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A Conceptual Model for Integrating Sustainable Supply Chain, Electric Vehicles, and Renewable Energy Sources

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Abstract: The effects of climate change can be seen immediately in ecosystems. Recent events have resulted in a commitment to the Paris Agreement for the reduction of carbon emissions by a significant amount by the year 2030. Rapid urbanisation is taking place to provide room for an increasing number of people's residences. Increasing the size of a city and the number of people living there creates a daily need for consumable resources. In the areas of transportation, supply chains, and the utilisation of renewable energy sources, deliver on pledges that promote the accomplishment of the Sustainable Development Goals established by the United Nations. As a result, the supply chain needs to be handled effectively to meet the requirements of growing cities. Management of the supply chain should be in harmony with the environment; nevertheless, the question of how to manage a sustainable supply chain without having an impact on the environment is still mostly understood. The purpose of this study is to present a conceptual model that may be used to maintain a sustainable supply chain with electric vehicles in such a way that caters to both environmental concerns and human requirements. As part of the continual process of achieving sustainability, interrelationships between the various aspects that are being investigated, comprehended, and applied are provided by the model that was developed. It is self-evident that governmental and international organisations that are concerned with supply-demand side information will benefit from such a model, and these organisations will locate viable solutions in accordance with the model's recommendations. Beneficiaries consist of individuals who are active in the supply chain and are concerned with supply-demand side information. These individuals also need to understand how to effectively manage this information.

Keywords: COVID-19; electric vehicles (EVs); renewable energy sources (RESs); supply chain management (SCM); sustainable supply chain (SSC); sustainable development goals (SDGs)

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1. Introduction

The coronavirus pandemic, commonly referred to as COVID-19, is an event that has never before been seen. Since the beginning of its global onset in early 2020, it has been determined that there have been significant problems with SCM as a result of demands for certain goods and services that were beyond expectations. This conclusion was reached as a result of the fact that these demands were not met. Because of the constraints placed on movement and supply chains around the globe, the repercussions of these problems are significantly more severe. Therefore, as a result of these limits, it was fairly difficult to maintain normal operation of the supply chain process [1,2].

The downturn in global economic activity that occurred during COVID-19 had a substantial impact on the international vehicle market. According to a report by the IEA [3] nonetheless, sales of electric vehicles managed to more than quadruple to an all-time high

of 6.6 million in the year 2021. This is the result of regulatory regulations implemented by the government, which will ultimately lead to more sustainable forms of transportation. As a result, the path that leads to a change toward EVs as a component of the supply chain is not impossible to implement in the near future. The rate at which this transformation will be commercialised is totally dependent on the OEMs and how rapidly they will bring EVs on the road that are efficient, robust, and broadly accepted. This is especially relevant for the processes that start-up companies go through in their supplier chains. The authors of [4] gave a satisfactory description of the long-term solutions for electric vehicles (EVs) and their application in the process of supply chain management.

The term "renewable energy resources" refers to naturally replenishing sources of energy that have the potential to displace fossil fuels, such as coal, oil, natural gas, and nuclear power, in the generation of electricity. This allows for the production of electricity that is clean, safe, and reliable, with carbon emissions that are either minimal or non-existent. Renewable energy is a long-term strategic option that can limit the risks and cost consequences of fluctuations in the price of fossil fuels as well as changes in regulatory requirements [5,6]. Customers, partners, and workers who are interested in corporate responsibility are drawn to the company as a result, and the company's growth is driven by its ability to keep up with its rivals. It is necessary to do a comprehensive preliminary assessment of the practicability of renewable energy, considering the accessibility of resources and infrastructure, investment strategies, financial returns, and other secondary factors. There is a possibility that an increase in revenue will result from expanding the usage of renewable energy in supply chains. Consumers are increasingly opting to make their purchases from, and investments in, businesses that demonstrate more environmental and social responsibility [7]. A significant portion of today's supply networks still relies heavily on human labour. The argument in favour of using renewable energy sources is strengthened when considering a favourable influence on corporate talent. The supply chain for renewable energy consists of five stages: procurement, which refers to the acquisition of goods and services; generation, which refers to the production of energy; transmission, which refers to the transportation of energy; distribution, which refers to the distribution of energy from generation facilities to end-users; and demand, which refers to the consumption of energy at end-users.

Industrialization of cities in a sustainable and inclusive manner, also known as the "green" economy, can provide opportunities for the development of synergies, such as decoupling economic growth from environmental degradation and creating employment, while at the same time fostering innovations in clean energy. Over the course of the last few decades, corporations, and the SDGs of the United Nations have paid a lot of attention to the topic of sustainability in supply chain management. Incorporating the principles of SSCM into the SDGs will make it possible for business owners to design sophisticated and intricate SCM plans, which, in turn, will result in supply chains that are more reliable, effective, and environmentally friendly. Because of this synergistic effect, economic activity ought to grow [8].

