focus on *consumer understanding* (literacy) of technology among certain demographics.

This validation aligns the majority of our findings with broader consumer insights, reinforcing their relevance across regions and demographics. Some discrepancies in the insights arise from the nature of text-based research, where theory is developed *inductively* from data, rather than through the hypothetical-deductive reasoning commonly used in IS research [136]. This inductive approach allows for the emergence of novel perspectives that may not surface in traditional survey-based studies. As a result, it broadens our understanding of the factors influencing both the adoption of electric vehicles (EVs) and continued loyalty to internal combustion vehicles (ICVs).

TABLE 13. **Factors of the customer experience of electric vehicles with examples of the most representative comments.**

No.	Factor Label	Factor description	Comments Example
1.	Pricing	Reviewers paid attention to the pricing policy, and its affordability for consumers. Prices were compared to prices in different dealerships, together with a tax on those vehicles.	*High Price, all-electric I bought a Nissan Leaf SL and this review tells the pros and cons. The dealer, Koons Nissan in Virginia, would not disclose the costs. Here they are: Standard MSRP = $38,100. Processing fee = $499. Tax = $1,157.97. Filing Fee $10. Business License tax = $72.40. Plates = $105.50. Total Price = $39,944.88, not including floor mats. Honestly, you have to pay an extra $175 for floor mats. The Federal E.Car subsidy of up to $7,500 will come in April (tax return) if you buy or is taken off immediately if you lease.* *I regret waiting 16 months to pay way too much for all-electric. It seems worth about $20-22k. Other than the price, Nissan proprietary GPS, and no floor mats, it is fun to drive.* *(...) I'm a car guy and incline toward the sporty end of things -- but when I started shopping for affordable EVs, it was clear instantly that this was the car for me. (...)"* *"(...) The purchase price was very affordable even though as a used car it is not eligible for any tax incentives. (...)"*
2.	Presentation	Here reviewers focused on the way car presents itself in general. They were assessing the car in its entirety, not talking about anything specific. Most frequently used words include phrases like "amazing", "awesome", or the word "wow".	*Ultimate All Around Sport Sedan I'm a car enthusiast and I've been running a car rental business on Turo since 2015. I typically have a fleet of 10-15 cars at a given time. Mostly Luxe cars BMW 3, 4, 5 series, X1, X5, Audi SQ5, Q5, Lex IS250, NX300, MB E300 and C300...I loved playing musical chairs with the cars but, ever since I added a couple of Model 3 LR, I only drive the Model 3. Best performance, most comfortable, most convenient, zero issues and withstands the car rental market 10x better than all of my other cars!! Even storage is amazing. Rivals my X1 with interior space and I have 2 kids! Amazing car! Can't believe this is their FIRST MASS PRODUCED CAR!!?? Can't wait to see gen 2 and 3 of this.*
3.	Safety features	Consumers were assessing the car's safety features, like for example lane keeping/line assist, which is the ability of the car to stay in the driving lane and when the driver starts to go over the lane, he is alerted. Speeding alerts were also mentioned, which alerted if certain speed was exceeded.	*Surprisingly fun and well equipped I was looking for an electric vehicle with range over 250 miles, and price around 40,000. The Kona limited is exactly what I wanted. It's very feature rich, including air-conditioned seats which are amazing. The safety features like lane keeping and Geo fence and curfew and alerts if our teenagers are speeding are easy to use. I highly recommend the blue link, and this vehicle overall*
4.	Speed	In this case, the speed of the car was assessed. This means, that reviewers were determining whether the car was fast. A very interesting word used by some of the reviewers was phrase "sleeper", which describes a car that doesn't look fast but in the reality can accomplish incredible speeds.	*Absolute Thrill The Tesla is a stunning automobile. It is sleek, futuristic, and incredibly fast. If set up with LUDICROUS mode, it can been most super cars from 0-60. That is insane! The ride is ultimately comfortable and a complete joy. One word: BLISS.*
5.	Comparisons	Here reviewers were comparing their car to other electric and internal combustion vehicles regarding their handling, amount of features or the quality of the car.	*Better than an E46 M3 My previous car was an older model (E46) M3. The RWD Tesla model 3 is better in every way except handling in turns during spirited driving. However, keep in mind I have the stock high efficiency 18" wheels. I assume having stickier 19 or 20 inch wheels would improve handling.*
6.	Technical Service	This factor focuses on the service in the dealerships, together with customer service. This topic is visibly negatively assessed as consumers were mostly complaining about the customer service in dealership and the quality of service as a process.	*Worst car Tesla 3 I have Tesla 3* *It's price is an much as Mercedes and Lexus* *But service is horrible* *They use cheap parts in Tesla 3*
7.	Charging	Charging being a crucial factor of every EV, as it works like refueling of an internal combustion vehicle, is assessed by reviewers. Here a various aspects of charging stations accessibility. Also charging time was graded together with the chargers specifications expressed in kWh.	*Charging stations are not very available (and I live in Los Angeles where stations are supposed to be more accessible* *If charging infrastructure were just a smidgen better in the mid-west, the Bolt could be my only vehicle. This is a Cleveland, Cincinnati, Toledo, Detroit, Louisville, Indianapolis, Dayton and Pittsburgh car. It is not a Denver, Nashville, St. Louis, Boston, New York and Bangor car. (At least, not yet it isn't.)*
8.	Manufacturing defects	Here specific issues that required car to be serviced were mentioned. They were mentioning issues with regenerative braking system, which main purpose is to restore the energy during "engine braking", when electric engine works as electric generator causing drag. This allows to save braking disks and pads from wearing down quickly and the car starts to slow down on its own.	*What service The lack of service will kill Tesla. Purchased a new $98k model X . The day after deliver scheduled a service call on the Tesla app (can not actually call service) to get a vibration issue fixed. 5 follow up service calls (3 month later) and issue is not fixable according to 20 year old Genius service advisor. Needless to say the attorneys are working it out*
9.	Battery capacity	Because the battery accumulates certain amount of power for driving, it needs to be charged frequently. The bigger the battery capacity, the longer the drive on one charge. The charging infrastructure must also take this feature into account.	*FUN Battery EV, low maintenance/great safety stats Funky style exterior, a blast to drive, safety ratings are great - a perfect car for college student/second car (LOW maintenance/no gas to buy).* *Only drawback is limited range, so make sure battery capacity is good when purchasing used (ideally would still be within the original 60 month warrant)* *Where the Bolt suffers most is its highway range. Driving at 60 - 65 just drains the charge relentlessly, and that coupled with the spotty charging infrastructure along highways makes me leery of trying a long road trip, so if that's your thing you might want to think twice, it takes a lot of advance planning*
10.	Driving experience	In this factor of the opinions on EVs, people were expressing their opinion on the driving experience. This comes down to the way the driver feels when driving a car. It answers the questions of how the car operates, does it feel good to drive it, whether the control of its movement is adequate and responsive.	*best car to drive nothing drives like a tesla. Most fun and practical car. extremely efficient. best driving experience*
11.	Fuel-cost savings	In this case reviewers were focusing on how much money they were saving on gas, when using EV comparing to internal combustion vehicle. Because of the high gas prices it is very economical to charge your car instead of filling it up with fuel.	*What's missing ... Outside of no gas bills or oil changes there is: no exhaust, no transmission, no fuel tank, no bulky internal combustion engine, barely any moving parts, and no guilt about ruining the planet. Nice.*
12.	Financing	Various options of leasing, credits, government incentives and rebates that affect the affordability of electric vehicle purchases.	*as my two kids started multiple after-school activities which averaged 45 miles round-trips per day, the carbon footprint (and gasoline bills) started climbing. We decided to look at EV again. With attractive year-end incentives and government rebates, we went out and leased one.* *(...) Not cheap to buy, but the government rebates took most of the sting out of that. Would I recommend the Kona EV? Absolutely! (...)* *(...) Leasing tends to be the preferred option for new leafs, because the leasing company can claim the government incentives and roll that into the price, whereas if you buy outright, you have to wait until tax-filing time to claim the electric-vehicle-tax-credit. (...)"* *(...) After credits, rebates and other environmental incentives, the BOLT is extremely affordable. (...)*
13.	Transition experience (ICV -> EV)	In the case of transition from internal combustion vehicles to EVs, reviewers had much to say. Because of the fact that most of the consumers for electric vehicles at some point in their life had contact with ICVs, they were able to share their opinion on this transition. Whether the transition was smooth, good or even fantastic in some cases.	*Niro Hero The perfect transition EV from a Toyota corolla.*
14.	Software updates	Because of the feature- heavy culture in electric vehicles market, computers built into the center console of the car are able to receive various software updates. This allows older models to keep up with the new ones by adding new features through updates, like in mobile phones for example.	*Most Satisfying Purchase This vehicle will change the way you think about driving. Like switching from your flip phone to your smart phone, this vehicle represents the next leap in technology. The user experience is unique and the car is fun to drive. The technology and software far exceed the competition, and with over the air software updates, your car is always improving and adding new features. I would buy this car all over again given the chance.*

