Modeling the Key Barriers to the Development of EV Industry in India: using ISM and MICMAC Analysis

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Abstract - *The world is facing yet another crisis of 'global warming' due to rising air pollution levels caused by thoughtless human actions. Road transportation is a major contributor to air pollution. It is the need of the hour to transform our road transportation systems using the traditional IC engine to alternative sustainable transportation systems such as 'pure EVs'. The adoption of EVs in India in particular, has not been easy. The Indian EV industry is still in its nascent stages and has a lot more to achieve in terms of innovation and sales. There are a number of companies in India like – Tata Motors, Mahindra and Mahindra, etc. which produce EVs locally. Still, there are many challenges faced by these manufacturers; in terms of sales and adoption of their EV models. This study covers a number of such challenges. This study aims to provide an ISM-based approach to analyze the barriers faced by the EV industry of India and to determine the intensity of their influence by sorting them into various levels. This study is confined to the analysis of the barriers causing hindrance to the development of EV industry in India; not to mention, a small peek into the Global EV scenario is also included.*

Key Words: Electric Vehicle, Barriers, MICMAC Analysis, Interpretive Structural Modeling, Internal Combustion Engine Vehicle

1. INTRODUCTION

Humans have always needed a medium for transportation and the development of road transport began soon after the invention of the wheel. The development of 'the Wheel' has been one of the most important inventions; it caused the development of chariots, carts and other various modes of road transport in ancient times. Fast-forwarding to modern times, Karl Benz - a German engineer is credited as the builder of the first true car. Automobile systems like engines, drive-train systems and the automobile itself have gone through various developments in the past century. The automobile industry has faced a lot, from continuously rising fuel prices to severe economic recessions wiping out a huge chunk of manufacturers due to bankruptcy. Transport is a significant and growing contributor to particulate air pollution. There are over 800 million motor vehicles being used in the world today, consuming around 40 million barrels of petroleum per day, producing about a half of the urban pollution, and emitting over a one-tenth of the world's anthropogenic greenhouse gases [33]. Automobiles have always been running on fossil fuels, but due to a world-wide understanding about the CO_2 emissions and environmental pollution due to the usage of fossil fuels, various governments around the world are trying to reduce their dependency on fossil fuels and phase out ICEVs from their markets by introducing and encouraging the adoption of EVs and alternative modes of sustainable transportation.

Vehicles running on electric motors rather than a conventional combustion engine are known as 'electric vehicles'. Pure EVs make use of battery packs to run their electric motors as compared to fossil fuels required to run the traditional IC engine. These vehicles can provide better efficiency in urban regions where stop-and-go traffic prevails and on the other hand, they can provide performances close to those of the traditional ICE vehicles only by employing small size and small weight batteries [58].They have been given a lot of attention in the past few decades; primarily, due to rising environmental concerns but, that is not the only concern. Fossil fuels – which have been widely adopted as a fuel to run an automobile is a non-renewable resource; it is not going to last forever and one day all the oil wells on this very earth may go dry. This has led to a highly accelerated adoption of renewable sources of energy and hence, it has created a favourable environment for the development of electric vehicles. Today, almost every automotive company around the world has at least one pure-EV model included in their official line-up for their customers and a number of start-up companies have been established which produce only pure EVs; one such company which was able to make a huge impact is Tesla, Inc. EVs have been in existence for more than a century, but were neglected due to cheaper alternative of ICEVs at that period of time with Ford leading the race with its mass production system making ICEVs much cheaper to produce. But now, the times have changed, with consistent developments in e-mobility systems, and unification of thought between citizens of various governments for implementation of an all-electric vehicle fleet around the globe, this transition from ICEVs to EVs is an inevitable future, which will surely revolutionize road transportation.

1.1 Global Scenario

In December 2015, the Paris Climate Agreement was introduced and enforced in November 2016. The 194 participating countries pledged to limit the global increase in average temperature below 2°C in this century and further limit the temperature rise to 1.5°C in the next century [19]. The top three countries with the highest greenhouse gases emissions are China, USA, and India. According to a study, China and the United States makeup 65% of global electric four wheeler users and China has successfully surpassed the United States to become the largest market for electric vehicles in 2015. China accounted for about one-third of the global share for electric vehicles in 2017 [31].The second position is held by Europe, which makes up 23% of the global share. Norway had a national PEV market share at 22% in 2015 [28].

In March 2019, nearly 60% of new cars sold in Norway were completely electric-powered. The government of Norway was able to achieve this by comprehensively providing financial incentives to its citizens in terms of tax exemptions and developing charging infrastructure to encourage EV adoption [52]. Due to Norway's policy of incentivizing the EV, a price disparity against the conventional ICE vehicle began to develop. Norway has named this policy the "polluter pays principle". A lot of benefits in terms of exemption from roadway tolls, access to charging infrastructure and the right to drive in bus lanes were provided to owners of EVs. Whereas, the users of conventional ICE vehicles had to pay a VAT (value-added tax) of 25% and an extra burden of GHG (greenhouse gases) taxes was imposed [57]. According to various indicators, China is leading the way with its electric vehicle developments and manufacturing capabilities. Even before the recent developments of Tesla Gigafactory, China was one of the largest EV manufacturing countries on the planet. USA has one of the densest public EV charging facilities set up by Tesla, Inc. and various other companies to facilitate easy access to public charging infrastructure for EV users in the country. Tesla operates about 16,103 Supercharger points for its users in USA, which is very high compared to the number of charging stations in some of the developing countries around the world. The German Federal Government has invested about €1.5 billion in electric mobility development. The National Platform Electromobility (NPE) was established in 2010 and the ambitious 'National Electro-mobility Development Plan' was launched which targets 5 million electric vehicles on road by 2030. Several tax incentive measures and road traffic management schemes under the Electro-mobility act were launched by the German Government in order to prioritize the purchase of EVs by its citizens [69].

1.2 Indian Scenario

According to research by the International Energy Agency (IEA), the global fleet of electric vehicles has increased from just five thousand vehicles in 2008 to more than two million in 2016. When it comes to India, the development and adoption of EVs has rather been slow. The first EV to be manufactured in India was 'REVA' which was launched in the year 2011 [74]. Since then, the adoption rate of EVs in India has started to pick up with indigenous companies like TATA Motors and Mahindra & Mahindra introducing a few models to test the market and increase EV penetration. Though there are other players in the market, the adoption rate is not at that pace where it should be in a vast country like India. The government has been keen on local manufacturing of EVs to make India – 'the world's destination for EV manufacturing' and hence, has increased the import duty on Electric vehicles to encourage local EV manufacturing.

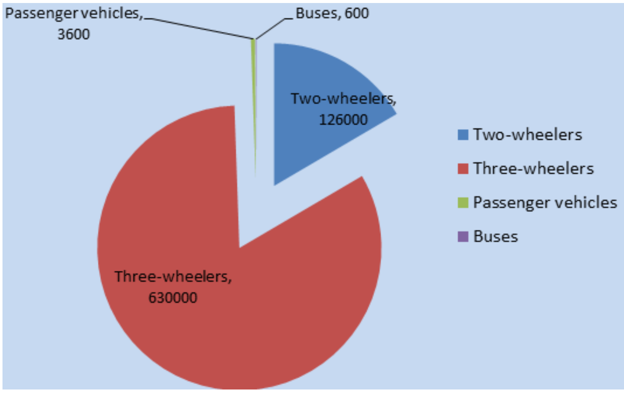

Fig -1: EV Sales in India for FY2019

The government's recent announcements on phase-II of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles scheme (FAME II), which will be implemented between 2019 to 2022, and road tax and registration charge exemption for hybrids and EVs, will bring a major turnaround in growing India's EV space. A number of state governments in the country are embracing the set-up of EV manufacturing plants and adoption of EVs in their states and hence, have formulated their own policies and regulations regarding the manufacturing and selling of EVs in their respective states. India highly depends on its oil imports for functioning of its transportation systems and to reduce this dependency it is very much necessary to incorporate e-mobility systems in the Indian road transport ecosystem. With a view to protect human health and maintain environmental well-being, the Government of India has recently implemented the emission norms Bharat Stage (BS)-VI, which is equivalent to Euro-VI standards of Europe. These norms came to effect from April 1, 2020 [63]. The automobile industry in India has gone through a lot of transformation since inception and in particular in the last decade [39]. The growth of e-mobility in India is expected to be driven by public procurement and public transport through the purchase of government vehicles, three-wheeled vehicles and buses for public transport. Growth in the four-wheel vehicle market is also expected to be driven by private ride hailing services such as Ola and Uber, where increased daily traffic makes electric vehicles more economically viable. In May 2017, India witnessed its first-of-a-kind multimodal electric mobility project in Nagpur, in the state of Maharashtra. As of January 2019, the electric vehicle fleet in Nagpur – a combination of e-rickshaws and e-cabs operated by the ride-hailing and rideshare platform Ola – had served more than 350,000 customers, clocked more than 7.5 million clean kilometres, saved more than 5.7 lakh (570,000) litres of import-dependent fossil fuel and reduced CO_2 emission by more than 1,230 tons since its introduction [95].As per the Society of Manufacturing of Electric Vehicles, the population of e-vehicles is growing at the rate of 37.5% in India. The Indian government has set an ambitious target for reducing the import of fossil fuels by 10% and introducing an all-electric car fleet by 2030 [47]. Though efforts are being taken, there are many roadblocks which restrict the growth of EV-ecosystem in India. From charging infrastructure to consumer awareness, a number of obstacles form a threat to the India's high ambitions. In the light of the above background, it makes a compelling objective to study and determine the most influential factors greatly affecting the development of EVs in India.