To make the transportation of future supply chains more environmentally friendly and reduce the CO_2 emissions that are linked with our vehicles, we should be prepared to put new generations of vehicles, such as hybrids and electric vehicles, on the road. On the other hand, it has been observed that the field of sustainability is not only narrowly focused, but also extremely disregarded, particularly from an SSCM point of view. It is abundantly clear that there is an urgent need for research on various aspects of the three primary factors that will have a significant impact on the development of smart cities in the foreseeable future; these factors are a sustainable supply chain, electric vehicles, and renewable energy sources. In this investigation, we make a conscious effort to build a detailed road map in the form of a conceptual model that links all of the components that were discussed earlier. The presented model produces a critical, solutions-oriented approach to ensure that both SDGs and climate goals are explicitly weighted and studied. This method is provided as a result of the model's output.

The following is the structure of this paper: In Sections 2–4, respectively, we provide a concise explanation of the role that sustainable supply chains, electric vehicles, and renewable energy sources play in relation to a number of different characteristics. The proposed model that connects sustainable supply chains, electric vehicles, and renewable energy sources, as well as its implementation, is discussed in Section 5 of the report. The challenges that are associated with the proposed model are discussed in Section 6, along with a literature assessment of models that are already in use. In Section 7, a summary of the conclusions is presented.

2. Sustainable Supply Chain

A supply chain is considered to be sustainable if it completely incorporates ethical and ecologically responsible business practices into a model that is also effective and competitive. It is essential to have complete transparency throughout the entire process; sustainability activities need to reach from the sourcing of raw materials through the product returns and recycling operations [9,10]. At the same time, SCM has altered the strategy of innovation in the supply chain in enterprise businesses, which consequently produces green revolution on an ongoing basis [11–13]. This is due to the fact that it is supported by three primary pillars (refer to Figure 1), which are commonly referred to as structural dimensions [14]. These pillars are the economic, the environmental, and the social.

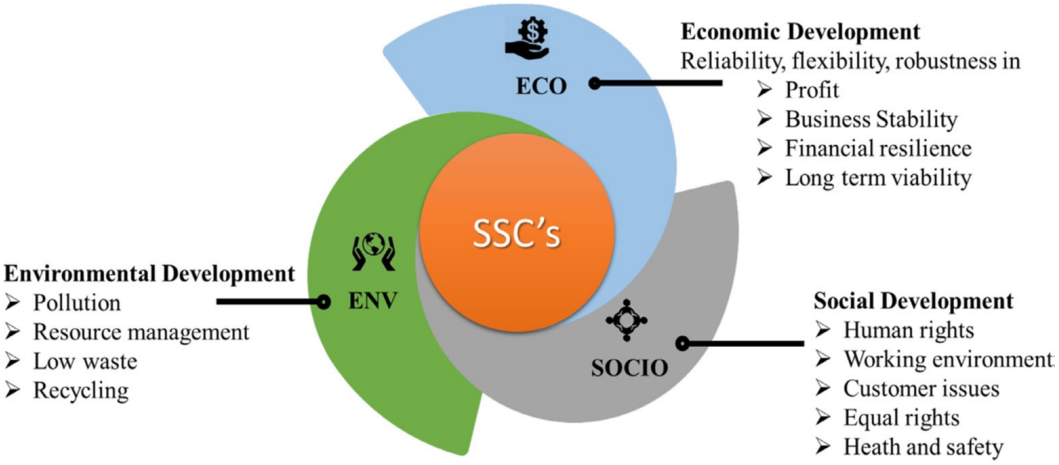

Figure 1. Structural dimensions of sustainable supply chains.

We have seen first-hand how the pandemic caused by the coronavirus had a detrimental effect on the global supply chain. Before the pandemic, the primary drivers for supply chain process improvements, digitalization, and investment were cost reduction and productivity increase. These drives are still very essential, but they have to fight with other difficulties because of the unparalleled disarray that COVID-19 generated. These factors have posed a danger to competitive positions in global markets and even the continued existence of many companies since they are unable to fulfil the requirements of their customers. The provision of a cleaner, more intelligent, and more environmentally friendly supply by SSC is a fundamental necessity from both the industry and humanity [14,15].

3. Electric Vehicles

It is common knowledge and readily apparent that the transportation industry alone is responsible for 27 percent of all greenhouse gas emissions [16]. If we want the cities of the future to have smarter, cleaner, and more accessible supply chains, we need to provide more inclusive mobility solutions than are currently available. The growing carbon footprint and other economic and environmental implications of vehicles powered by oil and gas have encouraged politicians to investigate EVs. As can be seen in Figure 2 [17], there are primarily four categories of EVs that are now on the market.

