

# The Development of the Hybrid Electric Vehicle Market by the Use of Interpretive Structural Modelling

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## Abstract

The last few years have seen the automobile industry grow at its fastest rate ever thanks to groundbreaking advancements in information technology and higher living standards brought about by Bangladeshi people. Naturally, the burgeoning market places a great deal of strain on the available non-renewable resources, such as fossil fuels, natural gas, and crude oil. If an alternative doesn't emerge to alleviate the current crisis, the supply and demand are beyond the breakeven point, and things could get worse. One of the other options for resolving the crisis is the hybrid electric vehicle (HEV). However, in Bangladesh, the HEV market is still in its infancy as compared to other developed and developing nations. The market for hybrid electric vehicles is expanding in Bangladesh due to a number of factors. With the aid of an Interpretive Structural Model (ISM), the current study examines the most important variables for the growth and promotion of the HEV market in Bangladesh.

## 1. Introduction

The motorization curve has been moving up very quickly in the last ten years. Consequently, all major metropolitan cities and towns experience worsening air quality and urban traffic congestion. The transport sector in Bangladesh accounted for about 18% of CO<sub>2</sub> emissions. In Bangladesh, fossil fuel-based vehicle technology is prevalent. If an alternative does not emerge to alleviate the current crisis, the supply and demand are beyond the breakeven point, and things could get worse. Bangladesh is becoming more and more dependent on other nations to manage its economy as a result of importing roughly 70% of its petroleum needs, which could either directly or indirectly impede the progress of the nation [1]. The Bangladesh government is working to improve vehicle technology that runs on alternative fuels. One of the alternate ways to get out of the crisis is the hybrid electric vehicle (HEV). A comprehensive assessment of the various socioeconomic and environmental factors that may impact the adoption of new vehicle technology is necessary. It is necessary to conduct a thorough debriefing and analysis. In comparison to other developed and emerging nations, the survey report reveals that the HEV market of Bangladesh is still in its infancy [2]. The growth of the hybrid electric vehicle market in Bangladesh is influenced by a multitude of factors and barriers [2,3,4,5]. The current paper aims to bridge the research gap by identifying and categorizing the obstacles to the growth of the electric vehicle market in Bangladesh, taking into account the factors that drive and rely on these barriers building an Interpretive Structural Model (ISM) around these obstacles. One of the common methods for ranking the obstacles according to a specified issue is the Integrated Systems Method. The obstacles must be removed in order for Bangladesh market for Hybrid electric vehicles to

grow. The following section discusses the key obstacles that were discovered through repeated analysis and observations.

### 1.1 Battery Technology

As is common knowledge, the battery that powers an electric car needs to be recharged on a regular basis. Worldwide usage of Lithium-ion batteries (Li-ion) is currently prevalent, however there are a number of drawbacks, including range of travel, charging stations and battery life [6]. For instance, Mahindra Reva, regarded as the pioneer of electric car manufacturing in India, produces the REVAi model, which can travel up to 80 km (without air conditioning) and 80 km/h on a single charge [7]. The model's shortcomings include its two-seat capacity and the fact that it is completely impractical for a customer to travel more than 80 kilometers without stopping to charge along the way.

Many other foreign businesses have not yet surfaced, but they have promised to release their more efficient models than Reva [1]. It is undoubtedly necessary to recharge the car while travelling long distances. Just as there are petrol stations on the roads for cars, there can be developed a similar idea for charging hybrid electric vehicles. A battery exchange station, where a discharged battery is swapped out for a charged one via an automated mechanism, is what some private companies suggested. Installing charging stations, particularly in parking lots, could be an additional option to allow for battery recharging whenever a car is parked. As was mentioned in the Germany case study, the fast charging infrastructure is subject to severe discrimination on reduced profits [6]. In other regions of the world, a comparable circumstance occurs. The battery's disposal is yet another major issue. There is an international issue here, and efforts are being made to find a secure way to get rid of the batteries.

### 1.2 Supplier Management

The sales of hybrid electric cars in Bangladesh will be a clear indicator of the public's mistrust. Indeed, in a down economy, it will be more difficult to find a supplier in a city. There will be fewer suppliers as well. Suppliers should be given government incentives to promote the sale of electric vehicles, as opposed to sales of fuel-powered vehicles [1,8].

