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Technological innovation, product development, and operational efficiency for new energy vehicle industry: Basis for a synergistic framework

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Abstract

The study aimed to explore the relationship between the technological innovation, product development and operational efficiency in China's new energy vehicle industry and to develop a synergistic framework for the new energy vehicle industry. This study adopted descriptive research, and used survey questionnaires as a data gathering instrument. The study selected 400 employees from 5 new energy vehicle enterprises in the Chinese market for investigation and research, including BYD, Ideal Automobile, NIO, Xiaopeng Automobile and Geely Automobile which are located in Shenzhen, Beijing, Shanghai, Guangzhou and Hangzhou. Based on the results of the study, the respondents generally agreed that technological innovation has played a crucial role in transforming the new energy vehicle in enhancing connectivity, personalization, and in-car tech features. The study revealed agreement that product development in the new energy vehicle (NEV) industry has demonstrated significant advancements in innovation, safety, and sustainability. The respondents generally agreed that the operational efficiency in the new energy vehicle (NEV) industry has significantly improved through advancements in data-driven operations, manufacturing efficiency, and service efficiency. There were high significant relationships between technological innovation, product development and operational efficiency. A synergistic framework for the new energy vehicle industry was developed.

Keywords: new energy vehicle industry framework, operational efficiency, product development, technological innovation

Technological innovation, product development, and operational efficiency for new energy vehicle industry: Basis for a synergistic framework

1. Introduction

In recent years, the global new energy vehicle market has been growing rapidly. According to the International Energy Agency (IEA), global energy vehicle sales have reached 10 million units in 2023, and that number is expected to grow to 60 million by 2030. China, Europe and the United States are the world's largest market for new energy vehicles. The Chinese market is particularly important, accounting for more than half of global sales (International Energy Agency, 2023).

New energy vehicles have the characteristics of zero emission or low emission. Compared with traditional fuel vehicles, new energy vehicles use electric energy or other clean energy, which reduces the dependence on oil, improves energy security, and also helps to reduce urban air pollution and improve the health and quality of life of residents (He et al., 2021). China has been the world's largest market for new energy vehicles for many consecutive years. In 2023, the sales volume of new energy vehicles in China exceeded 6.5 million units, accounting for more than 60% of the global sales volume. At the same time, the market share of new energy vehicles in China's new car sales has been increasing year by year, reaching about 25% in 2023 (International Energy Agency, 2023). The continued growth of new energy vehicles in China is due to policy support, technological progress and improved consumer recognition. First-tier cities and coastal areas are the main markets for the sales of new energy vehicles, and the market potential of the central and western regions is also gradually being released. The rapid advancements in technology have significantly reshaped the automotive industry, giving rise to the emergence of new energy vehicles (NEVs). The development of new energy vehicles (NEVS) has taken the center stage in the automobile industry. NEVs, either electrically powered or fueled by alternative sources, are seen as a viable response to the environmental issues that the world is facing and of reducing the use of fossil fuel. Nonetheless, the encouragement and the market introduction of NEVs strategies involve technological innovation, product development and operational efficiency.

In terms of technological innovation, the current range of most new energy vehicles can meet the daily commuting needs to a certain extent, but in long-distance travel or extreme weather conditions, the range may be significantly reduced, affecting consumers' use experience and purchase decisions. In addition, the fast-charging technology is not fully mature, compared with the traditional fuel vehicle refueling only a few minutes, new energy vehicles even if the use of fast charging equipment, it takes several hours to be fully charged, which has a great impact on the user's travel convenience. At the same time, the battery's cycle life is limited, but the cost is high, and the cost of replacing the battery may make consumers prohibitive. The autonomous driving technology of new energy vehicles also faces many technical challenges. Most of the current autonomous driving technology is at the L2-L3 level, which is still a long way from true full autonomous driving (L5 level). In the complex traffic environment, the automatic driving system may have misjudgment, missed judgment and other situations, resulting in safety accidents (Li et. al.,2020).