TABLE 13. *(Continued.)* **Factors of the customer experience of electric vehicles with examples of the most representative comments.**

15.	Size	Every car has its purpose and it stands for electric vehicles as well. In looks like in the minds of consumers, electric vehicles are seen more as commuter cars rather than grand tourers and reviewers were highlighting the purpose of the car as being more city focused, rather than long-trip.	*Great little car This is a great little car for what it is great commuter if it's not a long journey or for a weekend fun car great pep and handling rides like it's on rails avg 80-100mile range depending on how you drive it*
16.	Design	Here various interior and exterior design choices made by manufacturers were assessed. Whether they are ergonomic or even "stupid" in some cases.	*Good car with stupid rear hatch design The biggest issue with this car is the pointy triangles on either side of the hatch that are easy to hit your head on when the hatch is open. Other than that, there was an issue to learn how to turn on just the cabin fan without also turning on the air conditioning and lowering your range. Over all, we are quite happy with the car and charge it off our solar electric system at home. The car's range is perfect for the Big Island of Hawaii, but I would not buy an all electric car if I lived on the mainland due to long distances and long charging times at level 2 stations. Just watch your head around that hatch.*
17.	Ecology (no tailpipe emissions)	Probably one of the most significant factors of electric vehicles and their major selling point, which is ecological factor. People were expressing their opinion on how the car is emission free and environment friendly.	*Very nice really nice and beautiful, very quite- green car, very high tech and very smart. I may say this car really a car of the future and it helps save our environment on pollution.* *Living in the future I want to be Apart from a market that is mostly ignorant of what they are selling (the Nissan Leaf seems too new for sellers to want to invest in being informed about it), it is a great buy if you go ahead with your research and know that you want zero emissions, clean air, and a quiet and comfortable driving experience, experiencing the sounds of nature around you and knowing that you are not polluting the environment from emissions* *(...) I care about the future, the environment, and ultimately I see more and more of them, which to me says more people are thinking of their children and grandchildren, and future generations. (...)*
18.	Spaciousness	Driver, passengers and cargo need space in the car and this is the factor, which was assessed in this case. Whether the car has enough room for the driver and its passengers also how much cargo space the car has.	*Overall, very good. Jusgt not very comfortable. The Bolt has plenty of headroom for tall drivers. The driver seat is a bit too narrow for me. Similarly cramped like an airline seat. The center console is too far back, making it hard for the driver to access. Two small cup holders and a lot of wasted space in front of the center console. Performance wise the Bolt is a rocket. Very smooth acceleration and excellent visibility. It looks very nice from the outside. Overall I really like it, however it is a bit uncomfortable for anything over 100 miles.*
19.	Superchargers	Electric vehicles besides normal chargers placed on petrol stations or near huge business centers are also able to be charged on stations which allow driver to use superchargers. This factor however is reserved for Tesla owners, that can use supercharger stations to charge their car faster. In this case the availability of those stations was assessed together with the speed at which they charge the car.	*Skeptics—drive a Tesla 3 and see the future Now 12 months and 10,000 miles on my dual motor long range model 3. Pros continue to be the joy of driving a responsive well built car, the incredible technology the acceleration, the front seat comfort. The list goes on. Several long trips have been a pleasure since there are Superchargers everywhere that charge at almost 500 miles per hour. Updates continue free which add to the experience.* *The only con in my opinion is the paucity of service centers.*
20.	Range	Range is another vital factor of an electric vehicle. This is also the one factor that determines the purpose of the car. Usually grand tourers will have higher range on one charge and city/commuter cars will have a smaller one. This factor was assessed by reviewers in this case and they were expressing their feelings about it. Whether it is small, high or just enough for their needs.	*My Second Niro Lots of pep and 250 mi range if you drive reasonably. Don't need sport mode for more pep and eco mode sucks. Doesn't have full dual zone climate control and voice recognition that were on my 2018 Niro hybrid. VESS warning sounds are loud and annoying.*
21.	Build quality	Even though the car comes from the factory as new, it is not unusual for it to have a bad quality. Reviewers in this topic were assessing the build quality and factory support of the car, determining various problems, like rushed paint job for example.	*Excellent but expensive Great car overall. Range not an issue and Superchargers are great. Great acceleration and no need to wait for downshift. Steering feel can be better.* *My major issue is factory support. Had an accident with the car and had to wait two and a half month for parts.*
22.	Customer service	Dealerships' customer service and whether it was good or bad was assessed in this factor. Whether it was easy to book an appointment or what was the attitude of dealership employees towards a consumer.	*There is 0 customer Service I want to be very clear I enjoy my Tesla. From there I would never recommend anyone to buy a Tesla or ever buy another Tesla again. There is an intentional lack of customer service with Tesla. The service center here WILL NOT ANSWER. Leave a message, no response, leave 4 messages, nothing. So ok you buy a car, there are issues that stop you from being able to use the vehicle and your only means of solution is to schedule an appointment app for service. What if that's 2 and half weeks later? Call customer service? There isn't one. Email Tesla? I did that, it's been 2 days, no response. So then what are you buying when you buy a Tesla? A brand new peace of technology that is prone to have issues that you have 0 customer service with. Where I applaud Tesla for changing the world. I frown on them for getting something as simple as keeping happy customers so wrong. Again if you are thinking about buying a Tesla please know that they will try and charge for things you did not order or need, they will out right lie to your face about calls or emails, and you have access to an app and a calendar for customer service outside of when your vehicle is in service and that's it. Tesla has forced all the other major car companies to change to electric, and due to the horrible customer service they give I would encourage to wait for the car company you know and love to come out with there own electric vehicle. At least that way you know if there is an issue you can pick up the phone email w.e. and solve the issue and not be sent down a rabbit whole chasing help that just isn't there.*
23.	Overall performance	This factor is about the performance of the car which combines acceleration, speed and time from 0-60 miles.	*Still no competition Upgradede to p85d from my P85. Drove all kinds of performance cars but none beats the pd models of tesla. Brutal instance acceleration and then relax with auto pilot.*
24.	Steering wheel functionalities	Car needs a steering wheel to be driven and reviewers in this topic were expressing their opinions on various steering wheel functionalities like for example heating or leather finish. Moreover some tesla cars incorporate new kind of a steering wheel called a "Yoke" which differs from well-known circle shaped steering wheel and this was also assessed by consumers.	*Cute and fun to drive All electric cross over with heated leatherette seats and heated steering wheel. Front wheel drive gets up my snowy icy hilly driveway better than my F250 4x4. Comfortable ride and green for the environment. Charges on either 120 v or 240 v.*
25.	Quality	This factor of the car seems similar to the one mentioned before, however it has some differences. Here consumers were more focused on the interior rather than exterior and were assessing, whether the car feels luxurious inside.	*Premium Luxury Ride Quality I've owned my LEAF for 8 months and nearly 6,000 miles at this point. I'm truly impressed with this vehicle. The technology is amazing. The ride is planted because the battery pack creates a low center of gravity. Also, it's very quite. Those two attributes inspire a luxury feel to the vehicle. I like the open feel of the interior. Being a completely new vehicle, in every way, I expected we would have some early adopter issues. But thus far it's operated flawlessly.*
26.	Maintenance	Huge selling point of electric vehicles is the fact, that they don't have that much mechanical parts as internal combustion vehicles. This factor of the car was assessed by reviewers by mentioning that EVs for example don't require the oil to be changed. Consumers were vocal about the lack of maintenance of electric vehicles saying that it requires "zero maintenance".	*Not just the best car, The best THING I?ve owned ! It?s Not just the best car I?ve owned , it?s The best THING I?ve owned !* *I should have made the purchase / transition to Tesla years ago....especially since I have solar, I?m charging at home and driving for free (Not counting Tesla?s 10,000 + free Superchargers across the US)* *So consider the savings from :* *1)Not purchasing gasoline/diesel/natural gas or propane or hydrogen.* *2)Not paying for oil changes.* *3)Not paying for cooling system / radiator antifreeze maintenance,* *4)Not paying for smog checks and or smog related repairs .* *5)Not paying for brakes, brake related expenses till way over 100,000 miles due to Tesla?s regenerative braking .* *6)Not having to pay for motor/engine belts and hoses.* *7)Not having to pay for Transmission oil/filter service or maintenance and repairs since Tesla?s do not have*