2. LITERATURE REVIEW

The Indian auto industry is the fourth largest in the world and is expected to become the third-largest in 2021. The industry accounts for 7.1% of India's gross domestic product (GDP) and through the 2016-2026 automotive mission plan, the Indian Government aims to pump this figure up to 12%. The Indian auto-industry (including component manufacturing) is expected to grow at 5.9% per year and reach ₹16.18-188 billion ($251.4 to $282.8 billion) by 2026, which will make it the fastest growing industry in the country. But, due to rapid technological advancements in EV technology, the country has to take a stand and make sure that this projected growth is not disrupted due to the EV technology, instead, it becomes a contributor to this development. It is captivating enough to study and analyze the influence of various barriers restricting EV development in India. To do so, varied research papers and conference papers have been deliberately studied. The research papers in consideration, discuss many important issues related to EV-domains such as sales, future-scope, working, drivetrains incorporated, powertrains, the challenges faced by India and other countries in the world, and the efforts being taken to tackle the effects of climate change through adoption of sustainable transportation systems. This literature review aims to outline the views, comments, and strategies suggested by different authors on EV development and the challenges that need attention.

Anu G. Kumara in 'A strategy to enhance electric vehicle penetration level in India' explains how the introduction of the FAME (Faster Adoption and Manufacturing of Hybrid and Electric vehicles) scheme by the Indian Government helped provide little, but valuable subsidies for EVs, where the cost of an EV would soon come down to the same level as that of a conventional ICEV. The author also discusses strategies to increase the cost competitiveness of EVs by reducing their depreciation period by developing a vehicle-to-home (V2H) technologies and encouraging the adoption of EVs. The author also explains the major boost that the Indian power grid would be subjected to thorough the implementation of such schemes. The scheme will enhance the load-carrying capacity of the Indian power grid during peak hours in Indian households through the usage of the stored energy available in the electric vehicle using the V2H system. The electric vehicle would be used as an electric storage device for the household when parked and charged. It will allow owners to sell their battery capacity to electric grid operators when the vehicle is not being driven and can make it more economical for the masses. The author also emphasizes that greenhouse emissions can be considerably reduced if this system is further incorporated with renewable energy sources such as solar and wind power. The author concludes by stating that the technology will be viable to the public as and when advancements in the EV technology, battery systems, government reforms, subsidies, charging infrastructure takes place. The research paper pushes the ideology and technology of EVs beyond roads to directly our households [10].

'A survey on electric vehicle transportation within smart grid system' by N. Shaukat and his fellow author emphasize the incorporation of renewable energy sources in the EV-sector. The research paper is survey-based and presents a qualitative analysis of enhancing the transportation electrification (TE) and Smart Grid (SG) technology. The author further describes the impact of TE on SG technologies. Various questions are answered through this research paper such as the impact on smart grid technology, load capacity, impact on power quality, on the economy, on the environment, etc. [3].

Jiya Ying Yong and her fellow authors in 'A review on the state-of-the-art technologies of an electric vehicle, its impacts, and prospects' discuss the history of EVs and state that the first electric-powered carriage was prototyped in between 1832 and 1839, which was invented by Robert Anderson. A vague comparison is presented to showcase the development that the EV has gone through in terms of technological advancements. The study also discusses technologies in the EV-domain such as power trains used, battery technology, charging equipment, its standard, methods of charging, etc. The authors also describe the impacts of EV usage rather than deployment on roads in terms of economic impact, environmental impact, impact on the power grid, and other technical factors affecting which would get impacted. The prospects of EV deployment with smart grids and scope in R&D are possible which can be achieved as time passes and global competition intensifies are also discussed. This study summarizes the past, present, and future of EVs in an orderly fashion [7].

The authors of 'Electric Vehicle Charging Infrastructure in India: Viability Analysis' are of the strong notion that extensive reliance on ICEVS has led to rising pollution and degradation of air in major cities of India like Mumbai, Delhi, Bangalore. Keeping this in mind, it is high time that India looks up to alternatives such as EVs and Hydrogen fuel-cell vehicles as modes of transportation not only in the cities forming the golden quadrilateral but also in other 2 and 3 tier cities. The study also provides an insight into the impact of charging on the power grid system. Households with a combined population of 1.3 billion will also require a power supply and with the increasing power demand, a smart charging system and its management will be essential for the 'EV revolution' to be successful. The authors conclude with a comparison between India and countries like China and the USA; and point out the developments that India needs to pay close attention to, to cope up with other countries. These developments include scaling up the infrastructure, formulation of the required policies, and the overall development of the EV-ecosystem [62].

To conclude, developments in EV technology in terms of battery technology and range enhancement hold a lot of research scope. The Indian EV market is an emerging market with a lot of advancements to come. The review outlines the importance of the research in this domain and other possible as well as effective ways to successfully increase the penetration of EVs in India. Newer technologies such as vehicle-to-home (V2H) technologies, the development of feasible charging infrastructure and numerous case studies related to EV adoption in different countries are also discussed. Topics such as conversion of ICEVs to EVs, enhancement of the TE and SG technology, and also the impact of EVs on the overall market are highlighted. India has a huge potential in developing the EV market which is certainly, sightful and achievable.

3. METHODOLOGY

3.1 What is ISM methodology?

There are always some difficulties encountered while dealing with complex issues and systems. This is mainly due to the presence of a large number of elements as data which is poorly structured. The relation between the elements is also very unclear. It is very difficult to deal with such a system which does not have a clearly defined structure. Hence, it becomes necessary to use a tool which helps to identify the structure present within the system. Interpretive structural modeling (ISM) is such a tool or a methodology that transforms unclear, poorly structured mental model of systems into a clear well-defined model. The information added (by the process of ISM) is zero. But, the value added is structural. ISM can be termed as a qualitative analysis technique. The process of ISM begins with identification of variables i.e. elements which are related to the problem or issue faced while working with an unstructured system. Then a contextual relationship is established between each of the variables chosen. After deciding on the elements to be included in the study, and the contextual relation being established, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of variables. In the next step, the SSIM is converted into an initial reachability matrix (RM). After checking the transitivity embedding in the initial reachability matrix (RM), the final reachability matrix is developed. After this, the iteration matrix is developed which is used to partition the variables in a number of levels, according to their influence on other variables in the system. A digraph is then developed to represent a clear and structured model of the system. This digraph consists of transitive links between the elements which are then set-aside in the next step, i.e. the main ISM Model representing the hierarchical order of elements according to their influence in the system.

3.2 Why choose ISM?

The primary objective of this study is to develop a hierarchical order of the barriers affecting the development of EV industry in India and determine the most and the least influential barriers. It is the need of the hour to prioritize sustainable transportation for the well-being of the environment around us and protect it from harmful air pollution caused by conventional fossil fuel-based transportation systems. Hence, it is very much necessary to bring a change in the current auto-industry of India to match the rapidly amplifying global EV industry. The adoptability of EVs in India has been very low due to a number of barriers. ISM as a tool to determine the influence of these barriers is an ideal choice in our case. ISM is interpretive, as the results of this process depend on the judgment of the group which decides whether and how the different elements are related to each other. As in our case, input from industry experts was crucial to fulfill the primary objective of this study; ISM was chosen to be the correct modeling tool which would provide us with a structured set of variables i.e. barriers and present them in their hierarchical order to determine the most and the least influencing factors. In the global context, the growth of EV industry has seen exponential growth in the past few years and it is very much necessary that India copes up by eliminating these barriers and achieves its e-mobility goals as early as possible to be a world leader in sustainable transportation.

4. STEPS OF ISM

4.1 Research Variables

The research variables are identified and selected through literature review and this is where SME also comes into knowledge about a particular topic. The SME along with the individuals working on the ISM discuss the research variables selected and the necessary changes are made, if required. This increases the understanding about a particular topic among the group of individuals working with ISM methodology. The selected research variables are then assigned element values which are purely representational. The various factors which affect EV industry in India are as follows:

1. Lack of a stable policy for EV manufacturing

The government of a country plays as important role in the development of its nation by formulating polices for its economic growth. Governments all around the globe have formulated their policies for the sale and manufacturing of EVs and India too, is taking the strides towards EV adoption. The Government of India introduced FAME (Faster Adoption and Manufacturing of Hybrid and EV) for encouraging the adoption of EVs in the country. FAME was formed to provide incentives and benefits to personal vehicle buyers [67]. It was seen as a major boost for the still-growing EV industry. Then, the FAME II was introduced in 2019 which aimed at providing incentives and benefits to public transport operators. Wherein, the purchase of e-Buses and e-rickshaws was encouraged and incentivized [100]. However, the manufacturers in India aim to produce EVs in the country for exports, but due to changes in the related policies and lack of regional policies, the manufacturers are reluctant in investing in this sector. And also, due to many demotivating elements such as inadequate infrastructure, higher cost and range anxiety, the consumers do not prefer purchasing EVs. These elements are directly or indirectly related to lack of stable EV policy.