Product development in the new energy vehicle industry is equally critical. The manufacturers ought to direct their efforts towards developing vehicles that will accommodate the ever-changing demands of the consumers. Such considerations include vehicle range, charging time, safety characteristics, convenience, and appearance. Besides, product development should also explore the issue of the aesthetics of existing technologies in a bid to enhance the user experience (Wang et al.,2019). In terms of product development, in recent years, new energy vehicle battery fires have occurred from time to time, causing consumers to worry about battery safety. Battery safety issues involve battery materials, structural design, production process and many other aspects needed to improve the safety of the battery through technological innovation, such as the development of more stable battery materials, optimize the structural design of the battery, and strengthen the safety management

system of the battery. In addition, at present, the homogenization of products in the new energy vehicle market is more serious, and many models have little difference in appearance design, performance parameters, configuration, etc., and lack unique product competitiveness. This not only makes it difficult for consumers to distinguish between different brands of products when choosing, but also makes the competition between enterprises more fierce, difficult to form differentiated competitive advantages, lack of innovation and personality. It is worth noting that another determinant impacting the competitive performance of new energy vehicle producers is operational efficacy. According to Zhao et al.,(2022), cost, quality, and customer satisfaction may all be addressed through the optimization of production operations, supply chain, and service after sales activities, among others. Additionally, efficient operations enhance the overall sustainability of the NEV industry with respect to the environment by lowering negative impacts and increasing the efficiency of resources used.

One of the primary challenges facing the NEV industry is the need for continuous technological innovation. The development of advanced battery technologies, efficient electric motors, and intelligent charging infrastructure is crucial to enhance the performance, range, and affordability of NEVs. Moreover, breakthroughs in autonomous driving systems, connected car technologies, and energy management systems can further differentiate NEV products and attract a wider consumer base (Huang et al.,2021).

In terms of operation, the current profit model of new energy automobile enterprises mainly relies on vehicle sales, and the profit model in the fields of after-sales service, battery leasing, data services is not mature. The single profit model limits the profitability of enterprises and makes it difficult to achieve sustainable development. In addition, the second-hand car market is still in its infancy, and the evaluation standards, transaction processes and quality assurance policies of second-hand cars are not perfect, which affects consumers' confidence in buying and the development of the second-hand car market. In addition, the number of charging piles is far from meeting the development needs of new energy vehicles, especially in some old communities, remote areas and other places, the coverage of charging piles is low, resulting in consumers facing great difficulties when charging. At the same time, the charging interfaces and charging standards used by different brands and different models of new energy vehicles may be different, leading to problems with the compatibility of charging piles. When using charging piles, consumers may encounter situations such as inability to charge or slow charging speed, which affects the convenience and efficiency of charging. The technical structure of new energy vehicles is very different from that of traditional fuel vehicles, and its maintenance technology is also more complex. At present, there is a shortage of professional new energy vehicle maintenance technicians, and many maintenance personnel are not familiar with the technical characteristics and maintenance methods of new energy vehicles, which may lead to misdiagnosis and mis-repairs in the maintenance process, affecting the maintenance quality and efficiency of vehicles.

The study aims to contribute to the existing knowledge on the area of the new energy vehicle sector by helping with the detailed assessment of the relationship between technological innovation, product development and operational efficiency. By determining the critical components for the success of the NEV sector in the study, it benefits the researcher, policymakers, and other stakeholders in this sector. The study may be beneficial to the industry players as it gives them sufficient information which they can use in making measurable solutions like investing, creating new products or improving the existing processes. As the new energy vehicle industry continues to develop, its manufacturers will be able to learn more strategies in the industry and how to increase their sales and enhance competitive strategies.

Objectives of the Study - This study aimed to examine the technological innovation, product development and operational efficiency in the new energy vehicle industry in China that will be the basis in developing a synergistic framework for new energy vehicle industry. Specifically, this study aimed to describe the technological innovation as to connectivity, personalization and user experience and in-car tech; determined the product development in terms of innovation, safety and sustainability; assessed the operational efficiency as to data driven operations, manufacturing efficiency and service efficiency; tested the significant relationship between technological innovation, product development and operational efficiency and develop a synergistic

framework for new energy vehicle industry.

2. Methods

Research Design - This study aims to describe and analyze the current situation of Chinese NEV enterprises in terms of technological innovation, product development and operational efficiency. This study provided an integrated framework to provide theoretical support and practical guidance for the development of the new energy vehicle industry. Descriptive design is a type of research methodology that strives to describe and explain already existing things. Concerning the new energy vehicle (NEV) sector, such studies can capture the present level of advancement concerning technology, development of products, and operational efficiency. The descriptive method enables the researcher to assess the interactions and relations currently present among various aspects of the new energy vehicle system.