TABLE 13. ***(Continued.)*** **Factors of the customer experience of electric vehicles with examples of the most representative comments.**

			transmissions. *8)Not paying for fuel filters, DEF fluid (for new ?clean diesels) .* *9)GREATLY diminished waste of time in traffic due to the ability to use the carpool/HOV lane while driving solo.* *10) Tesla?s are the Safest vehicles made receiving the highest marks on crash tests.*
27.	Dead battery	Battery is the heart of every electric car and is very frequently mentioned by reviewers. Consumers were expressing their problems with battery life, which can be compared to the batteries in mobile phones. While the battery is being used, it degrades and a dead battery is not usable at all for an electric vehicle.	*Big Problems; small fix Was amazed that all problems with entry/key fob was the almost dead battery. Who would not put a fresh battery in a key fob for a new, luxury car? Musk should be aware that those not at the top are not doing his car's reputation any favors.*
28.	General	Here reviewers were expressing their thoughts on electric vehicles as a whole.	*Poor electric capibilties for an eletric vehicle, it does not utilize it like desired. i plugged my ipod into it and hit the gas expecting my ipod to charge. the only thing that happened is the engine revved. i couldnt even access my microsoft word documents. overall it was a poor electric experience.*
29.	Traffic performance	Car's performance in traffic is an important factor of any vehicle whether it is electric or not. Here consumers were determining how the car handles in a city and whether the battery capacity is enough for them to comfortably cruise through urban area.	*Never thought I would like it... But do! I live in Belgium, and have driven fast vauxhalls, a few beemers, and about 5 Japanese fast icons (WRX STI, EVO 9, etc.) and was about to buy a 2018 Nissan GT-R.... Drove the tesla model S 100D for a day and 500km the week after I drove the Nissan.... I bought the Tesla! Does that say enough?* *No, it is not as fast, certainly not as track capable, and with a different emotional dynamic.... But in day to day traffic... It is the fastest thing on the road, overtaking is effortless... Driving in congested traffic becomes a doddle...the first car that managed to relax me dispite the traffic... And since I'm only driving between 50 and a 100 miles a day and charging at home... What was range anxiety again? once or twice a year I'll try to soothe my lust for track driving by hiring something fun like a lotus Elise and indulge in a track day...* *As a daily driver? The Tesla has not many equals... And none that are capable of keeping your hands and/or shoes clean (as in, no smelly unhealthy fuel on them)*
30.	Quietness	Lack of the internal combustion engine means that the EVs are very quiet and this factor of the car was assessed by reviewers in this topic.	*I love this car!! The Modle S is a fantastic car that is not matched by many others out there. It is super cheap to drive, it is awesome plugging while sleeping and waking up to a fully charged ready to go 200+ mile car! It is quiet, it handles well! It is great in the snow. If I have one complaint it is that the interior could have been a bit more functional. With things like map pockets in the doors. But overall you will not be disappointed!* *"(...) Way quieter ride. (...) Range extender engine is much quieter in the BMW (...) I'm sure the germans can figure out a way to make recycled material look nice and have a soft finish which would make the car even quieter.(...) Summary? I'm liking the much quieter ride and super power acceleration and better comfort of the Beemer."*