### 1.3 Customer Service

It is essential to maintain and accelerate the growth of the hybrid electric vehicle concept rather than just introducing it to the market. In order to facilitate repairs and maintenance of hybrid electric vehicles, service stations should be set up similarly to those for regular gasoline-powered cars. Additionally, authorized service facilities tailored to electric car ownership can be established. In a hybrid electric vehicle, repairs to the electric motor, battery, and other components are primary. The government of Bangladesh enacted a regulation mandating a one-year guarantee for electric batteries, regardless of the car manufacturer [9].

### 1.4 Financial Constraints

One of the main obstacles to the growth of Bangladesh's hybrid electric vehicle industry is the lack of available funds. The government of Bangladesh would have a difficult task in allocating funds specifically for the green revolution. The financial budget appears to be detrimental to Bangladesh's hybrid electric vehicle industry, according to news from a major news source. The price of a car will increase by 1% due to the increase in the basic excise duty from 5% to 6% and the increase in the excise on parts from 10% to 12%. Although there is no customs duty on lithium batteries, their cost will increase as a result of the 5% increase in countervailing duty to 6%.

### 1.5 Awareness on Electric Vehicles

According to a recent Economics Times survey, almost 75% of respondents said they would like to purchase green products. They were asked if they had recently purchased any environmentally friendly products after the question was slightly changed. Given that the poll results had been inverted, it was strange [10]. The results of the poll represent everyone on the planet, but particularly Bangladesh. People are not sure if they should purchase green products or not. This conundrum is crucial to the expansion of the sector. It demonstrates the important role the government must play in raising public awareness of any new issue.

### 1.6 Industry Growth

All of this should eventually add up to the industry's expansion of hybrid electric vehicles. As was previously mentioned, growth up until 2011 was dismal and will soon pick up speed [1]. When the idea starts to gain traction, it should not stop and should instead pick up speed. As the spark ignites the market, certain standards should be developed concurrently to prevent a potential market implosion [11, 12].

## 1.7 Research and Development

Worldwide, research and development are continuously underway, with a particular focus on creating better batteries for hybrid electric vehicles. Customers are dissatisfied with average electric battery performance, which makes the electric vehicle battery one of the most important research topics. Two of this field's most closely examined challenges are range and recharge time. In an effort to develop a better battery, research is being done on Li-Air batteries, which IBM has stated can have a range of 800 km between charges [13]. The issues raised here mirror the state of the world. In the Bangladeshi context, the average daily mileage of a passenger car is roughly 35 km [12]. The development of domestic hybrid electrical vehicle batteries should be the main focus of research in Bangladesh.

## 1.8 Training

Every customer using this technology needs to be trained. The staff members should also receive training on handling technology. To avoid frequent malfunctions, technology should always be used carefully and with great ease. Businesses should also ensure that their staff members are trained to handle any issues that may arise from clients. Employees should receive training as well in order to conduct R&D in a new capacity and for a better future [2, 5].

## 1.9 Government Commitment

By 2030, the government of Bangladesh wants to cut 3.4 million tons of carbon emissions from the transportation sector. This means that at least 30% of the nation's cars must be electric. Still, the government has not finished building the EV infrastructure. The electric car tax rate and the Electric Motor car Registration and Operation Guidelines 2023 have been finalized by the Bangladesh Road Transport Authority (BRTA). As per these regulations, all kinds of electric cars would be registered under the E or EV classifications. For electric vehicles to be driven on public highways, they will need a route permission, fitness certificate, tax token, and registration, much like combustion engine vehicles. The vehicle's motor capacity (kW) will, nevertheless, determine the registration cost. The annual tax on electric vehicles in Bangladesh is set at 1 kW every 20 cc, following the policy (Table 1). However, Bangladesh has not yet finalized the tariff structure for the import of electric vehicles.

**Table 1** Motor tax rate

S/L No	Engine or Motor Capacity	Taka
1.	Up to 1500 or 75kw	25,000
2.	1500 – 2000 or 75-100kw	50,000
3.	2000 – 2500 or 100-125kw	75,000
4.	2500 – 3000 or 125-150kw	1,25,000
5.	3000 – 3500 or 150-175kw	1,50,000
6.	Above 3500 or 175kw	2,00,000

The current range of the overall tax and tariff incidence on imported electric vehicles is 85–96 percent. For instance, the Audi e-Tron EV's base model costs between \$70,000 and \$72,000. The starting price of this car in Bangladesh is Tk 1.59 crore. The overall tax incidence on this car is approximately 95% when the dollar exchange rate and several taxes such as regulatory duties, customs duties, VAT, and advance income tax are taken into account.