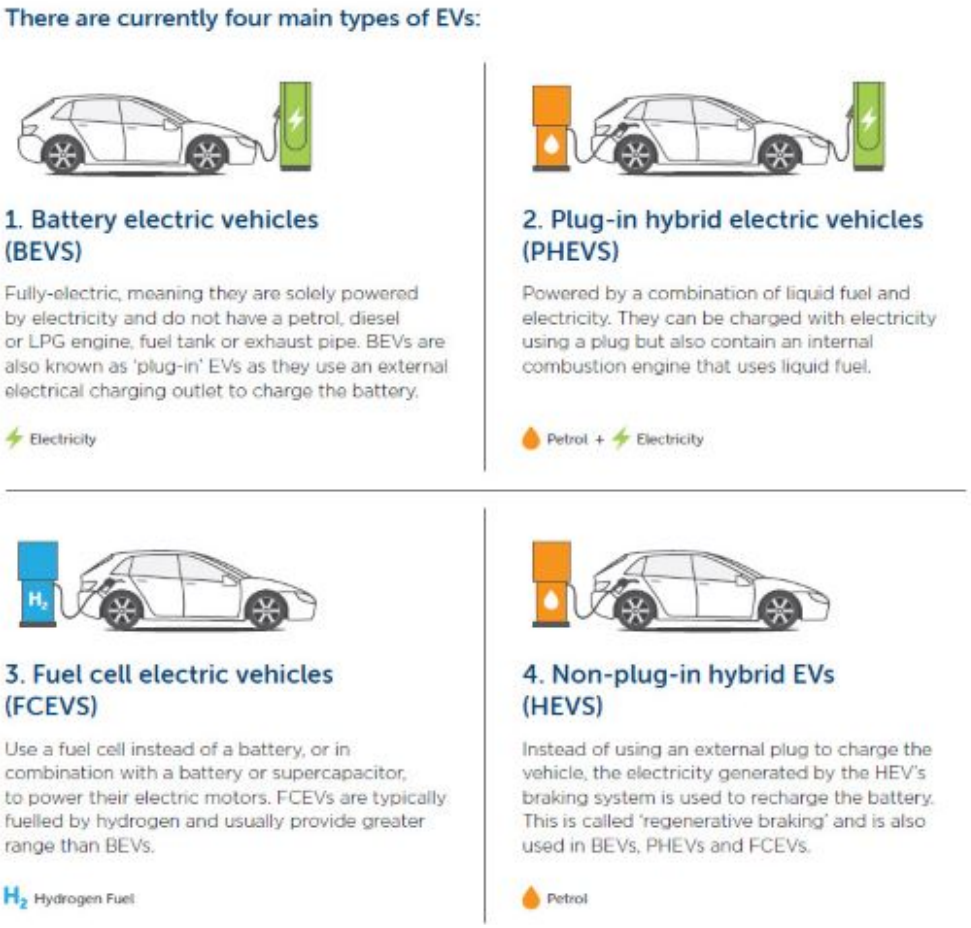

Figure 2. Descriptions of the four main types of EVs.

We envision electric vehicles as a component of the supply chain that not only has the potential to satisfy all of the requirements that humans have, but is also kind to the natural world. In addition, electric vehicles are able to integrate with the grid, which positions them as a more ideal agent for the promotion of sustainability [18]. As a result, there is a significant likelihood that electric vehicles (EVs) will be able to realise a profitable agent as a service business model in smart cities [19,20]. In addition, the use of electric vehicles is certain to lessen the amount of air pollution caused by greenhouse gas emissions while at the same time creating new employment prospects for locals [4,21]. This is a win-win situation.

4. Renewable Energy Sources

The renewable energy supply chain, often known as the RESC, is broken down into three distinct stages. The first is upstream, which refers to the beginning of the process; production refers to the physical generation of materials and energy; and downstream refers to the end-user or consumer, who uses the products that have been produced by the RESC as shown in Figure 3. Upstream refers to the beginning of the process; production refers to the physical generation of materials and energy, and downstream refers to the end-user or consumer [22].

To achieve the objectives that were outlined in the Paris Accord, countries all over the world have started putting into tangible measures for the accord's implementation. In order to meet these objectives on schedule, we need to make headway in the implementation of renewable energy sources, such as solar and wind power, not only in the transportation sector but also in other areas [23,24].