2. Lack of government incentives
Until 2017, no subsidy or incentives were provided for EVs in India due to absence of the necessary regulations. But, countries like China on other hand started providing incentives to the EV manufacturers as well as consumers from the late '90s. This optimistic move by the Chinese government resulted in achieving the position of the global leader in EV sales and manufacturing [20]. For any successful penetration of any new venture, incentives form a mode of savior for the company or new undertaking. The incentives can be in form of capital, land, tax deductions, or any form of perks that could help flourish the particular cause. In the case of EVs, the cause of successful penetration can only be brought by directly intensifying the EV manufacturers and providing tax exemptions to the consumers which would encourage them to make purchase. The Indian government in recent years has begun to provide some incentives under the FAME policy to the consumers for the purchase of EVs which reduce the upfront cost but only units manufactured or assembled in India were eligible for the financial incentive [77]. As compared to other countries, the incentives provided in India are very low and hence, necessary actions must be taken to increase the incentivization of EVs.

3. Absence of an 'Independent' Government Body
The concept of a 'Pure EVs' is a not new, but wasn't mainstream few decades ago. Only in 2017 did the industry and the Indian Government take note that, if they failed to act, they would lose the race, and the country would be flooded with imported EVs in the future [85]. The EV industry of India is still in its nascent stages. Hence, to overlook this development and provide the necessary regulatory framework for the EV industry alone, an independent government body should be established. At present, there is a single Ministry in India i.e. the Ministry of Road Transport and Highways, which overlooks research for transportation in the country. But, there is no special cell or department under the Ministry of Road Transport and Highways that looks over the development of the electric vehicle. To improve the current scenario and to develop the EV industry as a whole, the government should setup a dedicated cell or department to overlook the development of the EV industry and to organize the EV industry of India [35]. Also, the economy of the country has been highly affected due to the recent 'COVID -19 Crisis', there has been a shift in focus from development to stabilization and recovery of the economy. Only a few states in India have formulated and planned their respective policies for EVs and only the union territory of Delhi has planned to set-up 'State Electric Vehicle Board' which would overlook the EV-ecosystem and adoption of EVs in the Delhi-NCR region. The establishment of a similar government body at a national level would direct all of its focus on EV development and help India, cope with the Global standards and developments pertaining to EVs [95].

4. Limited EV models
The support from the government is essential for the development of any new technology in a country. Before 2015, there was an absence of a concrete policy for EV manufacturing in India. Also, the awareness among consumers was poor which resulted into non-acceptance of electric vehicle. But in last 5 years, the consumer behavior towards EVs has increased considerably [53]. Some EV manufacturers had recently announced to improve the range of electric vehicles from 80-90 km per charge to 300-400km per charge. The recent EVs models such as TATA Nexon EV, MG ZS EV and Hyundai Kona were a moderate success in the EV-segment. But, with further development of EVs, the number of models introduced should increase. The consumers in India do not prefer EVs not just because of the high costs and low range, but also due to less variety of models available.

5. Lack of Awareness among Consumers
There is a significant lack of awareness regarding the benefits of EVs among the consumers in India [56]. EVs offer a number of benefits as compared to ICEVs and as every coin has two sides, the same way, EVs also have a few drawbacks of their own; limited range is a prime drawback which can is never overlooked by a customer. Consumer preferences also play an important role when opting to purchase an EV or an ICEV. The ICEV market is well established and offers a variety of models in terms of body style, performance and seating capacity, whereas, the variety of EV models available is still limited [18].The primary concern of the customer is the range that the EV offers and hence, the range anxiety of the customer comes into picture. Most of the consumers are unaware about the recent developments regarding batteries and their charging capabilities. With emerging technologies and with the introducing of some newer models, the range of an EV has been significantly enhanced to an at least 350kms, where the only drawback is its higher cost. Fast charging of an EV is also becoming much more common, provided the right infrastructure in present. Hence, an excuse of limited range for not purchasing an EV and then opting for an ICEV will soon go out of style with the recent developments. Specific strategies and methods need to be adopted, especially in India for the expansion of the EV-segment [43]. Many rumors regarding EVs are also present among consumers in India, which does have an effect on the sales. A proper explanation for the limited acceptance of EVs in the country would be that, it is a new product and higher range is not offered for most of the affordable segments. As the range of EVs in the affordable segment will increase, the average customer will surely prefer EVs since he will save a ton of expenses on running costs during the usage period of the vehicle [71].

6. Lack of R&D
According to the World Bank, India spends only 0.6% to 0.7% of its GDP in the field of research and development sector [2]. The argument for less allocation of funds in R&D in India is true because it's still considered as a developing country. Research and development in fields of battery technology, EV drive trains, smart-power grid technology,

charging technology, improving battery capacities for sustainable and long use of green cars are further possible and conducted on large scale. These research activities if successful, then it may reduce the cost of EVs and increase consumer confidence [100]. China, a global market for EVs had started the R&D program for EVs from as early as 1990 [24, 50]. The government provided subsidies worth 60k Yuan for R&D [49]. Due to this early effort by the government; it is the leading country to manufacture hybrid electric vehicles and buses and is also making progress in the manufacturing of taxis, e-bikes, heavy vehicles, etc. [81, 82]. The government of India in 2013 announced the National Electric Mobility Mission Plan (NEMMP) 2020, taking a step towards boosting the energy self-reliant India and to create awareness about the emissions of greenhouse gases from automobiles and impacting the environment.

7. High Dependency on Battery Imports

Sustainable transportation mediums such as pure EVs run on stored electric power. Hence, batteries form a principal component of the vehicle. Li-ion battery is the most widely accepted type of battery for EV applications. There are other cheaper alternative batteries available but the Li-ion battery is used for EVs despite its high cost as it offers lack of memory effect, long life cycle, higher energy efficiency, high energy density and power density. At present, the known lithium reserves available in world are sufficient to run only 33% of the current global vehicle fleet (if they were EVs). Large reserves of Lithium are found in China, Australia, and Argentina. When it comes to India, lack of lithium reserves is a major issue and India imports Lithium for nearly all of its requirements. At present, there is no local manufacturer that produces lithium-ion batteries for automobiles in India. Hence, EV manufacturers in India outsource batteries from foreign suppliers and results in higher cost of batteries which in turn increases the overall cost of the vehicle [1]. The processing of materials used for the production of lithium-ion battery is arduous and hence there are few manufacturers in world that produce Li-ion batteries for EVs. Also, mass production of batteries would surely generate E-waste which would require systematic recycle and reuse programs in place. Research on alternative battery composition specifically for EV applications in under-way and some major developments in this area are bound to happen [9]. China has abundance of lithium reserves and somewhat possess a monopoly on manufacturing and trading of Li-ion batteries which certainly makes it a little difficult for India to import Li-ion batteries or the Lithium itself due to rising political tensions among both the countries.

8. Inadequate Infrastructure

At present there is no adequate infrastructure for EVs in India. EV infrastructure includes charging stations, parking lots equipped with charging systems, and of course regulated electric supply. The charging system of EVs is divided into three stages viz. Stage1, Stage2 & Stage3. Pure EVs can travel mostly around 250-300km on a full charge so it becomes necessary to establish charging stations at least at an interval of 50-100kms. One major issue with EVs is their charging time. A conventional vehicle requires only 5-10 minutes for refueling whereas; an EV requires a minimum of 50-55 minutes for recharging with Stage3 charging equipment [12]. For charging of EVs, not only charging stations but adequate space to accommodate the vehicle itself is required [61]. A country like India, where most of the cars in urban areas are parked on streets, the government will have to make arrangements for charging such vehicles overnight. Also, the government will have to look over the grid supply and make the necessary developments suited for effective power distribution grid [15]. Wireless charging of EVs is another technology which is under development. EVs are mostly suitable for dense urban cities with stop-and-go traffic and travelling small distances usually for a day. As power cut and power failure is common in certain areas, proper and regulated power supply with adequate infrastructure is necessary. In India, lack of charging stations demotivates consumers to purchase an EV and hence, the government should encourage private firms to setup charging stations and at the same time, the government can offer subsidies for the same.

9. Catalyst for EV penetration

Catalyzing the market to increase the adoption of EVs is not a new concept but has been embraced by countries like China, Denmark, and other nations in the past. It will be important for India to embrace such a concept to achieve the goal of EV revolution. China has set a very good example by electrifying the public transportation and providing the required financial assistance for adoption of e-mobility systems which in turn acted as a catalyst and increased the pace of EV adoption in the country. Due to the collective efforts of both, the government and its citizens, the country leads the world in terms of EV sales, with more than 20 lakh actively running EVs on road [98]. The Indian automobile market largely consists of four-wheelers, two-wheelers, three-wheelers and commercial vehicles. Out of these, two-wheelers and three-wheelers contribute more than 70% of total sales. If these two wheelers and three wheelers are electric, then they can surely act as a catalyst, and accelerate the transition of ICEVs to EVs in the country. The shift to electric buses for public transportation will not only reduce carbon emissions but, will also save a lot of tax payer's money. A recent development by the Ministry of Heavy Industries in India, in 'Potential models for the adoption of EVs in public transport', sanctioned USD 67 million for the procurement of electric buses, e-taxis, and e-autos; it was a major step towards e-mobility in India [97].