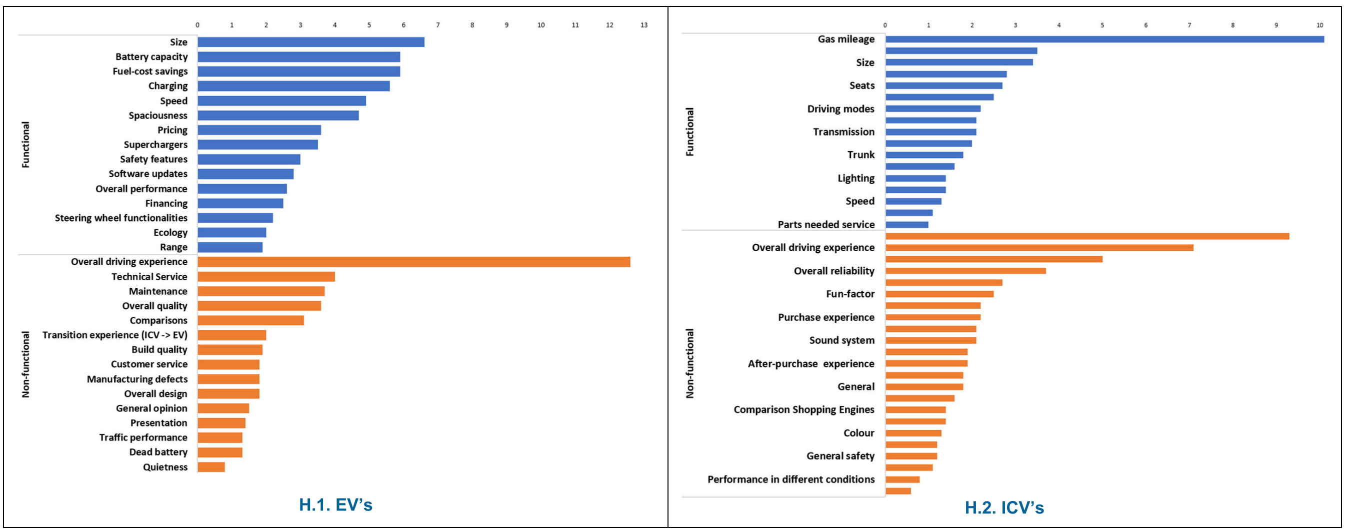


FIGURE 11. **Distribution of the prevalence (%) of the topics (factors) relating to the functional and non-functional values of vehicles.**

VI. CONCLUSION

This study *aimed* to increase our understanding of factors that shape the EVs' and ICVs' customer experience based on their online reviews collected from two American automotive websites. We employed STM to extract core factors defining customer experiences with EVs and ICVs. This approach revealed 30 factors (topics) for EVs customers, organized into 14 subcategories, and 40 factors for ICVs customers, organized into 12 subcategories. STM method was further enhanced by incorporating metadata as covariates, such as satisfaction levels (rating); review publication years; and the predicted gender of the authors, to identify patterns across different customer experiences. PCA was applied to identify the factors shaping consumers' images of electric vehicles.

A. THEORETICAL CONTRIBUTION

Our research *contributes* to the existing theoretical literature in the field of computational *text analytics* by expanding the understanding of the power of these methods to identify patterns that drive consumer perception as follows:

[27] https://www.statista.com/forecasts/997119/purchase-criteria-for-cars-in-the-us

TABLE 14. Factors of the customer experience of internal combustion vehicles with examples of the most representative comments.

No.	Renamed label	factor description	Comments Example
1.	Purchase worthiness	This topic focuses on whether the car in reviewers' opinion is worthy of buying.	*2021 Camry XSE Don't worry about the price just buy it, it'll be worth it!!!!*
2.	Driving experience	In this factor of the opinions on ICVs, people were expressing their opinion on the driving experience. This comes down to the way the driver feels when driving a car. It answers the questions of how the car operates, does it feel good to drive it, whether the control of its movement is adequate and responsive.	*Beautiful driving experience. This SUV is great to drive, it puts joy back in the experience.*
3.	Value for the money	Here people were expressing whether the value that car brings, is worth the amount of money needed to be paid.	*Great value and high feature content Had for about a month now. Cant beat the value for the money. 5 yr wty and 3yr free maint are nice too. Very nice quality vehicle. This is my 6th Hyundai . Many of the features on this car are thousands more $ on other makes.*
4.	After-purchase experience	In this case consumers focused on their feelings after they decided to buy a car. They were determining whether their decision to purchase it was good and whether they regret buying it or not.	*Best car I've ever owned Blown away by the tiguan . I've wanted it for so long and finally just committed . Best decision I've ever made . Rides super smooth and it just feels safe*
5.	Fun factor	It is vital for the car to be fun to drive as no one want to buy vehicle that they don't enjoy driving especially on the freeway. This topic focuses on the fun factor of the driving process on the freeway.	*Fun To Drive Peppy and fun to drive. Busy ride on bumps. Lousy low beam headlights but aftermarket LED bulbs available on the internet.*
6.	Sound system	Cars nowadays include a lot of multimedia that allow drivers to listen to music. In order to have an enjoyable ride, sound system also has to be good. In this case reviewers were expressing their opinion on the sound system, and different software features that allow to play music. Two of the most popular ones, that were mentioned in reviews were apple and android carplay.	*The worst sound system I've ever heard I am generally happy with my 2021 Spark, but the sound quality of the stereo system is awful. It's the worst quality sound of any car I've ever owned, sounding about as good as an AM radio. I replaced the speakers but it only improved the sound slightly. I looked into replacing the stereo unit and NOBODY makes a replacement option, not even Chevy. I'm surprised that no one else has commented on the Spark's sound. Music is important to me, and the sound is so bad that I'll never buy a Chevy product again.*
7.	Size	This factor of a vehicle is crucial for city/commuter cars, that is because they need to fit into small parking spaces and should have small gas mileage. Because of that reviewers were mentioning whether their car was economical and small enough for them.	*2018 BMW 330ix Bought this for my wife to replace her older jaguar,nice car, Rides smoother than the jag ,good power, a bit small on inside,I drive a Hyundai Santa Fe limited,everything on this car is smaller,harder to see,placement of some controls a bit odd,no where near the equipment the Santa Fe has Considering what this would cost brand new,verse's Santa Fe ,not really impressed.that being said it's a nice enough car*
8.	Package types	Cars come in different packages, bringing various option for consumer to choose from. Some cars can be bought as a base package without that many features, and some of them can come in more sporty and performance oriented package.	*Best Package of Safety Features I could find. I purchased the 2018 Chrysler 300 Limited with the SafetyTec Plus Group (Code ALP) because it had all of the safety features on the AARP Smart DriverTEK check list. This was an upgrade from a 2007 Chrysler 300 that Air Bags and Seat Belts. This new 2018 Chrysler has every safety feature you could want. Great Car.*