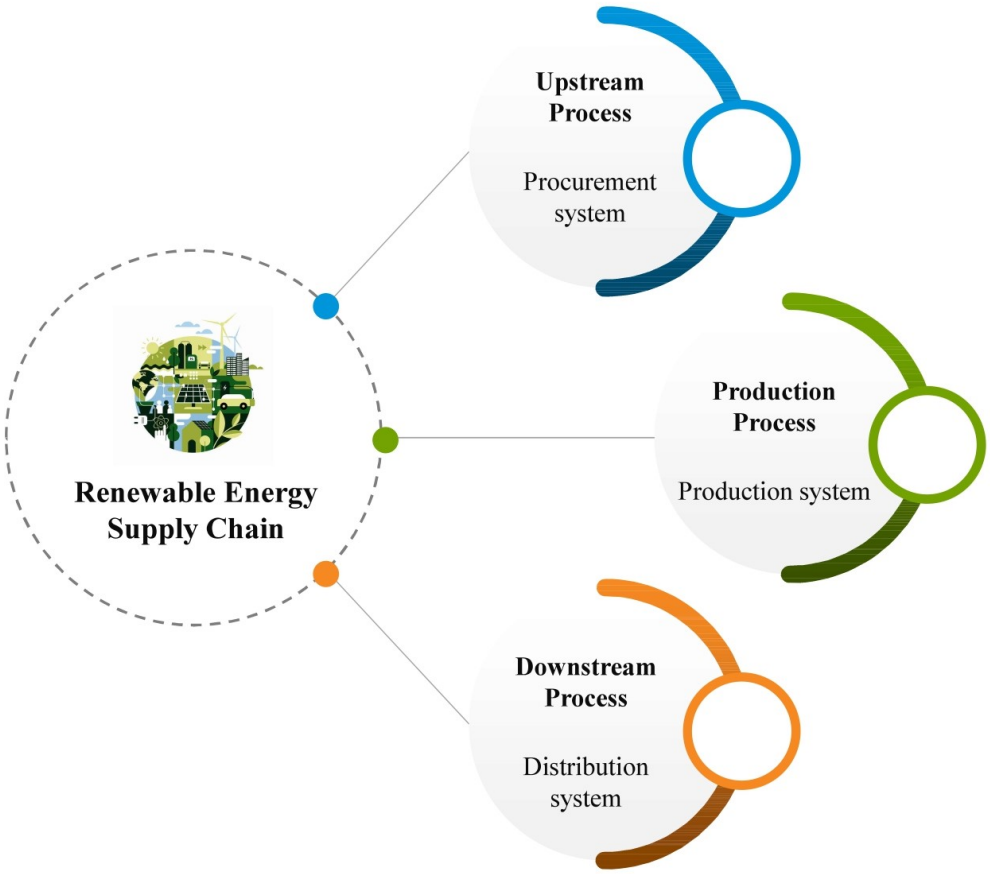

Figure 3. The automotive ecosystem for EV-dominated world.

5. Proposed Integrated Sustainable Supply Chain, Electric Vehicles, Renewable Energy Sources (SER) Model

Because it is linked with other aspects of the SSC process, such as production, market, sales, and purchasing, logistics is an essential and essential part of the process. There has been, and will continue to be, an ongoing requirement for standard protocols to handle supply-demand management. However, when there is a pandemic caused by the coronavirus, it is difficult to control the supply chain. Especially considering the limited travel restrictions that have been imposed in many regions of the world as well as the lack of conventional fossil fuels. The only viable answer is to implement EVs as a mode of freight transportation because of their ability to efficiently connect SSCs and RES. EVs have a number of benefits, some of which include the fact that they do not produce carbon dioxide emissions [25,26], accessibility because of the ease with which they can be charged at all points [27–29], tax and financial benefits from the government [30–33], and almost zero noise pollution [34,35].

According to a forecast published by the United Nations in 2019, there will be an additional 2.5 billion people living in the world by the year 2050; as a result, large cities will have a high population density [36]. Because of this, there will be an issue with the supply chain if we do not handle the demand and supply management of cities effectively enough. Therefore, the primary objective of keeping the supply-demand situations the same faces significant challenges in the form of two critical roadblocks, which are an unwelcome pandemic condition and a rising number of people living in metropolitan areas. A one-of-a-kind supply-demand channel that is equipped to handle even the most severe load changes and transients should be developed if the goals of satisfying the user requirements are to be attained (refer Figure 4).