Participants of the Study - The respondents of this study were the selected 400 respondents from 5 new energy vehicle enterprises in the Chinese market including BYD, Ideal Automobile, NIO, Xiaopeng Automobile and Geely Automobile located in Shenzhen, Beijing, Shanghai, Guangzhou and Hangzhou, covering major players in China's electric vehicle industry. The five companies were chosen because they are representative in terms of technological innovation, product development and operational efficiency, and have a great influence in the market. The employees who were used as respondents of the study have different positions and who have diverse perspectives on technological innovation, product development and operational efficiency. These employees in their respective fields have rich experience and professional knowledge, they are directly involved in the enterprise technology innovation and operation management, can provide first-hand practical experience and practical cases and can provide in-depth insights and data about the topic understudy. Choosing staff from five leading new energy vehicle enterprises can ensure the representativeness and reliability of the data. These companies have an important influence in the market, and the feedback from their employees can reflect the general trends and problems in the industry.

Instruments of the Study - This research utilizes a questionnaire survey as the primary data collection instrument. The questionnaire is meticulously self-designed to align precisely with the research objectives. By designing their own questionnaire, the researcher was able to construct the questions in accordance with the distinct research objectives. This guarantees that the gathered information is purposeful and beneficial to the study. The questionnaire was administered through online and offline channels. This approach was adopted to ensure a wide reach and to include respondents with diverse backgrounds and positions. By doing so, it guarantees the representativeness of the data collected. The questionnaire is structured into three parts. The first part of the questionnaire assessed the technological innovation in the NEV industry, including technological innovation in connectivity, personalization, user experience, and in-car technology. The second part described the product development, which is based on innovation, safety and sustainability. The last part of the questionnaire assessed the operational efficiency of the new energy vehicle industry, including three dimensions of data-driven operation, manufacturing efficiency and service efficiency.

Based on result, the Technological Innovation, Product Development and Operational Efficiency Instrument has an Excellent consistency as exhibited by the Cronbach’s Alpha value of (.975). This was validated by the Excellent remark from Technological Innovation (.954); it was confirmed by the Excellent result from Connectivity (.952), and Good result on Use experience and in-car tech (.831). Also, it was validated by the Excellent remark from Product Development (.920); it was confirmed by the Good results from Innovation (.824), Safety (.822), and Sustainability(.863). It was further validated by the Excellent result from Operational Efficiency (.925); it was confirmed by the Good results from Data driven Operations (.825), Manufacturing Efficiency(.817), and Service Efficiency(.826); which shows that the instrument at hand passed the reliability index test. Thus, the researcher can now proceed to the actual survey using the aforementioned instrument.

Table 1
Reliability Summary Table

Indicators	Cronbach Alpha	Remarks
Technological Innovation, Product Development and Operational Efficiency Instrument	.975	Excellent
Per variable		
Technological Innovation	.954	Excellent
Connectivity	.952	Excellent
Personalization	.880	Good
Use experience and in-car tech	.813	Good
Product Development	.920	Excellent
Innovation	.824	Good
Safety	.822	Good
Sustainability	.863	Good
Operational Efficiency	.925	Excellent
Data driven operations	.825	Good
Manufacturing efficiency	.817	Good
Service Efficiency	.826	Good

Data Gathering Procedure - After completion of the self-constructed questionnaire, the questionnaire underwent content validation from the experts to evaluate the indicators used in the study. The suggestions and modifications were incorporated in the questionnaire for clarity and relevance. The pilot testing was done and the questionnaire was administered in a small group to test its reliability. An ethical review was also done to ensure that ethical standards were observed and an ethics certificate was issued. The researcher also sought permission from the HR heads of the five companies to allow for the administration of the questionnaire from their employees. The actual administration of the questionnaire was done through online and offline modes in order to maximize the number of respondents. After collating the answers, the data entry was collated and carried out using statistical analysis. The researcher further interpreted and analyzed the results.