Audi installed the nation's first electric vehicle charging station at Tejgaon, Dhaka, in January 2023. Here, you may charge any kind of electric car. There are currently no further EV charging stations accessible in Bangladesh except from this one. The government has already completed its strategy regarding the installation of charging stations, which includes plans for both new charging stations and facilities for recycling batteries. Private groups are also permitted, subject to regulation, to install charging stations in addition to governmental entities. Nonetheless, home charging unit installation assistance is offered by certified EV dealers and importers. Fully charged electric vehicles can often cover 300 kilometres on a single charge. Savar, Gazipur, Narayanganj, and Munshiganj are 20–50 kilometers away from Dhaka, which is the sixth-largest metropolis in the world at 306 square kilometres. Because of Dhaka's traffic, most fully charged EVs may operate for three to four days on a single charge during typical journeys within these areas. This indicates that Dhaka is ready for consumers to begin routinely using EVs.

## 2. Methodology

The interpretive nature of ISM stems from the group's decision-making regarding the interconnections between the system's elements. It is structural since the relationship serves as the basis for it, and the intricate collection of system variables is used to create the final structure. Numerous researchers have previously employed the ISM approach to illustrate relationships and hierarchical links [15, 16, 17, and 18]. The final relationship is depicted in a directed graphical model, so it is also modelling. The subsequent subsections provide a breakdown of the various stages that were involved in the creation of the ISM model.

## 3. Result and Discussion

### 3.1 Structural Self-Interaction Matrix (SSIM)

It is necessary to identify the interdependencies among the barriers. To get their thoughts, we held a brainstorming session and conferred with four academicians. The four were compared, and SSIM employed the best fit. The relationships between all the barriers are generally indicated by the four alphabets V, A, X, and O. The table displays the SSIM for each interdependency.

**Table 2** Structural Self-Interaction Matrix (SSIM) for each interdependency

S N	BARRIERS	Barriers							
		2	3	4	5	6	7	8	9
1	Consciousness	W	W	W	W	W	W	W	W
2	Governmental Assist		W	W	W	0	W	W	W
3	Purchasing Administration			1	1	1	0	W	1
4	Client Support				1	1	B	W	1
5	Money Restraints					W	W	W	W
6	R&D						W	W	1
7	Battery Application Technology						W	W	B
8	Sector Development								B
9	Instruction								

When any two obstacles, i and j, are present

- V: Barriers i will assist in achieving j
- A: i shall attain barriers j.
- X: Barrier i and j will support one another's success.
- O: Barriers i and j do not connect.

### 3.2 The First Matrix of Reachability

By replacing V, A, X, and O with 1 and 0, respectively, according to the situation, the SSIM has been transformed into a binary matrix known as the Initial reachability matrix. The initial reachability matrix is as shown in **Table 3**. The following is an example of how to substitute 2s with 1s:

- In the reachability matrix, the (i, j)th entry becomes 2 and the (j, i)th entry becomes 1 if the (i, j)th entry in the SSIM is V.
- The reachability matrix's (i, j)th entry becomes 1 and the (j, i)th entry becomes 2 if the (i, j)th entry in the SSIM is B.
- The reachability matrix's (i, j)th entry and the (j, i)th entry both become two if the (i, j)th item in the SSIM is X.
- If the (i, j)th entry in the SSIM is 1, the (i, j)th entry in the reachability matrix becomes 1 and the (j, i)th entry also becomes 1.

**Table 3** Initial reachability matrix

S N	BARRIERS	Barriers								
		1	2	3	4	5	6	7	8	9
1	Consciousness	2	2	2	2	2	2	2	2	2
2	Governmental Assist	1	2	2	2	2	1	2	2	2
3	Purchasing Administration	1	1	2	1	1	1	1	2	1
4	Client Support	1	1	1	2	1	1	1	2	1
5	Money Restraints	1	1	1	1	2	2	2	2	2
6	R&D	1	1	1	1	1	2	2	2	1
7	Battery Application Technology	1	1	1	2	1	1	2	2	1
8	Sector Development	1	1	1	1	1	1	1	2	1
9	Instruction	1	1	1	1	1	1	2	2	2

### 3.3 Final Reachability Matrix

We determine the driving force and dependence for every barrier from the initial reachability matrix, as indicated in Table 3, for the final reachability matrix  $[aij]_{9 \times 9}$ . The total number of barriers (including the barrier itself) that the particular barrier may help achieve is its driving power. The dependence is the sum of all the obstacles that could prevent it from being accomplished.