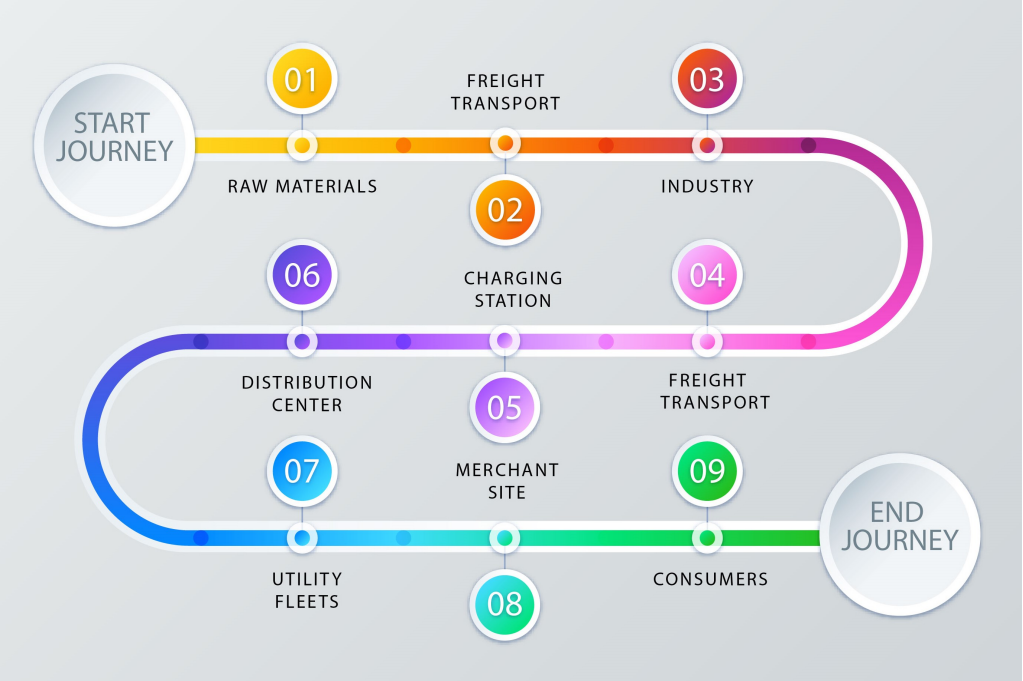

Figure 4. Sustainable supply chain module.

In light of this, the model that is being proposed will offer a workable solution (in addition to those that already exist, such as using SCM that is powered by fossil fuels) by employing EVs as freight transport [37,38] having benefits mentioned in Figure 5 and as per Figure 6 RESs as fuel for EVs [39,40], which will result in SSCM [41].

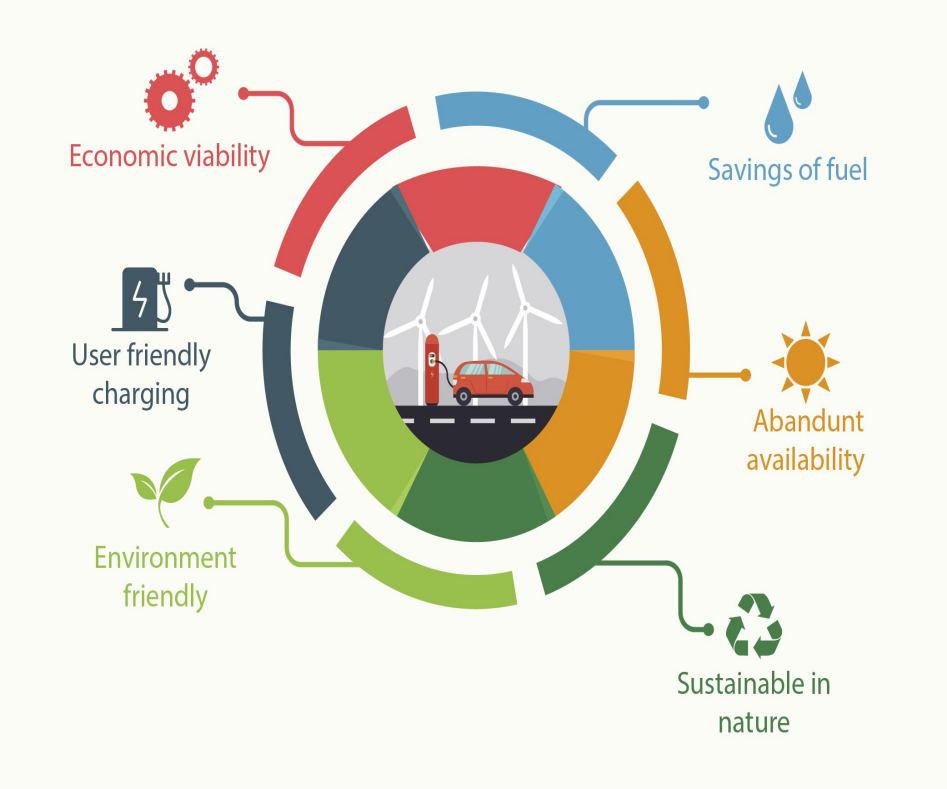

Figure 5. Electric vehicles module.