Data Analysis - In this study, the respective indicators of the different dimensions of the three core variables have been designed and coded to achieve the digitized structuring of statistical data. Module evaluation is conducted through pre-processing and statistical transformation for preliminary statistical analysis. Weighted mean and rank were used to describe the technological innovation as to connectivity, personalization and user experience and in-car tech; determine the product development in terms of innovation, safety and sustainability; assess the operational efficiency as to data driven operations, manufacturing efficiency and service efficiency. The result of the Shapiro-Wilk Test showed that p-values of all variables were less than 0.05 which means that the data set was not normally distributed. Therefore, Spearman rho was used as part of the non-parametric tests to determine the significant relationship. All analyses were performed using SPSS version 28.

Ethical Consideration - The following ethical considerations need to be fully considered when conducting the study to ensure study compliance and the safety of the participants. First, informed consent was obtained from the participants, meaning that the participants must be clearly informed about the purpose of the study, detailed procedures, risks and benefits of participation, and their right to withdraw from the study at any time. Second, the data privacy and confidentiality of the participants were strictly followed. The researcher took steps to protect participants 'privacy, ensure that no personally identifiable information is exposed during data processing, and use security technologies to prevent data leakage or unauthorized access, ensuring that participants' data is not shared with unauthorized individuals or organizations. Finally, the researcher had a responsibility to protect participants from any form of harm, both physical and psychological safety. By fully considering and implementing these ethical factors, transparency, impartiality and the safety of the research process was ensured, which further improved the credibility and effectiveness of the study.

3. Results and discussion

Table 2
Summary Table on Technological Innovation

Key Result Areas	Composite Mean	VI	Rank
Connectivity	3.20	Agree	1
Personalization	3.12	Agree	2
User Experience and In-car Tech	3.10	Agree	3
Grand Composite Mean	3.14	Agree	

Legend:3.50-4.00=Strongly Agree;2.50-3.49=Agree;1.50-2.49=Disagree;1.00-1.49=Strongly Disagree

According to the data in Table 2, the grand composite mean of is 3.14. This indicates that overall, the technological innovation indicators across connectivity, personalization, and user experience and in-car tech for new energy vehicles fall within the "Agree" range.

The highest ranked area is connectivity with a composite mean of 3.20, indicating a relatively strong agreement on the importance of connectivity in new energy vehicle technology. This could imply that the integration of new energy vehicles with the Internet and other external systems is seen as a crucial aspect of innovation. Personalization comes in second with a composite mean of 3.12, suggesting that tailoring vehicles to meet individual user needs is also an important area of innovation. User experience and in-car tech rank third with a composite mean of 3.10, highlighting the significance of providing advanced features and a seamless driving experience. Overall, this table shows that technological innovation in new energy vehicles is occurring in multiple areas, and these areas are all considered important for the development and competitiveness of the industry.

Technological innovation plays a significant and positive role in improving the performance and user satisfaction of new energy vehicles. Li et al. (2022) pointed out that the technological innovations in the new energy vehicle industry are mainly reflected in battery technology, intelligent driving system and charging infrastructure, which not only improve the energy efficiency and range of vehicles, but also optimize the driving experience and charging convenience of users (Li et al., 2022). Their research shows that advanced battery technology can extend the range of electric vehicles while shortening the charging time, thus improving the overall driving experience of users. In addition, Patil (2020) found that advances in battery technology and the application of autonomous driving technology not only improve the performance and utility of electric vehicles, but also significantly improve the overall driving experience and satisfaction of users (Patil, 2020). He stressed that autonomous driving technology makes electric vehicles more attractive by improving the safety and convenience of driving. Meanwhile, Brown et al. (2021) pointed out that the intelligent and interconnected technologies of new energy vehicles have also significantly improved user satisfaction. These technologies, including in-car entertainment systems, remote control functions and intelligent navigation systems, have significantly improved the user experience. To sum up, technological innovation plays a key role in promoting the development of the new energy vehicle industry. It not only plays an important role in improving vehicle performance, but also significantly improves user satisfaction and convenience of use.