For instance: As for Barrier 1,

$$\text{Driving power} = \sum_{j=2}^9 a_{2j} \quad (1)$$

$$\text{Dependence} = \sum_{i=2}^9 a_{i2} \quad (2)$$

**Table 4** Final reachability matrix

S N	BARRIERS	Barriers									Driving Power
		1	2	3	4	5	6	7	8	9	
1	Consciousness	2	2	2	2	2	2	2	2	2	9
	Governmental Assist	1	2	2	2	2		2	2	2	7
2						0					
3	Purchasing Administration	1	1	2	1	1	1	1	2	1	2
4	Client Support	1	1	1	2	1	1	1	2	1	2
5	Money Restraints	1	1	1	1	2	2	2	2	2	5
6	R&D	1	1	1	1	1	2	2	2	1	3
7	Battery Application Technology	1	1	1	2	1	1	2	2	1	3
8	Sector Development	1	1	1	1	1	1	0	2	1	1
9	Instruction	1	1	1	1	1	1	2	2	2	3
	<b>Dependence</b>	1	2	3	4	3	3	6	9	4	

### 3.4 Level Identification

The reachability and antecedent sets for every barrier are obtained from the final reachability set. The element itself and other elements that could aid in its achievement make up the reachability set, while the element itself and other elements that could aid in its achievement make up the antecedent set. As indicated in Table 4, the intersection of these two sets is referred to as the intersection set for every barrier. The table's uppermost barrier won't assist in getting any element above their current level. The top-level element is distinguished from the other elements once it has been located. Next, the next level barrier is ascertained using the same methodology. Until the level of each barrier is established, the procedure is repeated. The ISM model for the Indian market for hybrid electric vehicles is built using the  $j = 2$  levels.

### 3.5 ISM Modeling

The final graphical model is created as indicated in Figure 1 using the final reachability matrix. The barrier labelled "Industry growth" is at the top of the model because it cannot be overcome by any other barrier. The barriers labelled "Supplier Management" and "Customer Service" are at the second level and can be overcome by other barriers; the results also indicate that these two barriers do in fact assist each other in achieving the top barrier. On the third iteration, the barrier labelled "Battery Technology" was our top barrier, which can be overcome by barriers labelled "R&D" and "Training." Research and training activities can only be accomplished when financial constraints are addressed, and the government should provide the necessary funds. People's awareness can exert pressure on the government to provide funding for training and research and development initiatives.

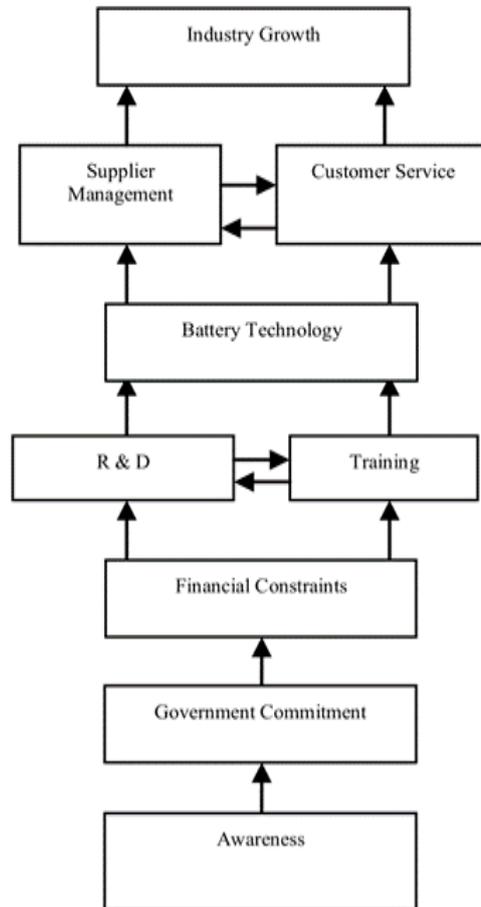


Fig. 1 ISM model

### 3.6 MICMAC Analysis

The driving force and dependence of each barrier are ascertained through the application of MICMAC analysis. The four quadrants of the driver-dependency diagram are occupied by the x- and y-axes, respectively, by driving power and dependence. Based on their driving force and dependence, each barrier is plotted on this diagram; the plot is displayed in Figure 2 and detailed in Table 5.