10. Higher upfront cost of EVs

The automotive industry of India is fast changing. Newer technologies such as EVs or fuel cell vehicles are in their nascent stage. As every new technology, higher cost becomes a major issue during the early phase. The same way, initial costs of an EV are significantly higher when compared to an ICEV and this cost increases linearly with battery size or the range of the vehicle [16]. Higher cost of an EV forms a major obstacle for the adoption of EVs by Indian consumers. These higher costs can be reduced by providing direct subsidies to consumers from the central or state governments. Local manufacturing of EVs would also benefit the consumers as costs would gradually decrease with increased local manufacturing [96]. The truth is that most Indians cannot afford an EV. But, EVs offer much lower ownership costs as compared to ICEVs. This is mainly because of substantial fuel savings as well as lower maintenance, service, and repair expenses which may be as much as 30% as compared to that of ICEVs. EV owners are protected from the price fluctuations intrinsic to global crude oil markets as electricity prices are cheaper and more predictable than those of gasoline, which increases the consumer savings.

11. Lack of trained manpower
Lack of skilled manpower is one of the biggest challenges faced by the Indian EV industry. There are very few individuals in the country well versed with this technology. As per the current scenario, the after-sale service technicians have knowledge and skills pertaining to maintenance and repair of ICEVs but not EVs; as this technology is relatively new to the Indian market. To curb this, the Industrial Training Institutes (ITIs) of India are providing the basic technical knowledge about EVs which mainly focused on repairing, installation, and assembly of EVs [16] along with this the government should collaborate with Technical Institutes, Polytechnics, IITs and engineering colleges to train individuals about the EV technology and promote the start-ups related to EV industry[96]. According to Mr. Rajeshwar Tripathi, Chief People Officer at Mahindra and Mahindra Ltd., hiring local talent for their company to work with the EV technology is a big challenge, because it is difficult to find qualified and skilled manpower in the country to work in the EV-domain [57]. Training should also be provided to employees on an organizational level, which would be a major boost for R&D of EVs [4]. Hence, for the EV revolution to be successful having skilled individuals and workforce with significant knowledge of the EV technology is the need of the hour for India.

12. The monopoly of oil and gas industry
If EVs are adopted as a regular means of transportation, the oil and gas companies may lose their dominance in the market. According to World Economic Forum, more than half of the cars running on Indian roads will be electric by the year 2040 [95]. The transition to EV technology will not be a boon for many firms which lack diversification as their revenue will be disturbed. Currently, most of the automobiles running on roads are ICEVs which are fuelled by petrol and diesel. The price of which, is dictated by a few oil-exporting countries and has resulted in a firm monopoly over the automobile market. The ambition of 100% electrification of passenger vehicles will certainly not be welcomed by these countries, as this move will disrupt their monopoly over the automotive markets. As an EV requires electric power, and with the increasing number of EVs on the roads the consumption of their products will subsequently decline implying to the end of their monopoly. The sales of the oil-based products will not completely be immobile but will definitely decline.

13. Frequent recessions
Taking into account the numerous slowdowns in the automobile industry over the course of history, it is clear that these slowdowns have a huge impact on any new development of ideas not only in the auto-sector but other sectors too. For example, automobile industry crises in 2008-2010 resulted in the Great Recession, the most recent collapse of industry in 2019, and the advent of COVID-19 made it even worst [95]. Due to these frequent slowdowns, the development of the EV industry is pushed to the back burner. Any new technology requires time for its penetration and adoption in the market. During recessions, the consumer confidence is very low because of low or no capital flow and also, business investors would be reluctant to invest in EVs due to uncertainty [97]. For a new technology to make its own identity in the market, the market itself should be stable enough with minimal high and lows which is impractical by nature, so it could make room for new ones. But due to frequent recessions and less demand for automobiles, the penetration of EV technology has been very slow in India [100].

14. Lack of retrofitting facilities
It is not necessary that the adoption of EVs can only be accelerated by mass production and sale of the subsequent EV units produced. 'Retrofitting' i.e. the conversion of an ICEV to an EV is an interesting practice which started as a DIY project for many but eventually became a commercially viable business model for EVs. Retrofitting consists of completely removing the IC engine and the drivetrain system and then, installing the electric drive train system with the additional electronic circuits required for battery management, driver analysis and control of the vehicle. It implements the principles of reduce, reuse and recycle which certainly benefits the environment. The electric vehicle conversion would increase savings since the maintenance and running cost of the vehicle would be significantly reduced; which justifies the costs born for the conversion itself. The conversion would make use of an already manufactured vehicle and thus reduce the carbon footprint produced [8]. In India, only a handful of start-ups provide services for conversion of an ICEV to an EV. The Government of India does not provide any incentives to the consumers for the costs they bear for the conversion. 'Retrofitting' is economically viable for 3-wheelers used in India, popularly known as 'rickshaws' which cover on an average 100kms in a day. Retrofitting services in the country can do business worth ₹6000CR per year considering 10% vehicles will be scraped after 15 years of usage [94]. This would be highly beneficial for the environment as it would result in reduced carbon footprint and would also serve as a business opportunity for start-ups in the country.

15. Optimum business model
For EVs to succeed in India, it is very much necessary for the manufacturers to adopt a particular business model which would certainly result in growth of EV sales. Adopting an optimum business model for sale of EVs in India will surely reduce the upfront cost of EVs and thereby increase the number of consumers interested in buying EVs. Business

models promoting the large-scale adoption of EVs in public transport such as state-run bus services have the potential to successfully create an early impact. Partnership between the government and the private operator or a partnership between the government and the energy supplier or a partnership among the government, the energy supplier, and a private operator may be conducive to improve operational efficiency of activities related to operation and maintenance of electric buses and supporting infrastructure. The 'battery swapping' business model adopted by WanXiang in Hangzhou, China was effective in providing incentives to individual consumers which reduced the risks of battery ownership and hence the caused the overall cost of the EV to reduce [92]. A similar business model may encourage an average Indian car buyer to purchase an EV rather than an ICEV, due to attractive benefits in terms of running costs for the purchased vehicle.

16. Low Power Generation Capacity

According to Aoife Foley, the ‘Electric vehicle’ is going to have a huge impact on the power supply grid in a country [42]. And, the demand for electric power is going to increase much rapidly which will surely affect the power supply rate [21]. According to statistics, 60% of the electricity generated in India is produced using coal [73]. India is the second largest producer of coal in entire world and according to the Ministry of Coal; there are 319 billion tons of coal reserves in India. [26]. As, the purpose of introducing and developing EV technology is to reduce pollution, using coal to generate electricity and then using the same generated electric power to charge EVs will not make a difference. To make EVs sustainable, the government has to adopt and develop means of generating electric power from renewable sources of energy [81]. India’s power generation capacity is comparatively less; such that it is not enough to fulfill the current energy demands and a growth in the EV sector will increase the load on an already overloaded power grid. Under such conditions, growth of the EV sector will certainly be hampered [68]. There should be proper developments and provisions made for generation of electric power from renewable sources of energy to reduce load on the traditional power generation plants and meet the requirements from various consumers, including the EVs [84]. Incorporation of technologies such as regenerative braking and solar charging are been developed in EV’s for wider scale of adoption [41]. Also, the inclusion of EVs will affect the regular residential distribution of electricity in India and power supply shortage will result into frequent power cuts, if the necessary developments are not under-taken [88].

17. Difficulty in recycling of batteries

The batteries of EVs significantly influence the cost, overall weight and performance of the vehicle. The Lithium-ion batteries offer high energy density, long lifespan and high efficiency and hence, are widely accepted for the application of EVs. This battery consists of precious earth elements which are arduous to mine and extract which considerably increases the cost [1]. When it comes to batteries which have been subjected to continuous usage or any damage, recycling or dumping them in landfills are the only two options available. Since, flammable and toxic materials present in the lithium-ion batteries can cause possible explosions, contamination of the soil and groundwater if disposed-off in landfills, recycling is a better option for environmental well-being. Approximately, 95% of a lithium-ion battery is recyclable. India faces a tough challenge where lack of lithium reserves in the country is hindering the local manufacturing of batteries and of the EV itself. India currently depends on imports for all its lithium requirements which in turn increases the upfront cost of EVs manufactured in India. The recycling of lithium-ion batteries can offer a $1000 million business opportunity in India. Currently, there is no structured model for collection and recycling of used batteries in India. With the current trend of EV development, establishment of a recycling network for lithium-ion batteries is necessary and potent for economies like India [93].

18. Shorter Battery Life

In an EV, battery is what heart is to human beings. Without a battery, the EV is just an assembled piece of metal. Even though the Li-ion battery offers a number of advantages, one major limitation is its cost. Still, it is widely preferred as no other type of battery offers the same performance as that of the Li-ion battery. It is heavy in weight due to its high energy density. For instance, the e-Rickshaws which are commonly seen in India and other South-Asian countries consist of a battery that weighs around 200kgs. There are many problems associated with the batteries of an EV, and one such is: the operational life, which is a maximum of 4-5 years [11]. Hence, the consumer who purchases an EV will need to replace the battery after an average of 5 years after purchase, depending on the usage. This is because the power output capacity of the battery would reduce to as low as 70% of its actual capacity after a specific period of time. The cost of a new Li-ion battery is very high; it is difficult for an average consumer to do so after every few years. At present, local manufacturing of Li-ion batteries is not a thing in India. Hence, the batteries need to be imported; increasing the costs.