Table 3
Summary Table on Product Development

Key Result Areas	Composite Mean	VI	Rank
Innovation	3.07	Agree	1.5
Safety	3.07	Agree	1.5
Sustainability	3.06	Agree	3
Grand Composite Mean	3.07	Agree	

Legend:3.50-4.00=Strongly Agree;2.50-3.49=Agree;1.50-2.49=Disagree;1.00-1.49=Strongly Disagree

Table 3 provides a summary of product development in new energy vehicles across three key result areas. Innovation and Safety both have the same composite mean of 3.07, indicating that they are equally emphasized in product development. The efforts in improving battery technology, electric drive systems, autonomous driving, charging infrastructure, and braking energy recovery systems for innovation, as well as implementing advanced

battery temperature control systems, strict charging system safety design, intelligent control and monitoring of electric drive systems, and communication security and emergency rescue systems for safety, are crucial for the development of new energy vehicles. Sustainability, with a composite mean of 3.06, shows that the industry is also making efforts in areas such as government policies to encourage development, increased consumer demand for environmentally friendly vehicles, manufacturers' participation in carbon neutrality, continuous technological innovation for efficiency, and improved social acceptance. Overall, this table shows that product development in new energy vehicles is a multi-faceted process that takes into account innovation, safety, and sustainability.

Table 4
Summary Table on Operational Efficiency

Key Result Areas	Composite Mean	VI	Rank
Data Driven Operations	3.04	Agree	2
Manufacturing Efficiency	3.05	Agree	1
Service Efficiency	3.00	Agree	3
Grand Composite Mean	3.03	Agree	

Legend:3.50-4.00=Strongly Agree;2.50-3.49=Agree;1.50-2.49=Disagree;1.00-1.49=Strongly Disagree

According to the data in Table 4, the grand composite mean of 3.03. This value indicates that overall, the operational efficiency indicators for new energy vehicles fall within the "Agree" range. Looking at the individual composite means for each key result area, Data Driven Operations has a composite mean of 3.04, Manufacturing Efficiency has 3.05, and Service Efficiency has 3.00. These values suggest a general consensus on the importance of these areas in operational efficiency for new energy vehicles. The relatively small differences in the composite means suggest that all three areas are considered important for improving operational efficiency.

Table 4 provides a summary of operational efficiency in new energy vehicles across three key result areas. Manufacturing Efficiency has the highest composite mean of 3.05, indicating that it is currently the most emphasized area among the three. This could imply that the new energy vehicle industry is placing a strong focus on improving production processes, adopting advanced technologies, and optimizing supply chains to enhance manufacturing efficiency. Data Driven Operations has a composite mean of 3.04, suggesting that the use of data analytics and technology to optimize operations is also an important aspect. Service Efficiency has a composite mean of 3.00, highlighting the significance of providing personalized and efficient services to customers. Overall, this table shows that operational efficiency in the new energy vehicle industry is a multi-faceted concept that encompasses manufacturing, data-driven operations, and service. In terms of data-driven operations, data-driven operational strategies can help enterprises quickly respond to market demand, reduce waste and inventory costs, and thus improve the overall operational efficiency. Service efficiency is also an important factor in improving user satisfaction. Chen et al. (2021) studies show that enterprise improvements in service efficiency and user experience not only improve user satisfaction, but also promote the sustainable development of enterprises. They note that efficient service measures, such as personalized services, remote diagnostics and data analytics, can significantly improve the user experience and satisfaction.

Table 5
Relationship Between Technological Innovation and Product Development

Variables	rho	p-value	Interpretation
Connectivity			
Innovation	0.569	< .001	Highly Significant
Safety	0.574	< .001	Highly Significant
Sustainability	0.557	< .001	Highly Significant
Personalization			
Innovation	0.591	< .001	Highly Significant
Safety	0.609	< .001	Highly Significant
Sustainability	0.577	< .001	Highly Significant
User Experience and In-car Tech			
Innovation	0.602	< .001	Highly Significant
Safety	0.624	< .001	Highly Significant
Sustainability	0.578	< .001	Highly Significant

Correlation is significant at the 0.01 level

According to the data in Table 5, the table shows various correlation coefficients (rho) and p-values for the relationship between different aspects of technological innovation and product development. The rho values range from 0.557 to 0.624, indicating moderate to strong positive correlations. The p-values are all less than 0.001, which means that the correlations are highly statistically significant at the 0.01 level. For example, the correlation between connectivity and innovation has a rho of 0.569 and a highly significant p-value. This suggests a strong relationship between these two variables. Similarly, other pairs of variables also show significant positive correlations.