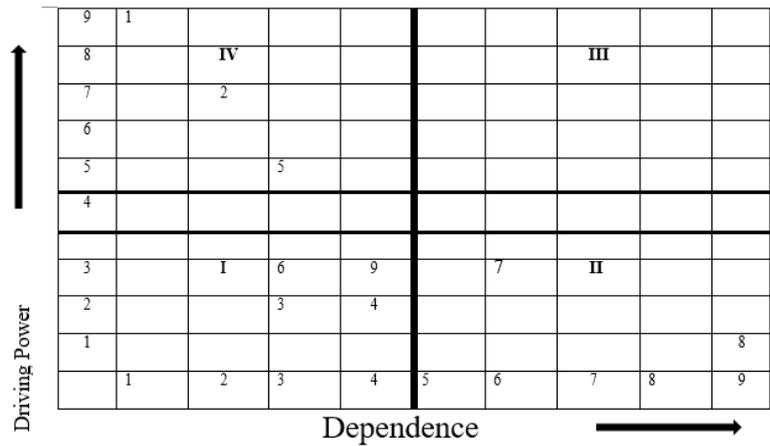


Fig. 2 Driver-dependency diagram

Table 5 MIMAC analysis

Replicate	Breakdown	Ability to Reach	Precursor Set	Intersection Set	Level
8	1	1,2,3,4,5,6,7,8,9	1	1	VIII
7	2	2,3,4,5,7,8,9	1,2	2	VII
3	3	3,8	1,2,3	3	III
3	4	4,8	1,2,4,7	4	III
4	5	5,6,7,8,9	1,2,5	5	IV
5	6	6,7,8	1,5,6	6	V
3	7	4,7,8	1,2,5,6,7,9	7	III
1	8	8	1,2,3,4,5,6,7,8,9	8	I
4	9	7,8,9	1,2,5,9	9	IV

- The barriers in Quadrant I have low (0 to 4) dependency and driving power. These barriers have few, sometimes very strong, links to other barriers and frequently have no relationship at all. They also go by the name of autonomous barriers.
- The barriers in Quadrant II have weak driving power (0 to 4) and strong dependency (5 to 9). Dependent barriers are another name for them.

There are no any barriers in Quadrant III. Barriers with strong (5 to 9) driving power and weak (0 to 4) dependency are found in Quadrant IV. They're frequently called independent barriers. They rely less on other people and possess a strong sense of drive. It should be possible for us to determine which barriers need to be removed first. Since the barriers in quadrant II are highly dependent on each other, it is advised to address them first, and those in quadrant IV last. Analysis of battery technology advancement and industry expansion can be conducted once the market is off to a strong start. The primary goal of this modelling is to establish an Bangladeshi assistance programme to mitigate global pollution. The human race will always aspire to a better day in the future.

#### 4. Conclusion

The current work uses the ISM approach to identify and rank the barriers based on their dependencies and driving forces. Raising awareness among Bangladeshi citizens is essential, in addition to the government's commitment. To start the market sales, the financial constraints must also be resolved appropriately.

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#### Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Md. Yousup Ali, Md. Samidul Islam Samid, Mohammad Minto Molla, Faridul Islam, Md. Ziaur Rahman; **data collection:** Md. Yousup Ali, Md. Samidul Islam Samid, Mohammad Minto Molla, Faridul Islam, Md. Ziaur Rahman; **analysis and interpretation of results:** Md. Yousup Ali, Md. Samidul Islam Samid, Mohammad Minto Molla, Faridul Islam, Md. Ziaur Rahman; **draft manuscript preparation:** Md. Yousup Ali, Md. Samidul Islam Samid, Mohammad Minto Molla, Faridul Islam, Md. Ziaur Rahman.. All authors reviewed the results and approved the final version of the manuscript.