4.2 Structural Self-Interaction Matrix (SSIM)

The ISM methodology suggests taking expert’s opinions for this step. Where, contextual relationships are established between the selected research variables (elements) with the help of SMEs. These research variables were identified and selected through brain storming and with the help of literature review in the previous step. The inputs by SMEs in this step are limited to four variables and they are:

- V: Variable ‘i’ will influence the variable ‘j’
- A: Variable ‘j’ will influence the variable ‘i’
- X: Variable ‘i’ and ‘j’ influence each other
- O: variable ‘i’ and ‘j’ are unrelated

The SSIM can be directly constructed by an SME or a questionnaire is to be prepared where, the inputs by an SME will be interpreted by the individuals working with the ISM methodology. The inputs will be converted into four outputs, namely, V, A, X and O and the final SSIM is constructed.

i \ j	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	O	X	A	X	V	O	A	O	V	O	V	A	A	O	V	O	V	X
2	O	O	O	V	O	V	A	O	V	O	V	V	A	X	V	A	X	
3	O	O	O	X	O	O	V	O	V	V	V	V	A	V	O	X		
4	O	O	O	A	O	O	O	O	O	O	X	O	A	O	X			
5	O	O	O	V	O	O	O	O	V	X	O	O	O	X				
6	V	V	V	A	A	O	O	X	V	V	A	V	X					
7	O	V	O	X	O	O	O	O	V	O	O	X						
8	O	A	X	A	O	O	O	O	A	A	X							
9	A	O	A	X	O	O	O	O	A	X								
10	O	V	O	X	A	O	O	O	X									
11	O	O	V	O	A	O	O	X										
12	O	O	O	O	O	O	X											
13	O	O	O	O	O	X												
14	O	A	O	A	X													
15	X	V	A	X														
16	X	O	X															
17	O	X																
18	X																	

Fig -2: Structural Self-Interaction Matrix

4.3 Initial Reachability Matrix

The step after completing SSIM matrix is to convert it into reachability matrix. To do so, the elements in the SSIM matrix i.e. (V, A, X, O) are eliminated and according to the contextual relationship they represent, 1s and 0s are used to construct the reachability matrix. For this, some rules are to be followed. These rules are used to fill the initial reachability matrix substituting the elements used in SSIM matrix. The rules to be followed while constructing reachability matrix are as follows:

1. If the (i, j) entry in the SSIM is V, where i influences j, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
2. If the (i, j) entry in the SSIM is A, where j influences i, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry in the SSIM is X, where both i and j influence each other, then the (i, j) entry in the matrix becomes 1 and the (j, i) entry also becomes 1.
4. If the (i, j) entry in the SSIM is O, where both i and j do not influence each other, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry also becomes 0.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1	1	1	0	1	0	0	0	1	0	1	0	0	0	1	1	0	1	0
A2	0	1	0	1	1	0	1	1	0	1	0	0	1	0	1	0	0	0
A3	0	1	1	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0
A4	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A5	0	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0
A6	1	1	1	1	0	1	1	0	1	1	1	0	0	0	0	1	1	1
A7	1	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	1	0
A8	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0
A9	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	0	0
A10	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	1	0
A11	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
A12	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
A13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A14	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0
A15	1	0	1	1	0	1	1	1	1	1	0	0	0	1	1	0	1	1
A16	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	1
A17	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0
A18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1

Fig -3: Initial Reachability Matrix

4.4 Final Reachability Matrix

After completing the initial reachability matrix, it is to be checked whether it abides with the 'Transitivity Rule'. It states that if A is equal to B and B is equal to C, then it is obvious that A is also equal to C. For the Initial Reachability Matrix, it will be interpreted as, if the entry for Element7 and Element8 is '1' and the entry for Element8 and Element9 is '1', then the entry for Element7 and Element9 will also be '1'. This way the entire Initial Reachability Matrix is to be checked for transitive links. And if, a '0' entry is found for a particular transitive link, it is to be replaced with '1*'.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
A1	1	1	1*	1	1*	1*	1*	1	1*	1	1*	0	1*	1	1	1*	1	1*
A2	1*	1	1*	1	1	1*	1	1	1*	1	0	0	1	1*	1	1*	1*	1*
A3	1*	1	1	1*	1	1*	1	1	1	1	0	1	1*	1*	1	1*	1*	1*
A4	0	0	0	1	0	1*	0	1	0	0	0	0	0	0	0	1*	0	0
A5	1*	1	1*	1*	1	1*	1*	1*	1	1	0	0	1*	1*	1	0	1*	1*
A6	1	1	1	1	1*	1	1	1*	1	1	1	1*	1*	1*	1*	1	1	1
A7	1	1*	1*	1*	0	1*	1	1*	1*	1	0	0	0	1*	1	0	1	1*
A8	1*	1*	1*	1	0	1	1*	1	1*	1*	1*	0	0	0	1*	1	1*	1*
A9	1*	1*	1*	1*	1	1*	1*	1	1	1*	0	0	0	1*	1	1*	1*	1*
A10	1*	0	1*	1*	1*	1*	1*	1	1	1	0	0	0	1*	1	1*	1	1*
A11	1*	1*	1*	1*	0	1	1*	1*	1*	1*	1	0	0	1*	1*	1	1*	1*
A12	1	1	0	1*	1*	0	1*	1*	0	1*	0	1	1*	1*	1*	0	1*	0
A13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A14	1*	1*	1*	1*	0	1	1*	1*	1*	1	1	0	0	1	1*	1*	1*	1*
A15	1	1*	1	1	1*	1	1	1	1	1	1*	1*	0	1	1	1*	1	1
A16	1	1*	1*	1*	1*	1*	1*	1	1	1*	0	0	0	1*	1	1	1*	1
A17	1	1*	0	1*	0	1*	0	1	0	1*	1*	0	0	1	1*	1*	1	0
A18	1*	0	1*	1*	1*	1*	1*	1*	1	1*	0	0	0	1*	1	1	1*	1

Fig -4: Final Reachability Matrix

4.5 Iteration Matrix (Level Partitioning)

After obtaining the 'Final Reachability Matrix', the next step in ISM methodology is construction of 'Iteration Matrix'. For this, reachability set and antecedent set of every element is found from 'Final Reachability Matrix'. The reachability set of an element consists of all the elements that a particular element influences including itself. The antecedent set consists of all the elements that influence a particular element.

Thereafter, the intersection set is derived, it consists of all the elements that are common between the reachability set and antecedent set of a particular element in consideration. After that, the elements are partitioned into various levels. The elements for which the reachability set and the intersection are same occupy the top level in the ISM hierarchy. Once the top-level factor is identified, it is removed from consideration i.e. eliminated. Then, the same process is carried out to determine the elements in the next level. This process is continued until the level of each element is found. These levels help in building the diagraph and the ISM model.

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A1	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11.A13.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11.A12.A14.A15..A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11.A14.A15.A16.A17.A18	
A2	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A13,A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A11, A12,A14,A15,A16,A17	A1,A2,A3,A5,A6,A7,A8,A9, A14,A15,A16,A17	
A3	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A12.A13.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11.A14.A15.A16.A18	A1,A2,A3,A5,A6,A7,A8,A9, A10.A14.A15.A16.A18	
A4	A4,A6,A8,A16	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A17,A18	A4,A6,A8,A16	1
A5	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A13.A14.A15.A17.A18	A1,A2,A3,A5,A6,A9,A10,A12,A15, A16,A18	A1.A2.A3.A5.A6.A9.A10.A15.A18	
A6	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11.A12.A13.A14.A15.A16.A17.A18	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11.A14.A15.A16.A17.A18	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11.A14.A15.A16.A17.A18	
A7	A1,A2,A3,A4,A6,A7,A8,A9,A10, A14,A15,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12,A14,A15,A16,A18	A1,A2,A3,A6,A7,A8,A9,A10, A14,A15,A18	
A8	A1,A2,A3,A4,A6,A7,A8,A9,A10, A11.A15.A16.A17.A18	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10,A11, A12.A14.A15.A16.A17.A18	A1,A2,A3,A4,A6,A7,A8,A9,A10, A11.A15.A16.A17.A18	1
A9	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A14.A15.A16.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A14.A15.A16.A18	
A10	A1,A3,A4,A5,A6,A7,A8,A9,A10, A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12,A14,A15,A16,A17,A18	A1,A3,A5,A6,A7,A8,A9,A10,A14, A15,A16,A17,A18	
A11	A1,A2,A3,A4,A6,A7,A8,A9,A10, A11.A15.A16.A17.A18	A1,A6,A8,A11,A14,A15,A17	A1,A6,A8,A11,A15,A17	
A12	A1,A2,A4,A5,A7,A8,A10,A12, A13,A14,A15,A17	A3,A6,A12,A15	A12,A15	
A13	A13	A1,A2,A3,A5,A6,A12,A13	A13	1
A14	A1,A2,A3,A4,A6,A7,A8,A9,A10,A11, A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A9,A10,A11,A12, A14.A15.A16.A17.A18	A1,A2,A3,A6,A7,A9,A10,A11, A14.A15.A16.A17.A18	
A15	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11.A12.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12.A14.A15.A16.A17.A18	
A16	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A14,A15,A16,A17,A18	A1,A2,A3,A4,A6,A8,A9,A10,A11, A14,A15,A16,A17,A18	A1,A2,A3,A4,A6,A8,A9,A10, A14,A15,A16,A17,A18	
A17	A1,A2,A4,A6,A8,A10,A11,A14, A15,A16,A17	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A17,A18	A1,A2,A6,A8,A10,A11,A14, A15,A16,A17	
A18	A1,A3,A4,A5,A6,A7,A8,A9,A10, A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11.A14.A15.A16.A18	A1,A3,A5,A6,A7,A8,A9,A10, A14.A15.A16.A18	