9.	Electronics	In this topic consumers were very vocal about issues connected with electronic devices, that are included in the car. Examples of them include dead battery which is necessary to power computer of the car.	*Nothing like an Electrical Fire to Ruin your Day The dealer while very nice has no clue on how to fix these cars nor for that matter Volvo. We had been having issues where the onboard screens would blank out when nav in use vehicle would do it twice and then reload while vehicle was in use. This was an issue as your speedometer goes out and we were planning on taking it when it happened on a short trip but this time we smelled an odor then smoke came bellowing out of the center console. We turned off the unit and contacted the nearest dealership. The car has been there two weeks, contacted Volvo North America only to be told they could not find anything but they thought it was due to software needing to be updated. Updates were made and when dealer went to move car, battery was dead. We were told they checked it out with meters and again felt it was a software issue. Car was checked out and I was told the car was repaired. I drove 100 miles to pick the car up only to get in and there was an error indicating the Battery Charge was low after being assured that despite my concerns that it had to be more than a software issue. The car is still at the dealership as I was not willing to have them jump it and attempt to drive it home until they could get with Volvo North America. I would hold off purchasing as no one seems to know how to fix it. Very disappointed*
10.	Reliability	Here consumers were assessing reliability of the vehicle. A reliable car is a car that doesn't brake often and don't need that many maintenance. Some of them even called their car "bulletproof" which indicates that car is very durable.	*2020 Camry SE If you're looking for something reliable this is definitely the car for you. Fuel efficient, stylish, sleek and comfy. This is actually my 3rd Camry. My 1st was a 2014 Carmy SE, then it was a 2019 Camry XSE fully loaded (my fav thus far) and currently have a 2020 Camry SE. I like the SE but definitely would recommend the XSE if its within you budget!*
11.	Engine	Engine is the heart of an ICV and its repair can be at times very costly. This topic focuses on those problems. Some of the reviewers mentioned malfunctions of the engine or called it "garbage". It wasn't unusual to find opinions that said they needed their entire engine replaced.	*Engine needs to be replaced I leased the car in June 2020, less than 10,000 miles and only 9 months old! Something in the engine area started making a rattling/knocking noise and a day or so later I noticed a lack of pick up on the highway. After making it off the highway, I pulled into a parking lot and lost all acceleration. The car would not move at all and the check engine light came on. I had it towed to the dealer who at first insisted there was nothing wrong with it as the check engine light was off and they couldn't replicate the acceleration problem. A day later they tell me Hyundai advised them to replace the engine! So, waiting on a new engine to be delivered...*
12.	Trunk	Driver and passengers aren't the only entities that need to fit into the car, people need some trunk space to fit some of their belongings. In this topic the trunk spaciousness and access to it was reviewed. Regarding the access to trunk, people were talking about the hands-free access enabled either from the car key or from inside of the car.	*Newest ive owned Has met all my needs haveing to get used to the idea how small it is and trunk space. Its cute for our family and friends*
13.	Legroom	In order for the car to be comfortable it needs a certain amount of place for drivers or passengers' legs. This factor is thoroughly assessed by the reviewers by determining whether it is enough or too little.	*Most luxurious car that I have owned and I like it Has much more room in the drivers compartment than what I would have thought. Plenty of legroom for someone who is over six feet tall.*
14.	Seats	Sitting feature of the seat itself isn't enough in todays automotive market. Consumers require seats to be heated or be covered in leather. factors of seats like heating and leather finish were mentioned by reviewers in this topic.	*New Car Craftsmanship I decided on the 2017 Camry purely due to the price. The car is nothing exciting and very basic. What disturbed me is the fit and finish. This has leather seats and some of them are not stretched so there are ripples which will only get worse.*
15.	Test drive	This topic focuses on opinions about the car after test driving it.	*Bimmer 340xi AWD This car has proved to be so much more enjoyable to drive since I replaced the run flat tires with conventional tires. Not only to drive but in the level of comfort experienced.*
16.	City/Highway performance	In this topic people were expressing their opinion on how the car performed while driving on the highway and in the city. They were assessing its gas mileage in those two conditions and the way the drive felt.	*Nice little city car 2016 golf looks very clean, distiller almost. In general the ride is very enjoyable: plush and quite. Ride wise my two biggest complains are: cornering and handling uneven pavement on stock 15" wheels/tire is entirely unpredictable, the car tilts and bobs diagonally at highway speed at times. The second complain is down-shifting of an automatic transmission: especially at lower gears, when downshift occurred the sound and the vibration comming from transmission is to much, almost feels as some sort of malfunction.*