Table 5 provides insights into the relationship between technological innovation and product development in the new energy vehicle industry. The significant positive correlations suggest that as one aspect of technological innovation increases, so does the corresponding aspect of product development. For instance, a higher level of connectivity is associated with greater innovation, safety, and sustainability in product development. The same pattern holds for personalization and user experience and in-car tech. This indicates that technological innovation in different areas is closely intertwined with product development, and efforts in one area can have a positive impact on multiple aspects of product development.

Research shows that technological innovation can not only significantly improve connectivity, personalization, user experience and in-car technology, but also enhance the safety and sustainability of products. First, technological innovation has made a significant contribution in connectivity. According to Chen et al.(2020), advances in Internet of Vehicles technology make information transmission between cars more efficient, thus improving driving experience and driving safety. These technological advances not only improve the interconnection performance of vehicles, but also promote the intelligent development of the overall transportation system (Chen et al., 2020). Secondly, individuation is one of the key goals of modern product development. Technological innovation also shows a strong impetus in terms of user experience and in-car technology. Johnson (2021) study found that the development of interior intelligent technology, such as voice control and autonomous driving functions, has greatly improved the convenience and comfort of driving. The application of these technologies not only improves the user experience, but also significantly improves the safety of vehicles (Johnson, 2021). In addition, safety and sustainability are also the beneficial areas of technological innovation. The data in this table is highly significant for the research on “Relationship Between Technological Innovation and Product Development”. It provides empirical evidence of the strong links between technological innovation and product development. This helps in understanding how different forms of technological innovation contribute to the development of new energy vehicles in terms of innovation, safety, and sustainability.

Table 6

Relationship Between Technological Innovation and Operational Efficiency

Variables	rho	p-value	Interpretation
Connectivity			
Data Driven Operations	0.560	< .001	Highly Significant
Manufacturing Efficiency	0.596	< .001	Highly Significant
Service Efficiency	0.562	< .001	Highly Significant
Personalization			
Data Driven Operations	0.573	< .001	Highly Significant
Manufacturing Efficiency	0.533	< .001	Highly Significant
Service Efficiency	0.609	< .001	Highly Significant
User Experience and In-car Tech			
Data Driven Operations	0.571	< .001	Highly Significant
Manufacturing Efficiency	0.579	< .001	Highly Significant
Service Efficiency	0.594	< .001	Highly Significant

Correlation is significant at the 0.01 level

According to the data in Table 6, the correlation coefficients (rho) range from 0.533 to 0.609. These values indicate moderate to strong positive correlations between technological innovation aspects (Connectivity, Personalization, User Experience and In-car Tech) and operational efficiency areas (Data Driven Operations,

Manufacturing Efficiency, Service Efficiency). The p-values for all correlations are less than 0.001, which means the relationships are highly statistically significant at the 0.01 level. For example, the correlation between Connectivity and Data Driven Operations has a rho of 0.560 and a highly significant p-value.

Table 6 shows that there is a significant relationship between technological innovation and operational efficiency in the new energy vehicle industry. The positive correlations suggest that as technological innovation in areas such as connectivity, personalization, and user experience increases, operational efficiency in data-driven operations, manufacturing efficiency, and service efficiency also tends to improve. This implies that investments in technological innovation can have a positive impact on different aspects of operational efficiency.

Research shows that technological innovation significantly improves data-driven operations, manufacturing efficiency, and service efficiency, while improving connectivity, personalization, and user experience, and in-car technology. Wang et al. (2021) research found that the application of advanced manufacturing technology and automation systems, can significantly reduce the production time, improve production efficiency, and reduce costs. These technological advances make the manufacturing process more flexible and efficient, thus improving the production capacity and market response speed of enterprises. In terms of service efficiency, technological innovation also shows a strong impetus. The application of smart technology not only simplifies the service process, but also improves the accuracy and timeliness of the service. In addition, technological innovation also plays a significant role in improving connectivity, personalization and user experience, and in-car technology. Developments in in-car technologies, such as autonomous driving and intelligent cockpit systems, have also significantly improved vehicle safety and comfort. The data in this table is of great significance for the research on “Relationship Between Technological Innovation and Operational Efficiency”. It provides empirical evidence of the link between technological innovation and operational efficiency. This helps in understanding how technological innovation can drive improvements in operational efficiency.