Table -1: Iteration Matrix 1

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A1	A1,A2,A3,A5,A6,A7,A9,A10, A11.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A9,A10,A11, A14.A15.A16.A17.A18	2
A2	A1,A2,A3,A5,A6,A7,A9,A10, A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A11, A12.A14.A15.A16.A17	A1,A2,A3,A5,A6,A7,A9,A14, A15.A16.A17	
A3	A1,A2,A3,A5,A6,A7,A9,A10, A12,A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A1,A2,A3,A5,A6,A7,A9,A10, A14,A15,A16,A18	
A5	A1,A2,A3,A5,A6,A7,A9,A10, A14,A15,A17,A18	A1,A2,A3,A5,A6,A9,A10,A12, A15,A16,A18	A1,A2,A3,A5,A6,A9,A10, A15,A18	
A6	A1,A2,A3,A5,A6,A7,A9,A10, A11.A12.A14.A15.A16.A17.A18	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A9,A10, A11.A14.A15.A16.A17.A18	
A7	A1,A2,A3,A6,A7,A9,A10,A14, A15.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11.A12.A14.A15.A16.A18	A1,A2,A3,A6,A7,A9,A10,A14, A15.A18	
A9	A1,A2,A3,A5,A6,A7,A9,A10, A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A1,A2,A3,A5,A6,A7,A9,A10, A14,A15,A16,A18	
A10	A1,A3,A5,A6,A7,A9,A10,A14,A15, A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12,A14,A15,A16,A17,A18	A1,A3,A5,A6,A7,A9,A10,A14, A15,A16,A17,A18	2
A11	A1,A2,A3,A6,A7,A9,A10,A11,A15, A16.A17.A18	A1,A6,A8,A11,A14,A15,A17	A1,A6,A11,A15,A17	
A12	A1,A2,A5,A7,A10,A12,A14,A15,A17	A3,A6,A12,A15	A12,A15	
A14	A1,A2,A3,A6,A7,A9,A10,A11,A14, A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A9,A10,A11, A12.A14.A15.A16.A17.A18	A1,A2,A3,A6,A7,A9,A10,A11, A14.A15.A16.A17.A18	2
A15	A1,A2,A3,A5,A6,A7,A9,A10,A11,A12, A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11.A12.A14.A15.A16.A17.A18	A1,A2,A3,A5,A6,A7,A9,A10,A11, A12.A14.A15.A16.A17.A18	2
A16	A1,A2,A3,A5,A6,A7,A9,A10,A14,A15, A16.A17.A18	A1,A2,A3,A4,A6,A8,A9,A10,A11, A14.A15.A16.A17.A18	A1,A2,A3,A6,A9,A10,A14,A15, A16.A17.A18	
A17	A1,A2,A6,A10,A11,A14,A15,A16,A17	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12.A14.A15.A16.A17.A18	A1,A2,A6,A10,A11,A14,A15, A16.A17	2
A18	A1,A3,A5,A6,A7,A9,A10,A14,A15, A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A14,A15,A16,A18	A1,A3,A5,A6,A7,A9,A10,A14, A15,A16,A18	

Table -2: Iteration Matrix 2

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A2	A2,A3,A5,A6,A7,A9,A16,A18	A1,A2,A3,A5,A6,A7,A8,A9,A11, A12,A14,A15,A16,A17	A2,A3,A5,A6,A7,A9,A16	
A3	A2,A3,A5,A6,A7,A9,A12,A16,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A2,A3,A5,A6,A7,A9,A16,A18	
A5	A2,A3,A5,A6,A7,A9,A18	A1,A2,A3,A5,A6,A9,A10,A12,A15, A16,A18	A2,A3,A5,A6,A9,A18	
A6	A2,A3,A5,A6,A7,A9,A11,A12,A16,A18	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A17,A18	A2,A3,A5,A6,A7,A9,A11,A16,A18	
A7	A2,A3,A6,A7,A9,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A12,A14,A15,A16,A18	A2,A3,A6,A7,A9,A18	3
A9	A2,A3,A5,A6,A7,A9,A16,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A14,A15,A16,A18	A2,A3,A5,A6,A7,A9,A16,A18	3
A11	A2,A3,A6,A7,A9,A11,A16,A18	A1,A6,A8,A11,A14,A15,A17	A6,A11	
A12	A2,A5,A7,A12	A3,A6,A12,A15	A12	
A16	A2,A3,A5,A6,A7,A9,A16,A18	A1,A2,A3,A4,A6,A8,A9,A10,A11, A14,A15,A16,A17,A18	A2,A3,A6,A9,A16,A18	
A18	A3,A5,A6,A7,A9,A16,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A3,A5,A6,A7,A9,A16,A18	3

Table -3: Iteration Matrix 3

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A2	A2,A3,A5,A6,A16	A1,A2,A3,A5,A6,A7,A8,A9,A11, A12,A14,A15,A16,A17	A2,A3,A5,A6,A16	4
A3	A2,A3,A5,A6,A12,A16	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A2,A3,A5,A6,A16	
A5	A2,A3,A5,A6	A1,A2,A3,A5,A6,A9,A10,A12, A15,A16,A18	A2,A3,A5,A6	4
A6	A2,A3,A5,A6,A11,A12,A16	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A17,A18	A2,A3,A5,A6,A11,A16	
A11	A2,A3,A6,A11,A16	A1,A6,A8,A11,A14,A15,A17	A6,A11	
A12	A2,A5,A12	A3,A6,A12,A15	A12	
A16	A2,A3,A5,A6,A16	A1,A2,A3,A4,A6,A8,A9,A10,A11, A14,A15,A16,A17,A18	A2,A3,A6,A16	

Table -4: Iteration Matrix 4

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A3	A3,A6,A12,A16	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A3,A6,A16	
A6	A3,A6,A11,A12,A16	A1,A2,A3,A4,A5,A6,A7,A8,A9, A10,A11,A14,A15,A16,A17,A18	A3,A6,A11,A16	
A11	A3,A6,A11,A16	A1,A6,A8,A11,A14,A15,A17	A6,A11	
A12	A12	A3,A6,A12,A15	A12	5
A16	A3,A6,A16	A1,A2,A3,A4,A6,A8,A9,A10, A11,A14,A15,A16,A17,A18	A3,A6,A16	5

Table -5: Iteration Matrix 5

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A3	A3,A6	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A3,A6	6
A6	A3,A6,A11	A1,A2,A3,A4,A5,A6,A7,A8,A9, A10,A11,A14,A15,A16,A17,A18	A3,A6,A11	6
A11	A3,A6,A11	A1,A6,A8,A11,A14,A15,A17	A6,A11	

Table -6: Iteration Matrix 6

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A11	A11	A1,A6,A8,A11,A14,A15,A17	A11	7

Table -7: Iteration Matrix 7

	REACHABILITY SET	ANTECEDENT	INTERSECTION	LEVEL
A1	A1,A2,A3,A5,A6,A7,A9,A10, A11,A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,,A16,A17,A18	A1,A2,A3,A5,A6,A7,A9,A10, A11,A14,A15,A16,A17,A18	2
A2	A2,A3,A5,A6,A16	A1,A2,A3,A5,A6,A7,A8,A9,A11, A12,A14,A15,A16,A17	A2,A3,A5,A6,A16	4
A3	A3,A6	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A3,A6	6
A4	A4,A6,A8,A16	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A17,A18	A4,A6,A8,A16	1
A5	A2,A3,A5,A6	A1,A2,A3,A5,A6,A9,A10,A12,A15, A16,A18	A2,A3,A5,A6	4
A6	A3,A6,A11	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A17,A18	A3,A6,A11	6
A7	A2,A3,A6,A7,A9,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A18	A2,A3,A6,A7,A9,A18	3
A8	A1,A2,A3,A4,A6,A7,A8,A9,A10, A11,A15,A16,A17,A18	A1,A2,A3,A4,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A17,A18	A1,A2,A3,A4,A6,A7,A8,A9, A10,A11,A15,A16,A17,A18	1
A9	A2,A3,A5,A6,A7,A9,A16,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A14,A15,A16,A18	A2,A3,A5,A6,A7,A9,A16,A18	3
A10	A1,A3,A5,A6,A7,A9,A10,A14, A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A17,A18	A1,A3,A5,A6,A7,A9,A10,A14, A15,A16,A17,A18	2
A11	A11	A1,A6,A8,A11,A14,A15,A17	A11	7
A12	A12	A3,A6,A12,A15	A12	5
A13	A13	A1,A2,A3,A5,A6,A12,A13	A13	1
A14	A1,A2,A3,A6,A7,A9,A10,A11, A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A9,A10,A11, A12,A14,A15,A16,A17,A18	A1,A2,A3,A6,A7,A9,A10,A11, A14,A15,A16,A17,A18	2
A15	A1,A2,A3,A5,A6,A7,A9,A10, A11,A12,A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A17,A18	A1,A2,A3,A5,A6,A7,A9,A10, A11,A12,A14,A15,A16,A17,A18	2
A16	A3,A6,A16	A1,A2,A3,A4,A6,A8,A9,A10,A11, A14,A15,A16,A17,A18	A3,A6,A16	5
A17	A1,A2,A6,A10,A11,A14,A15, A16,A17	A1,A2,A3,A5,A6,A7,A8,A9,A10, A11,A12,A14,A15,A16,A17,A18	A1,A2,A6,A10,A11,A14,A15, A16,A17	2
A18	A3,A5,A6,A7,A9,A16,A18	A1,A2,A3,A5,A6,A7,A8,A9,A10,A11, A14,A15,A16,A18	A3,A5,A6,A7,A9,A16,A18	3