TABLE 14. ***(Continued.)*** **Factors of the customer experience of internal combustion vehicles with examples of the most representative comments.**

17.	Purchase experience	In this case reviewers paid attention to the way their purchasing experience at the dealership felt. They were also mentioning other ways of purchasing the car, an example of that were various websites like Carvana from which consumers can buy vehicles.	*First BMW...good start. Excellent purchase experience at the dealership set high expectations for the vehicle. So far, so good, after only two months. Ideal town car for my driving needs. Visually attractive exterior and interior. Very smart design. Very satisfied and looking forward to many years with this vehicle.*
18.	Design	Aesthetics of both interior and exterior was very important for reviewers. This topic focused on assessing the design choices of manufacturers for their ICVs.	*After 5 months... I almost skipped this edition (G30) of the 5-series, because I wasn't thrilled with the conservative design. After 5 months of driving this, I'm blown away..the ride quality with the 540i is just...perfect, especially compared to the bulky previous generation (F10). The build quality is spot-on, the ergonomics are ideal, and the design aesthetic actually emerges more over time. Bravo, BMW.*
19.	Comparison shopping engines	In this topic consumers were expressing their opinion about websites, that allow people to compare prices of vehicles from different manufacturers.	*UPDATE: Purchased a 2020 BMW X1 Using the Edmunds site I was able to compare makes, model, features over several years for several makes. I was in no hurry to purchase a car and found just the car I wanted with a greater ice for my trade in. (More than the purchase price).*
20.	Lighting	In this topic headlights together with interior LED lights were mentioned and assessed by reviewers.	*very comfortable Had a panoramic roof and was fun to drive. Super Comfortable Chrysler u connect is sweet. The bright lights that automatically Dim should be standard on other cars great feature*
21.	Highway gas mileage	In this topic the gas mileage (fuel efficiency) that car can accomplish while driving on highway was assessed.	*2017 Toyota Camry SE My first ever Toyota Camry was a 2015 and it was a fantastic vehicle. Only requiring basic maintenance like oil Changes, and a tire replacement at 60,000 miles. I have replaced the 2015 with a same model 2017 and the car performs exactly the same as the 2015. We have taken a 1,000-mile trip and everything runs as it should. The 4 cylinder 6-speed Automatic transmission gets up to Highway way speed quickly and delivers good gas mileage averaging 32.2 mpg.*
22.	Gas mileage	This topic is more general variation of the previous topic focusing on the overall gas mileage (fuel efficiency) of the car.	*Great Car This car is very comfortable and smooth riding. It has plenty of power and gets great gas mileage. It looks great and has an excellent safety record. I like its style.*
23.	Driving modes	Different driving modes like eco mode and sport mode allow the car's handling to be tailored to the driver's needs. This topic is talking specifically about those different driving modes which can improve the car's gas mileage or make the car faster.	*The best at Integrated tech Of all the current 2019 & 2020 SUV's the cayenne has integrated the "glass" cockpit the best into the dash and driver functionality. Distant pacing crise is outstanding and the sport mode utilizing the paddle shifters provides great performance. 95MPH in this vehicle feels like 55.*
24.	Parts needed service	In this topic consumers were mentioning particular parts that needed to be replaced like for example AC module or water pump. Some of the parts of the car were even mentioned to be rattling during the ride.	*Rattling time bomb Car rattles a lot. First time seal was used but failed. Needed part replaced. Lazy service advisor, technician, and service manager lack good communication skills with each other and customers .*
25.	Pricing	In this topic prices and discounts that consumers were able to get on the car were mentioned.	*A good catch finally Dealers (such as Audi IRA Peabody, MA and Audi Westwood, MA) are still giving $15K discounts off MSRP price for new Audi A6 2018 models. Money well spent, can't go wrong with this discounts.*
26.	Expectations	Expectations for the car can be sometimes set too high to fulfil. In this topic consumers were assessing whether their car exceeded, met or was below their expectations.	*Our second Q5 has exceeded expectations Great car, but sticker price is way inflated. Don't buy for anything less than 10% of MSRP.*
27.	Performance in different conditions	Snow can be a difficult obstacle for some cars to get through. In this topic people were expressing their opinion on how the car operated in the snowy weather.	*don't cry about the rain or the snow Just drove a 2018 Nissan Altima all the way from Las Vegas Nevada to Missouri through winter storm Bruce the traction control work excellent over the mountain passes in Colorado on ice packed snow roads following that we had another 500 miles or so of ice pack roads through Kansas and into Missouri all y'all saying that your cars don't work good in the snow is because you can't drive in the snow every time we started to slide the traction control would take over and we would even out learn how to drive your car if you give before you give it a bad review.*
28.	Looks	How the car looks definitely influences its sales. In this topic consumers were grading visual appeal or attractiveness of a vehicle's design.	*I love this cst..would recomend it to my friends.. Mrrts all of my needs..hope it will last a long time it is a smooth ride for the money.. like the way it looks inside and out*
29.	Handling	In this topic people were expressing their opinion on how the car operates and whether it is responsive.	*Grand Slam Roomy stylish and fun to drive. Doesn't handle like my last car a2015 4 series grand coupe but still a lot of fun. A grand slam for BMW.*
30.	Speed	In this case, the speed of the car was assessed. This means, that reviewers were determining whether the car was fast.	*Built for speeding tickets! When accelerating pay close attention to the speedometer, you go from 0-Mach50 in seconds. It's hard to go the speed limit. But it does get great mpg and great for having children and car seats. Built for highway not country roads*
31.	General safety	In this topic the overall safety of a vehicle was assessed.	*Best choice for me I am a very careful shopper, and found the VW Tiguan gave me everything I needed in my next vehicle, at a much more competitive price than similar vehicles. My main priority is safety, then comfort. Top marks on both!*
32.	Transmission	In this topic any transmission related problems were mentioned by reviewers.	*Transmission Nissan has a known transmission issue they are unwilling to do the right thing and make it right. We have a 2016 Altima with 70000 miles and a non functioning transmission. It is a $5000 repair which is a "refurbished" transmission. This is our 4th Nissan and will not be buying again not because they have an issue but because they do not stand behind their product.*
33.	General	In this topic reviewers were expressing their general opinion on the vehicle.	*Excellent car! I love this car model. It is spacious and comfortable. Instrument panel and video audio configuration is excellent. Systems and security devices that you have installed give me the necessary security so I can enjoy it with all my family.*
34.	Safety features	Consumers were assessing the car's safety features, like for example lane keeping/lane assist, which is the ability of the car to stay in the driving lane and when the driver starts to go over the lane, he is alerted. Cruise control was also mentioned as one of the features that provided safety for the driver.	*Like No Other Vehicle On The Road Semiautonomous PilotAssist cruise control, Apple CarPlay, Head Up Display (HUD), and loads of safety technology are the features that make the Volvo XC90 stand apart from the crowd.*
35.	SUVs	In this topic consumers were expressing their opinions on the car, mentioning that they chose SUV body type. This body type nowadays is one of the most popular ones in the industry, together with a cross-over which combines different body types with an SUV body type.	*Sporty Closest SUV to a sport sedan. Totally contemporary.*
36.	Dealerships' service	This factor assesses the dealership's attitude towards the buyer, and whether it was easy or not to deal with it.	*Autex Mazda Keene NH Very good Dealership I would recommend Autex Mazda any day they have very good customer service in sales and service.I have purchased some vehicles from them and all the times were great .Out of a lot of the dealership in Keene Swanzey area you were one the easiest to deal with .Thank you again Autex Mazda.*
37.	Color	In this topic people were mentioning their car's color, and the color black was the most popular there.	*So glad to have a black BMW back in my gargage! This car is proving to be the appropriate vehicle for me. The navigational camera and driving aids as well as the ease and comfort of driving have increased my confidence on the road.*

TABLE 14. ***(Continued.)*** **Factors of the customer experience of internal combustion vehicles with examples of the most representative comments.**

38.	Phone integration	In this topic people were mentioning whether their car included Bluetooth, which allows to connect one's phone with the car multimedia.	*2017 Camry XLE, Very nice car with poor GPS App Solid, comfortable, quiet, feels like a luxury car. My car does not have integrated GPS. The only GPS app compatible for this car is Scout GPS Link which works poorly. I ignore it and use portable GPS or Google Map in my cell phone.*
39.	Brand opinion	In this factor consumers were mentioning their brand affiliation and opinion on the brand. Majority of consumers were calling affiliating with BMW the most.	*Best BMW in my 47 years as an owner! I have owned 31 BMW's over the last 47 years and impressed with the 2021 540i, which is classified as a mild hybrid sedan.*
40.	After-purchase opinion	In this factor of the review people were expressing their general opinion about the purchase. They were expressing whether they are happy from the purchase, even calling their vehicle of choice "the best car ever bought".	*Fun car I love it For the price I think this car is t he best car I have ever bought I have owned new cars for Orr 60. Years I am 80 years old. And this car impressed me more than any other car I have ever owned I have owned over 40 new cars*

(1) *Ensuring control and quality assurance of the process of analyzing vehicles' consumer opinions using STM*:

1.1. Proposing an approach for human (experts) *validation* of the *quality* of topics generated by STM by introducing and providing quantitative measures of human-verified coherence and exclusivity.

1.2. Comprehensive implementation of a multi-step process for evaluating the quality of topic labels derived from *human interpretation*. This approach ensures the quality of research insights and mitigates biases of subjectivity in human labeling, which is often cited as a primary limitation of topic modeling approaches [138].

(2) *Building the framework of factors that influence consumer perception of Electric Vehicles and Internal Combustion Vehicles*:

2.1. Developing a contextualized *taxonomy of subcategories* describing consumer experience factors. Unlike prior studies that use k-means, hierarchical clustering [132], [133], PCA [118], CONCOR [47], or Deep Learning [54] for grouping topics by semantic similarity, our taxonomy aligns with established categories from domain-specific literature and industry sources (Table 3) and is further enriched by categories identified in our study.

2.2. Introducing the contextualized *typology* of *vehicle values*– functional and non-functional – from the vehicles' customer/consumer experience perspective and defining the rules for assigning consumer experience factors to them. This typology helps structure analysis and highlights value differences across vehicle types and brands.

(3) *Constructing a comprehensive overview of patterns characterizing consumer perceptions of Electric Vehicles and Internal Combustion Vehicles:*

3.1. Validation of *sentiment* analysis was conducted by assessing its consistency (high correlation) with consumers' overall *ratings*. High consistency suggests that overall ratings can be used as (i) an indicator of consumer *satisfaction* and (ii) a validation tool for *sentiment* analysis results. Existing studies often rely on general lexicons (e.g., Vader [46], [118], [120])) or supervised machine learning techniques (e.g., SVM, Logistic Regression, Random Forest) for sentiment analysis, specifically trained on vehicle-related data ([35], [48], [50], [52], [118], [120], [134]). Our findings are particularly valuable given the challenges in accurately assessing sentiment due to language nuances like sarcasm, idioms, and context-dependent meanings that sentiment analysis tools may overlook [48].