We offer a model that incorporates all crucial aspects connected to supply and demand to make them sustainable, and the Figure 7 for this SER model is presented below, which is

capable of meeting all of the requirements set forth from the point of view of the industry, the end-user, and the environment.

The following essential components were included in the model that was proposed:

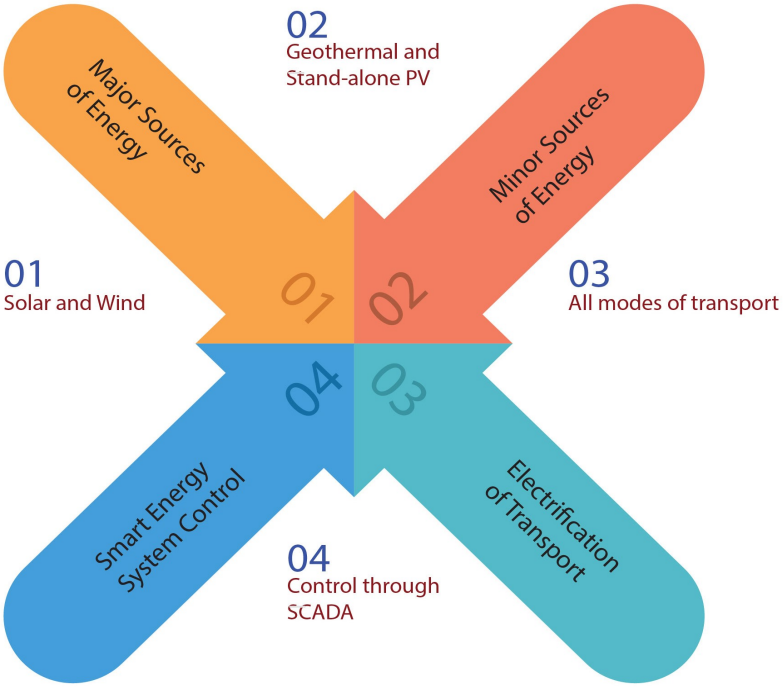

Figure 6. Renewable energy sources module.

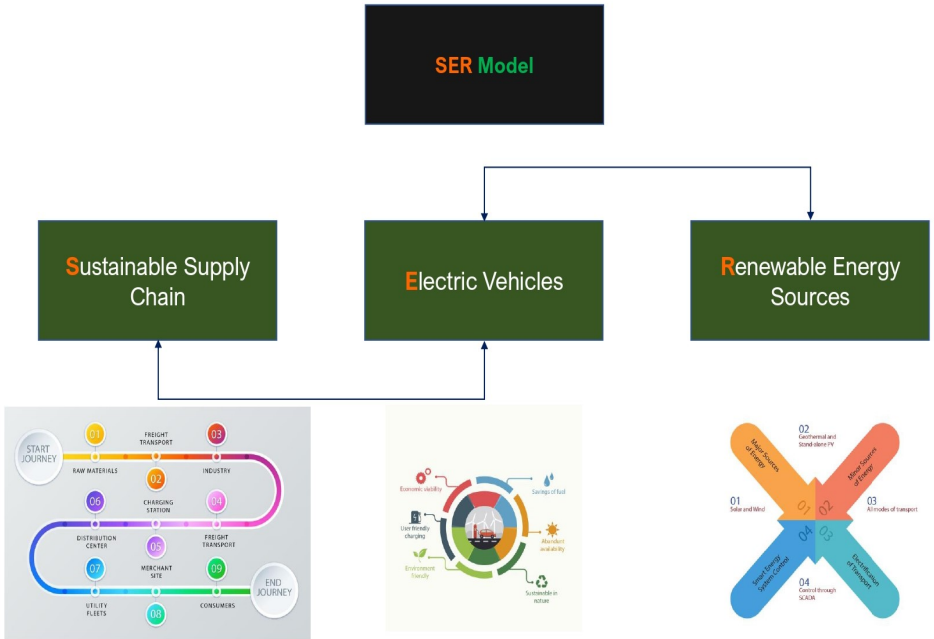

Figure 7. Proposed SER model.

5.1. RESs and EVs Synergy

Electric vehicles that are propelled by electricity do not produce any pollutants from their tailpipes. However, in order to receive credit for this positive impact on the environ-

ment, the electric power that was utilised to propel the vehicle must have originated from renewable sources such as the sun or the wind. Electric vehicles are the greatest alternative among other essential actors to increase grid stability while maintaining ease of flexibility because of the inherent synergy that exists between electric vehicles and renewable energy sources, which can help to facilitate their integration. Flexibility can come from either the supply or the demand side, and where it comes from is determined by a wide range of factors, including the preferences of customers and the policies of governments [42–47].