Table -8: Final Iteration Matrix

4.6 Conical Matrix

Conical matrix is developed using the final reachability matrix. The drive power of a particular element is derived by summing up the number of ones in the rows and its dependence power by summing up the number of ones in the columns. These values of drive power and dependence power are used for MICMAC Analysis. The development of Conical Matrix is essential for MICMAC Analysis.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	Dri.
A1	1	1	1*	1	1*	1*	1*	1	1*	1	1*	0	1*	1	1	1*	1	1*	17
A2	1*	1	1*	1	1	1*	1	1	1*	1	0	0	1	1*	1	1*	1*	1*	16
A3	1*	1	1	1*	1	1*	1	1	1	1	0	1	1*	1*	1	1*	1*	1*	17
A4	0	0	0	1	0	1*	0	1	0	0	0	0	0	0	0	1*	0	0	4
A5	1*	1	1*	1*	1	1*	1*	1*	1	1	0	0	1*	1*	1	0	1*	1*	15
A6	1	1	1	1	1*	1	1	1*	1	1	1	1*	1*	1*	1*	1	1	1	18
A7	1	1*	1*	1*	0	1*	1	1*	1*	1	0	0	0	1*	1	0	1	1*	13
A8	1*	1*	1*	1	0	1	1*	1	1*	1*	1*	0	0	0	1*	1	1*	1*	14
A9	1*	1*	1*	1*	1	1*	1*	1	1	1*	0	0	0	1*	1	1*	1*	1*	15
A10	1*	0	1*	1*	1*	1*	1*	1	1	1	0	0	0	1*	1	1*	1	1*	14
A11	1*	1*	1*	1*	0	1	1*	1*	1*	1*	1	0	0	1*	1*	1	1*	1*	15
A12	1	1	0	1*	1*	0	1*	1*	0	1*	0	1	1*	1*	1*	0	1*	0	12
A13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
A14	1*	1*	1*	1*	0	1	1*	1*	1*	1	1	0	0	1	1*	1*	1*	1*	15
A15	1	1*	1	1	1*	1	1	1	1	1	1*	1*	0	1	1	1*	1	1	17
A16	1	1*	1*	1*	1*	1*	1*	1	1	1*	0	0	0	1*	1	1	1*	1	15
A17	1	1*	0	1*	0	1*	0	1	0	1*	1*	0	0	1	1*	1*	1	0	11
A18	1*	0	1*	1*	1*	1*	1*	1*	1	1*	0	0	0	1*	1	1	1*	1	14
Dep.	16	14	14	17	11	16	15	17	14	16	7	4	7	15	16	14	16	14	

Fig -5: Conical Matrix

4.7 MICMAC Analysis

MICMAC analysis stands for 'Matrice d'Impacts croises-multiplication appliqúe an classment' (cross-impact matrix multiplication applied to classification). The purpose of MICMAC analysis is to analyze the drive power and dependence power of the factors. It is based on the multiplication property of matrices. MICMAC analysis is done to identify the main factors which drive the system in different categories. The results of driving power and dependence power are further classified into four categories:

i. Autonomous factors: These factors have weak drive power and weak dependence power. They are relatively disconnected from the system, with which they have few links, which may be very strong.
ii. Linkage factors: These factors have strong drive power as well as strong dependence power. These factors are unstable in the fact that any action on these factors will have an effect on others and also a feedback effect on themselves.
iii. Dependent factors: These factors have weak drive power but strong dependence power.
iv. Independent factors: These factors have strong drive power but weak dependence power. A factor with a very strong drive power, called the 'key

factor' falls into the category of independent or linkage factors.

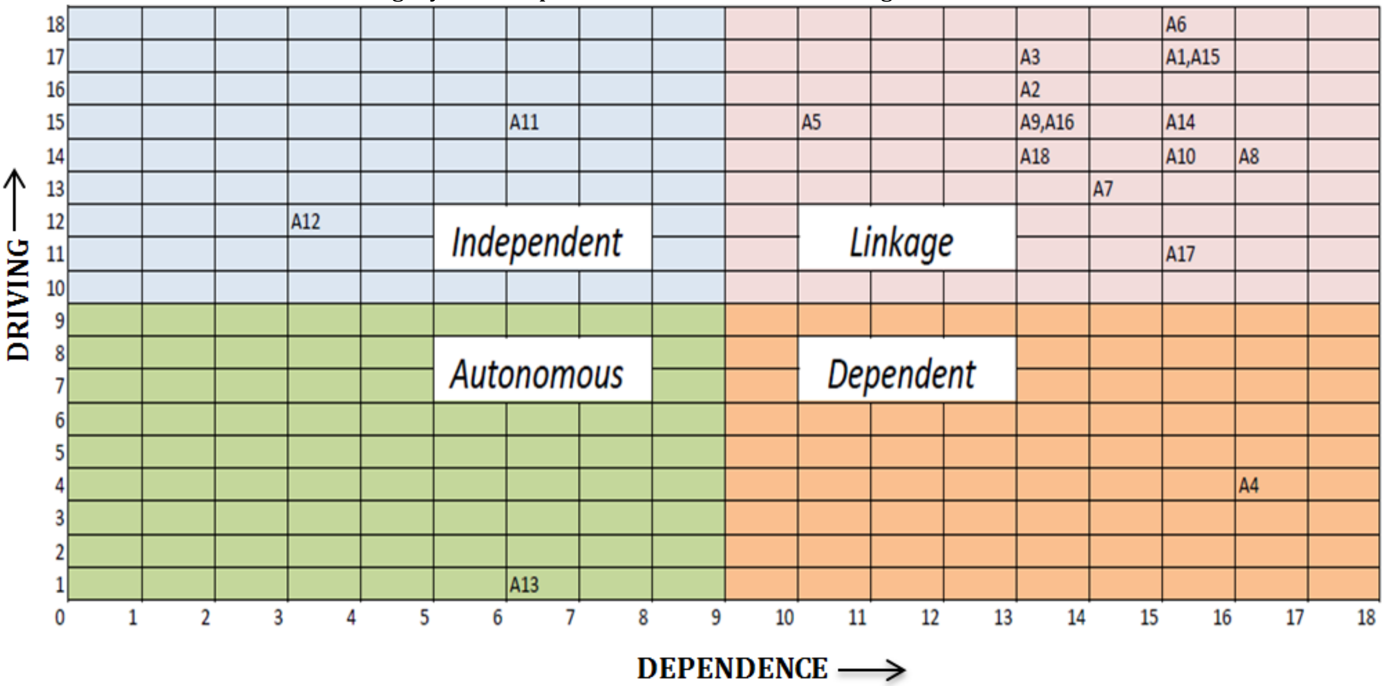

Fig -6: MICMAC Analysis

4.8 Digraph

From the conical matrix developed using the final reachability matrix, the digraph including transitive links is prepared. It is generated to present the interdependencies between the various elements under consideration. The diagraph consists of all the elements in a hierarchical order. The diagraph is used to illustrate transitive links between the elements, where the top level factor is positioned at the top of the digraph and second level factor is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph. The elements in diagraph are represented using the numerical values assigned to each individual element during the initial stage.

4.9 ISM Model

Diagraph is the medium to represent the interdependencies among the elements under consideration. But, a final hierarchical order i.e. the 'ISM Model' is required to illustrate a well-defined and structured order of the elements according to the levels allotted in the Iteration Matrix. The transitive links from the diagraph are eliminated to develop the ISM Model. At the same time, the representational numerical values assigned to the research variables i.e. elements are replaced with the entire statement or phrase of the variable itself. This ISM Model representing a hierarchical order of the variables in consideration is the result or final outcome obtained through the process of ISM methodology.