3.2. Introducing a new approach to *prioritizing factors* in consumer experience by considering two dimensions: factor *importance* (measured by discussion volume) and *satisfaction* level (linked to ratings and sentiment). Unlike previous studies, which often rank factors based on prevalence alone (e.g., [113], [172]), or sentiment alone (e.g., ([2], [35], [38], [45], [47], [49], [50], [112], [113], [118], [123], [130]),), our approach uses STM, allowing us to account for ratings and publication dates in analyzing topic prevalence. This method captures a fuller view of consumer preferences, organizing vehicle perception factors into four main groups and offering actionable insights to enhance strengths and address key improvement areas.

3.3. Introducing an approach for evaluating *temporal changes* in consumer experience by considering two dimensions: factor *importance* and *satisfaction* level. Unlike existing studies that primarily focus on topic prevalence dynamics or sentiment trends (e.g., [2], [49], [114], [120], [128]), our method categorizes consumer perception factors into four main trend-based groups over time.

B. PRACTICAL IMPLICATIONS

Our research provides significant *technical implications* for industry stakeholders, including automotive companies, market analysts, and customer service teams. These insights can improve sentiment analysis, customer feedback systems, and predictive modeling to boost product offerings and customer satisfaction in the automotive sector, namely:

(1) The approach for identifying patterns in *temporal changes* in customer experience serves as a dynamic tool to track shifts in consumer preferences and satisfaction. These patterns can train machine learning models for trend forecasting, helping predict consumer adoption patterns in the automotive market. Such predictive models can guide marketing strategies, product development, and customer service improvements by anticipating how changes in vehicle features or services impact consumer sentiment.

(2) The approach for *prioritizing factors* based on their importance and customer satisfaction levels in [real-time] sentiment analysis provides a robust tool for customer feedback systems. This approach allows automotive companies to swiftly identify and address emerging issues while capitalizing on positive trends and enhancing customer satisfaction and loyalty.

(3) By validating *sentiment* analysis with *overall ratings*, we propose a method to integrate these two metrics. Machine learning models can use overall ratings as a proxy

TABLE 15. EVs customer experience factors loadings on the 2-dimensions (PC1 and PC2).

Topic label	PC1 (Battery capacity and Size)	PC2 (Financing and Size)
Pricing	0.14	-0.36
Presentation	-0.28	0.15
Safety features	-0.10	-0.19
Speed	-0.29	0.18
Comparisons	0.03	-0.39
Technical Service	-0.17	0.10
Charging	0.21	-0.06
Manufacturing defects	-0.24	0.08
Battery capacity	0.24	-0.07
Overall driving experience	-0.17	0.07
Fuel cost savings	0.19	0.18
Financing	0.17	0.28
Transition experience (ICV -> EV)	0.15	0.10
Software updates	-0.21	-0.11
Size	0.23	0.23
Overall design	-0.17	-0.21
Emission free	-0.24	0.16
Spaciousness	0.04	-0.19
Superchargers	-0.29	0.09
Range	0.00	-0.10
Build quality	-0.05	-0.01
Customer service	-0.23	-0.12
Overall performance	-0.28	0.12
Steering wheel functionalities	0.11	-0.26
Overall quality	-0.12	-0.29
Maintenance	0.22	0.22
Dead battery	-0.05	-0.11
General	0.12	0.11
Traffic performance	0.05	0.16
Quietness	-0.01	0.06

TABLE 16. **EVS vehicle models loadings on the 2-dimensions (PC1 and PC2).**

Car Model (Brand)	PC1 (Battery capacity and size)	PC2 (Financing and Size)
BMW	-0.54	1.47
Chevrolet	0.36	-0.59
FIAT	2.49	3.58
Hyundai	0.07	-1.80
Kia	1.28	-3.28
Nissan	3.90	1.16
Tesla	-6.40	1.67
Volkswagen	-1.15	-2.22

for sentiment, especially when textual data is ambiguous or sparse, enhancing predictive accuracy and reliability in customer insights.

(4) The proposed *quality control* method for vehicle consumer opinion mining with STM enhances the reliability and accuracy of customer review analysis by addressing biases in model selection and topic labeling. This approach provides high-quality insights to support better-informed product development and customer engagement strategies.

This study offers data-driven insights to help *policymakers* and *industry stakeholders* prioritize customer satisfaction and support the shift toward customer-focused automotive solutions. For the Electric *Vehicles* market: (1) To increase market penetration, strategies to lower vehicle prices should be explored, including subsidies, tax incentives, and the adoption of alternative energy sources to reduce overall operational costs [159], [167], [173]. Public-private partnerships could also help make EVs more accessible to a broader demographic; (2) Expanding accessible and efficient charging networks should be a priority, particularly in underserved areas. Initiatives to standardize charging stations and improve charging speeds can address one of the most significant barriers to EV adoption [159]; (3) Policymakers should intensify campaigns to highlight the environmental advantages of EVs, focusing on zero-emission benefits like cleaner air and reduced noise pollution. Marketing strategies could also target eco-conscious consumers by showcasing these advantages in relatable and impactful ways [159]; (4) Leveraging key functional values such as size, speed, and spaciousness as unique selling points can help EVs stand out from ICVs. These attributes should be emphasized in promotional materials and test-drive experiences to align with consumer priorities; (5) Addressing service-related frustrations in dealerships by training staff, enhancing technical support systems, and ensuring availability of spare parts can significantly improve the customer experience. This is critical for fostering trust and accelerating mainstream EV adoption; (6) Utilize customer feedback and market trends to refine and innovate EV offerings. Responding dynamically to consumer preferences will ensure EVs remain competitive and attractive in a rapidly evolving market.

For the *Internal Combustion Vehicles* market: (1) Highlighting factors such as positive test-drive experiences, superior highway gas mileage, and smooth purchase experiences can strengthen customer loyalty and market positioning; (2) Continuous innovation in reliability and advanced safety features – like lane-keeping assist and speeding alerts – can enhance the perception of ICV quality and maintain consumer trust; (3) Emerging concerns, such as seat comfort and heating problems, should be systematically monitored and addressed through design adjustments and customer feedback integration. Ensuring these issues are resolved promptly will safeguard long-term customer satisfaction; (4) Emphasize distinctive features such as Quietness for BMW, Range for Chevrolet, and Financing, Maintenance, Size, and Fuel-cost Savings for FIAT. Tailoring these attributes to target consumer segments can strengthen brand loyalty and market positioning.

C. CHALLENGES, LIMITATIONS AND FURTHER RESEARCH

This study encountered several *challenges* in interpreting the results of the STM. Although expert involvement improved quality, the varied *writing styles* in reviews, differences in customer *knowledge*, and the tendency to address multiple issues within a single review added *complexity* to the topic interpretation process. Extended pseudo-*Delphi* sessions were required to ensure reliable and consistent results. Additionally, categorizing topics into functional and non-functional factors proved challenging due to the overlap between tangible characteristics and emotional perceptions. Expert discussions and a careful *review of representative opinions* enabled an acceptable level of agreement.