According to the data in Table 7, the correlation coefficients (rho) range from 0.564 to 0.610. All p-values are less than 0.001, indicating highly significant relationships at the 0.01 level. For example, the correlation between innovation and data-driven operations has a rho of 0.569. This shows a moderate to strong positive correlation between different aspects of product development (innovation, safety, sustainability) and operational efficiency areas (data driven operations, manufacturing efficiency, service efficiency).

Table 7 demonstrates a significant relationship between product development and operational efficiency in the new energy vehicle industry. The positive correlations suggest that as product development in terms of innovation, safety, and sustainability increases, operational efficiency in data-driven operations, manufacturing efficiency, and service efficiency also tends to improve. This implies that efforts in product development can have a positive impact on different aspects of operational efficiency.

Table 7

Relationship Between Product Development and Operational Efficiency

Variables	rho	p-value	Interpretation
Innovation			
Data Driven Operations	0.569	< .001	Highly Significant
Manufacturing Efficiency	0.564	< .001	Highly Significant
Service Efficiency	0.572	< .001	Highly Significant
Safety			
Data Driven Operations	0.590	< .001	Highly Significant
Manufacturing Efficiency	0.601	< .001	Highly Significant
Service Efficiency	0.610	< .001	Highly Significant
Sustainability			
Data Driven Operations	0.590	< .001	Highly Significant
Manufacturing Efficiency	0.566	< .001	Highly Significant
Service Efficiency	0.589	< .001	Highly Significant

Correlation is significant at the 0.01 level

In recent years, the improvement of technological innovation and product development to operational

efficiency has become increasingly important in the new energy vehicle industry. Research shows that product development plays a significant role in improving data-driven operations, manufacturing efficiency and service efficiency, while also enhancing the market competitiveness and sustainable development ability of enterprises. First, the role of innovation in improving data-driven operations has been widely recognized.

Wang et al. (2021) The research pointed out that through the introduction of advanced data analysis and processing technology, enterprises can manage operations more efficiently and optimize resource allocation, so as to improve the overall operational efficiency. This data-driven operation mode enables enterprises to quickly respond to market demand and improve their competitiveness. Secondly, safety in product development also plays a significant role in improving manufacturing efficiency and service efficiency. Li et al. (2022) found that the application of advanced safety technology and standards can significantly reduce the risks and costs in the production process and improve production efficiency. Security improvements not only ensure the stability of the manufacturing process, but also improve the accuracy and timeliness of service delivery. In addition, the sustainability of product development is crucial to the long-term development and efficient operation of an enterprise. Chen et al. (2023) Research shows that adopting a sustainable production and operation mode can not only reduce the environmental impact, but also improve the efficiency of resource utilization, thus significantly improving the efficiency of manufacturing and service. These sustainability measures help companies to achieve long-term economic and social benefits by optimizing the user experience, enterprises can enhance their brand loyalty and market competitiveness, so as to stand out in the fierce market environment. The data in this table is highly significant for the research on “Relationship Between Product Development and Operational Efficiency”. It provides empirical evidence of the link between product development and operational efficiency. This helps in understanding how product development can drive improvements in operational efficiency.

Synergistic Framework for New Energy Vehicle Industry

The synergistic framework for a new energy vehicle (NEV) industry is an integrative strategy that incorporates the relationship between technology innovation, product development and operational efficiency. This framework seeks to build a system wherein all these components are interlinked for the betterment of the particular industry. For the new energy vehicle industry, this synergy can lead to enhanced competitiveness, improved product quality, and more efficient operations.

Technological innovation as used in the study includes connectivity, personalization, user experience and in-car technology. Product development involves innovation, safety and sustainability while operational efficiency focuses on data driven operations, manufacturing efficiency and service efficiency to ensure a reliable and sustainable manufacturing process in the new energy vehicle.