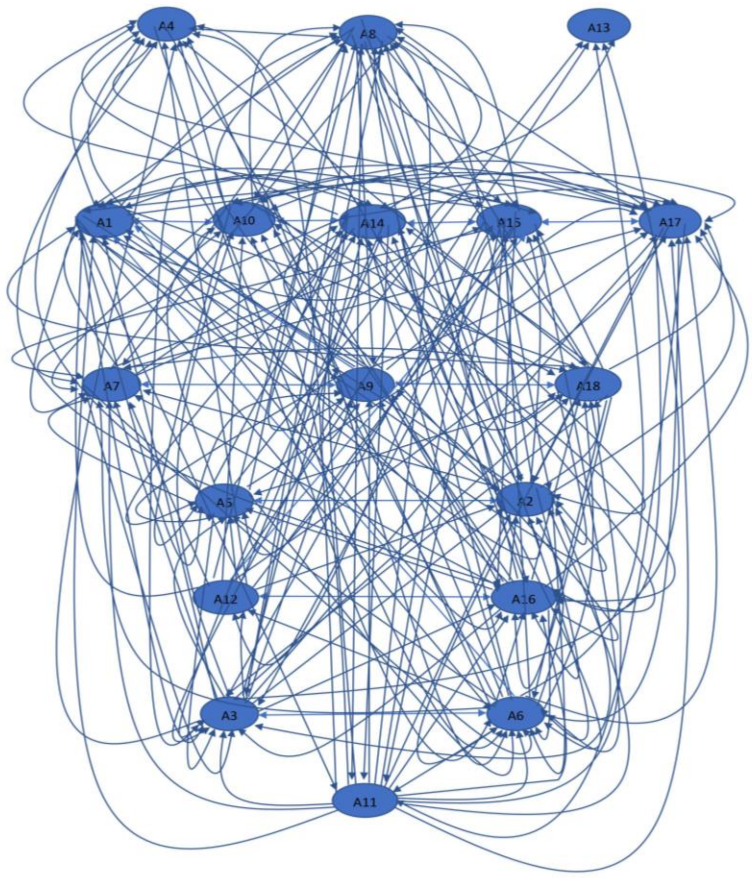

Fig -7: Digraph

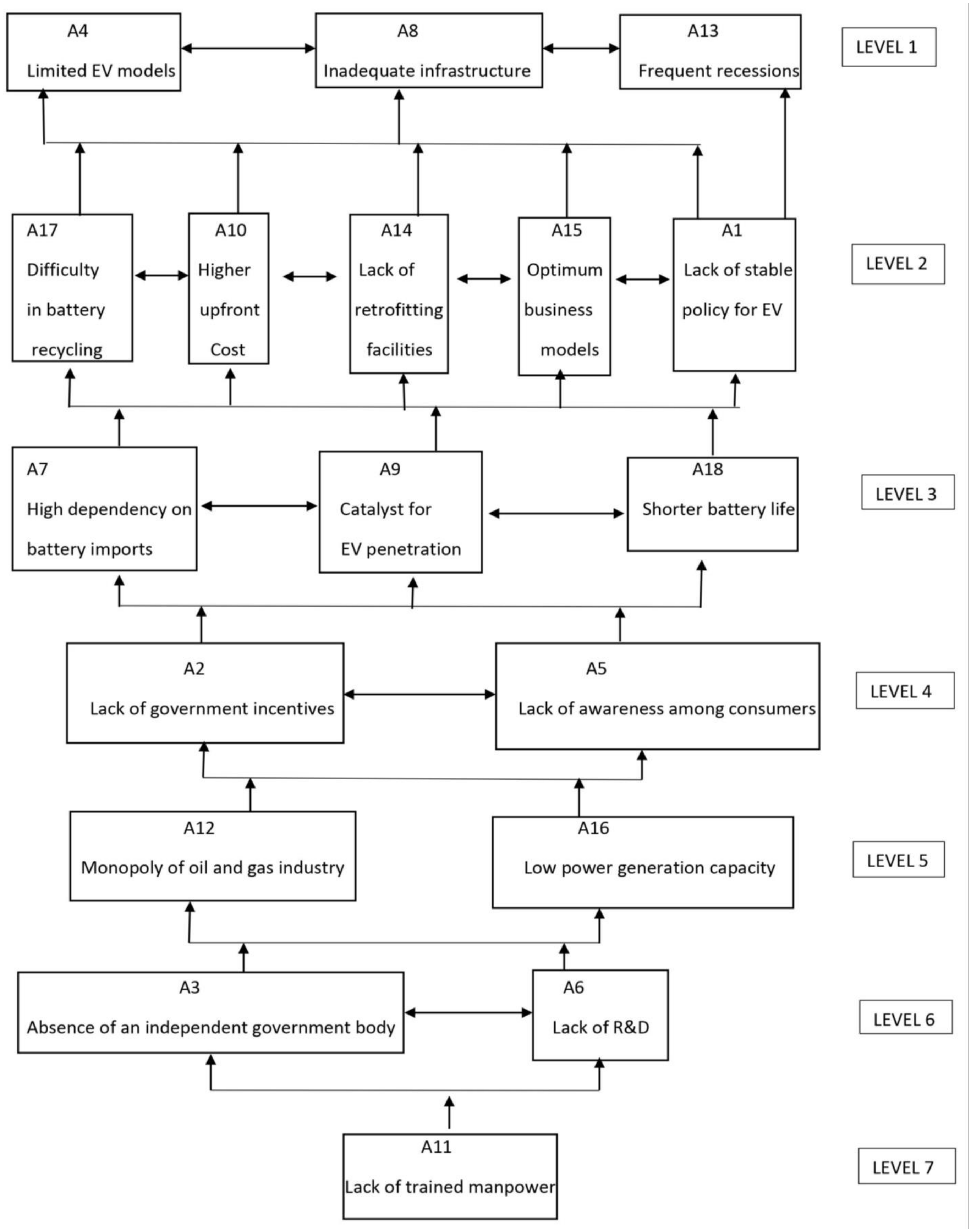

Fig -7: Final ISM Model

5. RESULT

The results obtained using ISM (Interpretive Structural Modeling) are quite convincing. India is a new, budding market for EVs; its development in this sector is slow but gradual with high ambitions. According to the final ISM model, the most influential barrier identified is 'lack of skilled manpower' in this newly emerging sector. In the year 2017, the Indian automotive sector employed about 1.3 million people which are relatively less, as compared to the European Union and the United States considering the colossal population of India. Considering the availability of manpower in terms of skilled, semi-skilled, or unskilled in the EV industry, the current numbers would not suffice for the EV industry. The other two influential factors identified were 'lack of an independent government body' and 'lack of research and development' activities in India. Having an independent and dedicated government body, to govern and regulate EV related policies is a must for a country like India; which has massive potential in developing the EV market. Currently, all the vehicle and transportation-related activities are under the Ministry of Road Transport and Highways (Parivahan Mantralay).

Lack of trained manpower also has its effect on the activities of research and development for EVs. This has a cumulative effect on the entire EV ecosystem. The moderately influencing factors are 'high dependency on imports', 'lack of government incentives', 'optimum business models' and 'lack of awareness among consumers'. The study has found 'limited EV models', 'frequent recessions' and 'inadequate infrastructure' as the most dependent factors among the ones considered. Considering the mind-set of an Indian consumer, in today's market scenario not many EV models are available, so as a result, the consumers can't put a finger on any of the models available. Consumer preferences and the models available in the market have a close relationship with each other and the leading automotive companies should consider this unusual behavior and plan their strategies accordingly. To conclude, the development of EVs in India is possible only if there is sufficient availability of skilled personnel who would possess the expertise required to work with the EV technology and achieve the e-mobility goals of India. The government should consider this and look into its development with solemn.

6. CONCLUSIONS

It might be right to say that EVs are an inevitable future but certainly, not the complete future. This study gives acquaintance to the barriers and challenges that somehow restrict the development of EV industry in India. Profound research and study was done to identify key barriers that hinder the development of EVs in the country. These barriers were analyzed using the ISM methodology wherein, contextual relationships between these factors were established according to the views and opinions of the experts involved in the study. The study indicates that the current situation is not much conducive for the development of this sector in India and needs immense attention for improvement and further development. If not given the right attention, the essential developments that took place in recent times may go in vain after a few years. The goal of achieving electrification in the road transportation sector can only be achieved until the basic operational requirements are met irrespective of the region.

Practically, only EVs cannot be considered as the complete future. The path of transition from the traditional ICEVs to EVs is full of obstacles but is certainly not impossible. To overcome these challenges, ingenious policies by the government with sufficient public support and minimum opposition is necessary. The improvement in battery technology and further research in other domains such as range enhancement, operating technology and costs should also be considered before any major move by the government or any private entity alike. The Indian automotive market is very fragile in terms of cost and the behavior of Indian consumers. Owning a car is a form of prestige and better social status in the Indian society and hence forms an important factor to be considered by any company before setting up its business in this embryonic sector. The efforts from both ends i.e. public as well as the private sector are equally important for developing this technology in India. But, solely EVs cannot be considered as the future of sustainable transportation; other alternatives should also be considered and developed namely, Hydrogen fuel cell vehicles, Bio-fuel vehicles, etc. The transition to EVs will not be instant, but will consume time, money, and resources which will all be worth it for the coming generations who will be safe from environmental hazards and will prevail with a cleaner, greener and brighter future with sustainable transport.

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