5.2. SSC and EVs

Because it has the potential to have a detrimental influence on the environment, traditional supply chain management is unable to adequately respond to the requirements of the existing partners [48]. It is essential for businesses to place a strong emphasis on their SCM in light of the fact that SMSEs are in charge of managing the flow of products from the early development stage up to the point where they are delivered to end customers [49]. The transition to electric vehicles has had significant repercussions for the automotive sector, and it is imperative that industry executives collaborate with governments and other businesses to promote environmentally responsible behaviour [50–52]. As a consequence of this, sustainable practises are now also applied to all of the actors in the supply chain, and electric vehicles play an essential role in all aspects, including design management, purchasing, transportation, warehousing, and packaging from raw materials to end-users [53–56].

5.3. DERs and EVs

An increase in the number of parties involved can be attributed to the growing interest in new types of distributed resources as well as a more decentralised electric grid. Customers in both the industrial and residential sectors have relied on these businesses for many years to install such systems in the distribution networks that serve them. Consequently, in order to meet the ever-increasing volumes of supply-demand criteria, DERs are playing a significant role since they provide reliability for the grid. In the same vein, we can charge EVs by utilising DERs, which will result in price reductions for customers of the charging service [57–61].

5.4. Social Sustainability

An expanding topic of research in sustainable development is the investigation of electric vehicles and how people think of them, as well as the effects they have on society and how people utilise them. It is possible to gain insight into both the current and future paths of research of this kind [62]. Nevertheless, people currently live in the 21st century, and environmental sustainability has always been and will continue to be a crucial factor for businesses to consider when integrating environmentally friendly technologies into their supply chain procedures. EVs have the potential to help make environmentally friendly modes of personal mobility more widely available and enable more environmentally friendly travel [63]. As a result, there is undeniable evidence that EVs have an effect on the social changes that consumers experience. The widespread adoption of EVs [64], the timings for charging facilities, which influence users' daily routines [27,65], and other factors are among the many things that have occurred as a result of the widespread adoption of EVs. As a result of the extensive adoption of electric vehicles, changes in land use for individual or standalone sources of renewable energy since they are utilised as fuel [66,67].

5.5. Freight Transportation

EVs do not produce any exhaust emissions, which means they do not contribute to poor air quality. Even when the manufacturing process is considered, these types of engines produce 15 to 40% less CO_2 than their internal combustion engine equivalents, reduce greenhouse gas emissions by 71%, and have roughly 28% lower operating costs [68]. The complete electrification of municipal supply fleets can be accomplished over a longer

period of time due to the support of competitive economics and existing technology [69,70]. This will generate tailwinds for the various market segments that will follow. There must be significant changes made throughout the entire ecosystem to increase the use of EVs as a mode of freight transportation [71]. The objective is to facilitate a quicker transition to environmentally friendly technology within the sector to reduce emissions and simultaneously leverage the volumes to allow the established order of a charging infrastructure and seller base for electric vehicles across all different types of automobile categories [21].

5.6. Maximum Usages of RESs

A rising economic system that is predominantly based fully on a green and green delivery system; despite this, climate change, pollution, congestion, and safety issues reduce the value of this. There is a lot of evidence that reducing greenhouse gas emissions from the power sector and helping to fight climate change can be accomplished by producing electricity using RESs rather than traditional fossil fuels [72]. As a result of concerns about climate change during the past few decades, eventually societies have adopted electric vehicles while simultaneously increasing their utilisation of renewable energy sources [73]. The most important question is how we may employ RESs in such a way as to produce the most amount of power, and in order to answer this question, the following principles [74–76] play a crucial role: I what kinds of renewable energy sources are accessible, and how may their operations be optimised? (i) I have a question on the cost of installation for RESs, specifically at freestanding locations. (ii) what kinds of engineering and technological adjustments were made to guarantee the highest possible utilisation of RESs?

5.7. GHG Emissions

Multinational corporations typically begin the process of implementing and adopting new technology concurrently with their efforts to reduce their carbon footprints. This covers businesses that power their buildings with solar energy or other forms of renewable energy and give their employees access to transportation in EVs. However, the vast majority of them look beyond the constraints, and they have devised a strategy for managing their production and distribution cycle while imbuing it with a sense of sustainability. It will be highly advised that key businesses such as the automotive industry, fast-moving consumer products, and freight transport equip themselves with EVs to accomplish the goal that was determined by the Paris Accord [77,78].