## References

- [1] Ganneri Giridhar and A. K. Digalwar (2011) *Sustainability Issues and Challenges in Automobile Industry: An Indian Perspective* in Proceedings of the International Conference on Sustainable Manufacturing: Issues, Trends and Practices, ICSM 2011, BITS Pilani, India, pp. 392-396.
- [2] Ganneri Giridhar and A. K. Digalwar (2012) *Road Map for the Growth of Electric Vehicles Market in India* in Proceedings of the Conference on Technological Advancements in Chemical and Environmental Engineering, TACEE 2012, BITS Pilani, India, pp. 7.
- [3] Bloomberg (April 2011), China to Overtake US in Electric Vehicles Sales in 2020, Consultant Says. Retrieved from: <http://www.bloomberg.com/news/2011-04-20/china-to-overtake-u-s-in-electric-vehicles-sales-in-2020-consultantsays.html>
- [4] Simon Shepherd, Peter Bonsall, Gillian Harrison (2012) Factors affecting future demand for electric vehicles: A model based study, *Transport Policy*, 20(1), 62-74.
- [5] Sandy C.E. Thomas (2012) How green are electric vehicles? *International Journal of Hydrogen Energy*, 30, 1-10.
- [6] Claas Hoyer, Karsten Kieckhäfer, Thomas S. Spengler (2011). *A Strategic Framework for the design of Recycling Networks for Lithium-Ion Batteries from Electric Vehicles, Glocalized Solutions for Sustainability in Manufacturing*, Proceedings of the 18th CIRP International Conference on Life Cycle Engineering, Springer p.79-84
- [7] Mahindra Reva (2012), REVAi, Retrieved from: <http://www.petrofreeworld.com/revai.php>
- [8] Jens Hölscher, Enrico Marelli and Marcello Signorelli (2010), China and India in the global economy, *Economic Systems* 34 (1), 212-217
- [9] Society of Manufacturers of Electric Vehicles (2012) Subsidy Announced for Electric Vehicles, Retrieved from: <http://www.smev.in/download/MNRE%20Subsidy%20Announced%20for%20Electric%20Vehicles.pdf>
- [10] The Economic Times, March 16, 2012: <http://economictimes.indiatimes.com/news/news-byindustry/auto/automobiles/budget-2012-is-disappointing-for-theelectric-vehicle-industry-says-chetan-maini-mahindrareva/articleshow/12295581.cms> (Accessed on March 25, 2012)
- [11] Jie Zheng, Shomik Mehndiratta, Jessica Y. Guo and Zhi Liu (2012). Strategic policies and demonstration program of electric vehicle in China, *Transport Policy*, 19, 17-25.
- [12] B. Jana, P. Roy, M. Majumder, and A. Mazumdar (2008) A Review on GHG Emission as CO<sup>2</sup> equivalent from Transport System in view of Advanced Vehicular Technology and Improved Fuel Quality, *Philica*, 131
- [13] IBM (2022), The Battery 500 Project, Retrieved from [http://www.ibm.com/smarterplanet/us/en/smart\\_grid/article/battery500.html?lnk=ibmhpcs2/smarter\\_planet/energy/article/battery\\_500](http://www.ibm.com/smarterplanet/us/en/smart_grid/article/battery500.html?lnk=ibmhpcs2/smarter_planet/energy/article/battery_500)
- [14] DNA India (2011), Why Gujarat government against promoting e-vehicles, Retrieved from: [http://www.dnaindia.com/india/report\\_why-gujaratgovernment-against-promoting-e-vehicles\\_1573757](http://www.dnaindia.com/india/report_why-gujaratgovernment-against-promoting-e-vehicles_1573757)
- [15] Warfield, J. W. (1974) Developing interconnected matrices in structural modeling, *Transactions on Systems, Man and Cybernetics*, 4(1), 51-81.
- [16] Ravi V. and Ravi Shankar (2005), Analysis of interactions among the barriers of reverse logistics, *Technological Forecasting and Social Change*, 72(8), 1011-1029
- [17] Singh M.D. and R. Kant (2008). Knowledge management barriers: An interpretive structural modeling approach, *International Journal of Management Science and Engineering Management*, 3(2), 3141-150.
- [18] Sunil Luthra, Vinod Kumar, Sanjay Kumar and Abid Haleem (2011). Barriersto implement green supply chain management in automobile industry using interpretive structural modeling technique - An Indian perspective, *Journal of Industrial Engineering and Management*, 4(2), 231-257.
- [19] A.K. Digalwar, Ganneri Giridhar (2015), Interpretive Structural Modeling Approach for Development of Electric Vehicle Market in India, *Procedia CIRP*, 26, 40 – 45.