TABLE 17. **EVS vehicle case studies.**

No	Source Type	Source	Market region focus	Factors customers care about	Factors customers care about confirmed in our findings
1	Potential Energy Coalition online survey	[166], [167]	US	Upfront costs Driving range Climate	Pricing Driving range Environmental impact (Ecology)
2	National Travel Attitudes Study (NTAS) is an online and telephone survey Which? survey	[160], [165], [167]	Europe (UK)	Clean air Environmental impact Local jobs Independence from foreign oil	Environmental impact (Ecology)
3	Pew Research Center survey	[161], [161]	US	Public charging stations Climate change	Charging Infrastructure (Charging, Superchargers) Environmental impact (Ecology)
4	McKinsey Mobility Consumer Pulse Survey	[168]	Europe (France, Germany, Italy, and Norway)	Battery range Purchase Price Charging infrastructure Battery lifetime Driving range Advance driving assist systems Accessibility of charging infrastructure Battery Decommissioning Change Travel Patterns	Battery capacity Dead battery Pricing Charging infrastructure (Charging, Superchargers) Driving range Environmental impact (Ecology) Transition experience (ICV -> EV)
5	daze.eu survey Generation Z young people	[158]	Europe	Functionality & Convenience Quietness Comfort Futuristic on-board technology Low emissions City cars & small cars (parking spaces) Competitive prices	Quietness Technology (Steering wheel functionalities) Comfort (Spaciousness) Environmental impact (Ecology) Pricing
6	Survey in Wroclaw	[169]	Europe (Poland)	Costs Free parking zones	Pricing
7	Compare the Market Survey	[170], [171]	US Canada Australia	Battery life Battery replacement Purchase price Driving range Charging times Charging price Understanding of technology	Battery capacity Dead battery Pricing Driving range Charging
8	Deloitte Consulting Survey	[202]	US Southeast Asia China India Germany Japan Republic of Korea	Low fuel costs Climate Driving experience Less maintenance	Environmental impact (Ecology) Driving experience Maintenance
9	BBC Article (based on US's electric vehicle market expert knowledge and statistical data)	[203]	US	Price Charging architecture	Pricing Charging infrastructure (Charging, Superchargers)
10	Autovista24 Article (based on electric vehicle market expert knowledge and statistical data)	[173]	Europe (UK, Germany)	Upfront costs Charging infrastructure Driving range Battery health	Pricing Charging infrastructure (Charging, Superchargers) Driving range Battery (Battery capacity, Battery dead)

The primary *limitations* of this study arise from the nature of the dataset and the *methodology*. *First*, the data exhibits a geographical bias, primarily from two American automotive websites in English, reflecting mainly American user perspectives. Including other markets, such as Europe or Asia, can provide a more comprehensive and balanced view of global automotive preferences, usage patterns, and user expectations, and would enhance the generalizability of the findings. *Second*, reviews were collected within limited date ranges: 2010-2022 for EVs and 2013-2022 for ICVs. *Third*, there's an inherent selection bias as we can't verify that reviewers are actual vehicle consumers, though comment distribution across models is relatively even (Appendix C). *Fourth*, demographic data such as age or region is unavailable, but we predicted reviewer gender, revealing a male bias (85.56% male for EVs and 72.98% for ICVs). According to

S&P Global, 72% of EV buyers are male, despite a 50/50 gender split in general car purchases [174], [175]. *Fifth*, the sample likely skews toward well-educated, internet-savvy, financially stable individuals, especially for EVs. *Sixth*, online reviews often lean toward extreme opinions [176]; in our sample, 50.20% of EV and 60.95% of ICV reviews rated the vehicles 5 stars (Table 2). *Seventh*, gender inference was based on first names using the gender_guesser tool, which may misclassify unisex or culturally ambiguous names. Due to the absence of ground-truth labels, performance metrics such as precision, recall, or F1 score could not be computed. These results should be interpreted as indicative trends, with validation through survey-based methods. *Eight*, platform-specific culture may influence review tone and content. *Lastly*

To build on the current findings and address existing gaps, several directions for *future research* are proposed. *Expanding data sources* to include multiple platforms, regions, and languages will provide broader insights into customer experiences. Incorporating additional *demographic variables* such as age, education, and income levels would enable a deeper analysis of consumer preferences. Collecting *user* and *expert reviews* and integrating data from social media and forums can further diversify the dataset.

Further exploration of how *environmental awareness*, particularly concerns about climate change, carbon emissions, and noise pollution, shapes consumer attitudes could offer a more nuanced understanding of the factors driving EV acceptance. It is also proposed to explore *temporal trends* in greater depth to better understand how consumer preferences for EVs and ICVs have evolved over time, particularly in relation to policy changes, technological advancements, and changing public perceptions.

Methodological advancements in STM should explore techniques that account for interrelated topics, moving beyond the assumption of topic independence [135]. A significant challenge remains in the *topic labeling process*, as the quality relies heavily on expert knowledge in the field [138]. Despite our multi-step approach to ensure label quality, selecting highly qualified experts is crucial. Future research could focus on more automated, transparent labeling methods, possibly using explainable AI (XAI) for enhanced interpretability.

Future *sentiment analysis* efforts should validate the correlation between sentiment and ratings across different domains. Employing diverse sentiment lexicons or industry-specific machine-learning models may refine accuracy, and integrating sentiment analysis with qualitative methods can offer a more comprehensive understanding of consumer sentiments.

Finally, findings related to *gender differences* in consumer experiences should be further investigated, given the lack of personal information on reviewer demographics and the gender prediction accuracy of approximately 60% [177]. Expanding future studies to include random sampling and longitudinal tracking can validate and extend these findings.

APPENDIX A
See Table 7.

APPENDIX B
See Table 8.

APPENDIX C
See Table 9.

APPENDIX D.1
See Table 10.

APPENDIX D.2
See Table 11.

APPENDIX E.1
See Fig. 9.

APPENDIX E.2
See Fig. 10.

APPENDIX F
See Table 12.

APPENDIX G
See Table 13.

APPENDIX H
See Fig 11.

APPENDIX I
See Table 14.

APPENDIX J
See Table 15.

APPENDIX K
See Table 16.

APPENDIX L
See Table 17.

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NINA RIZUN received the Ph.D. degree in technical sciences from Dnipro University of Technology, Ukraine. She is currently an Assistant Professor with the Department of Informatics in Management, Faculty of Management and Economics, Gdań sk University of Technology, Poland. Her research interests include computational linguistics, NLP, sentiment analysis, artificial intelligence, and machine learning and their application for business processes and service improvement in such domains as healthcare and IT service management. Within the last few years, she has also focused on the field of investigating ICT-related governance domains, including smart governance, smart cities, and open data. She has a strong ongoing publication record as a senior and second author in high-ranking international peer-reviewed journals (such as IEEE, *Decision Support Systems*, *Technological Forecasting and Social Change*, *Computers in Industry*, and *Telecommunications Policy*); an Editorial Board Member of the *eJournal of eDemocracy and Open Government*; a reviewer of several peer-reviewed journals; and a program committee member of many high-level international conferences.

BARTOSZ DUZINKEWICZ received the degree from the Faculty of Data Engineering, Gdańsk University of Technology, Poland. He is also a Software Engineer with EPAM Systems, Poland. His research interests include big data, PySpark, data warehouses, business analytics, text analytics, and NLP.