6. Discussion

A well-executed conceptual model will effectively and concisely portray the core concepts and aspects of a given problem space. The SER model was created to help achieve the UN Sustainable Development Goals and cut down on pollution from freight vehicles. The SER model places the most emphasis on the service system model. Users value the flexibility offered by the proposed paradigm, which allows them to utilise RESs in multiple ways. This allows users across the ecosystem to participate in shaping its evolution toward greater transparency and accessibility. In recent times, a variety of business models have been shown to exhibit a variety of uses, such as sustainable shared mobility using CANVAS [79,80], limited utilisation of renewable energy to ensure net-zero carbon supply [81], etc., amongst other applications. A confirmatory factor analysis model technique was used in the research for the case study of the eastern economic corridor in Thailand that was published in [82]. This particular focus of the research was on port and maritime freight transit. Although extensive research on the topic of service quality in maritime transport was conducted over a decade ago [83], the focus of that research was on only six main dimensions: resources, image, management, process, and social responsibility.

The basic model for a transportation and logistics observatory was defined in [84]. This model has been centred on the planning of resources, the gathering of information, and the monitoring of transport based on decisions taken according to the information

gathered. In the realm of smart cities, the conceptual model that comprises the integration of freight transport and urban transport development planning to create sustainable transport was provided in [85]. This was done to achieve the goal of having sustainable transport. In addition, the performance of a road-transport model that can improve the control of logistics and supply chain has been addressed in [86]. This model can do this by improving its ability to move goods. Making the net-zero transport transition through socioeconomic, regulatory, and political considerations has recently been well examined, albeit with a restricted supply of information and as a case study of Mahesana city in India [87].

Regardless of all the models that are already available, the core of "sustainable" is still lacking in that it is not possible to provide SSCs utilising just electric vehicles that are powered solely by renewable energy sources. By doing so, we will be able to realise the SDGs outlined in the UN charter and live up to the obligations of the Paris Accord. The model that is currently being provided has all of these characteristics, and as a result, it is the best model among those that have been presented to date, in terms of providing a holistic perspective, not only from the point of view of customers, but also from the point of view of the environment.

In spite of the many advantages offered by the model that has been provided, there are still a lot of challenges to beat before it can be implemented in a demand-supply chain. These include charging infrastructure facilities for electric vehicles; battery life issues for nationwide freight transport; adoption of EVs by SMSEs; recycling policy for batteries to make them sustainable; what kind of tax benefits the local and central authorities provide to companies to influence them to use EVs as a key transport handler; cost to produce RESs as they are the main fuel suppliers to EVs; availability of RESs on proper locations and land acquisition; and availability of RESs on proper locations and land acquis.

7. Conclusions

To be able to deal with the United Nations' Sustainable Development Goals, it is highly suggested that the supply chain should be sustainable in terms of reducing emissions of greenhouse gases. This recommendation comes from the UN. The current idea makes additional contributions to the supply chain by utilising electric vehicles as a key facilitator for freight transport and linking to renewable energy sources through supply chain connectors. This contributes additional inputs to the supply chain. Because it is powered by renewable energy sources, the concept itself is novel. As a result, it will help to reduce the amount of pollution that is created by freight vehicles. In the interim, it will keep the grid stable by utilising RESs as fuel for EVs, and when it is not being used for that purpose, it can be used for other things. When there is a wide selection of automobiles available for purchase, customers will have the opportunity to select from a wide range of electric vehicles in which to move their belongings. As a direct consequence of this, they will at long last be granted their freedom.

To make the model more robust in terms of its operation, additional research should be carried out; in particular, the requirements of the industry and end-users should be taken into consideration. More research should be focused on understanding drivers' acceptability of EVs as regular freight vehicles, how they feel in the case of range anxiety, users' daily behaviour after using EVs, what kind of other players to be included or interested in boosting up the smooth operative freight transportation, the role of regulatory authorities in tax benefits, what kind of socio-economic growth/challenges ahead of, and what about payback period for EVs that have been used are among the topics that should be researched. As a consequence of this, further investigation through interviews with individuals from supply chain and renewable energy producers who are highly motivated to know their present challenges. In conclusion, the model will be validated by empirical research in the context of user advocacy by gaining an understanding of the issues that users have regarding the process of preserving sustainability in supply chains.

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Data Availability Statement: There are no extra resources available for download because the model relies on conceptualization rather than empirical data. Despite this, researchers looking for the appropriate project page can access it at https://www.majorankit.com (accessed on 16 September 2022).

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

SCM	Supply Chain Management
EVs	Electric Vehicles
RESs	Renewable Energy Sources
SC	Supply Chain
SSC	Sustainable Supply Chain
SDGs	Sustainable Development Goals
OEMs	Original Equipment Manufacturers
SSCM	Sustainable Supply Chain Management
GHG	Greenhouse Gas
RESC	Renewable Energy Supply Chain
DERs	Distributed Energy Resources
SMSEs	Small and Medium-Sized Enterprises
MNCs	Multi-National Companies
IEA	International Energy Agency

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