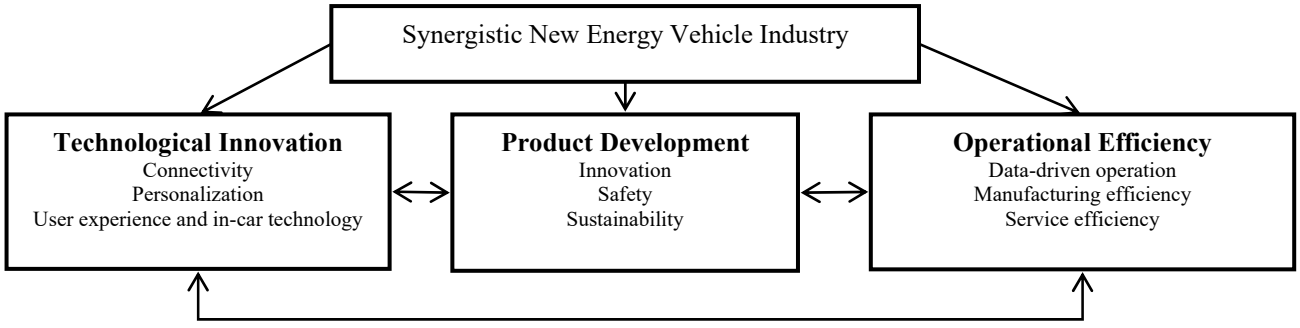

Figure 1: Synergistic Framework for New Energy Vehicle Industry

Technological innovation plays a crucial role in both product development and operational efficiency. In product development, innovation shows highly significant correlations with variables such as safety, sustainability, and personalization. In operational efficiency, it is significantly related to data-driven operations, manufacturing efficiency, and service efficiency. Product development also has a strong connection with

operational efficiency. Innovation, safety, and sustainability in product development are all highly significantly correlated with different aspects of operational efficiency.

Analysis of the study output shows that there are clear and strong relationships among these three key elements. The highly significant p-values indicate that these connections are not due to chance. The positive correlations suggest that efforts in one area can have a positive impact on the others. For example, investing in technological innovation can not only lead to better product features like increased safety and sustainability but also improve operational efficiency in manufacturing and service. This framework provides a useful guide for industry players to strategically allocate resources and focus on areas that can have a multiplier effect on the overall success of the new energy vehicle business.

By developing the synergy and ensuring the interplay of these 3 elements benefits the new energy vehicle sector to a great extent. While technological innovation enhances product performance, minimizes costs through battery technology, and fabrication, as well as broadens the scope of the market with more features, and fitting capabilities, product development seeks to ensure that NEVs appeal to the wants and needs of the targeted consumers. In addition to that, operational efficiency focuses on the reduction of cost, quality improvement as well as better customer satisfaction. Technological infrastructure and innovation, product development and operational efficiency strategy have a hybrid importance in ensuring the future of the NEV industry. It is in such areas that the industry plays several roles as it enables the evolution of automotive technologies, reduces pollution and makes the environment sustainable.

4. Conclusions and recommendations

The respondents generally agreed that technological innovation has played a crucial role in transforming the new energy vehicle in enhancing connectivity, personalization, and in-car tech features. The study revealed agreement that product development in the new energy vehicle (NEV) industry has demonstrated significant advancements in innovation, safety, and sustainability. The respondents generally agreed that the operational efficiency in the new energy vehicle (NEV) industry has significantly improved through advancements in data-driven operations, manufacturing efficiency, and service efficiency. There were high significant relationships between technological innovation, product development and operational efficiency. A synergistic framework for the new energy vehicle industry was developed.

To enhance user experience and in-car tech in NEVs, car manufacturers may look at the development of easy to use operational and personalized experience features, incorporating assistive technologies such as voice assistants and Advanced Driver Assistance Systems (ADAS), as well as ensuring the availability of good connectivity. To promote sustainability, production managers may focus on sustainable material sourcing, battery upcycling, and application of renewable sources of energy along with appropriate waste disposal solutions complemented by government subsidies. The production managers may utilize advanced techniques such as data-centric analytics, automating processes, employing lean manufacturing practices, using remote diagnostics, and customer relations management in the effort to enhance the operational efficiency of new energy vehicles. The synergistic framework may be adopted by the new energy vehicle industry with the emphasis on top management support, collaboration between functional units, and use of data-driven decision making, continuous improvement and external partnership. Future researchers may focus on the socioeconomic impacts of new energy vehicles, consumer behavior, emerging technologies, and global cooperation.

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