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Identification and Analysis of the Barriers for Autonomous Car: An Interpretive Structural Modeling Approach

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Abstract:
Background: Accidents involving passenger vehicles, trucks and busses are primarily caused due to human error. In automobile sectors, scientists and researchers have been involved to develop new technology to reduce the human effort with maximum safety. Autonomous Vehicle (A.V.) is milestone step for automobile industries. Adoptability of this technology depends upon the elimination of the various barriers in the AV's. So there is need to identify the different barriers for successful implementation of autonomous cars.
Purpose: The objective of this paper is to identify the different barriers and develop an interpretive structural model (ISM) which shows the inter-relationship of different barriers and their levels of importance. This study will help to sort out these barriers to increase the adoptability of the AV's.
Methods: Qualitative research has suggested methods that involve personal narratives and in-depth interviews. The effectiveness of such methods can be enhanced using the techniques of formal logic. The approach used for the case is a simulation of strategic group decision making process using interpretive structural modelling. In this paper, fourteen barriers have been selected from the literature. For ISM, contextual relationships among these barriers have identified with subsequent discussions with experts from academia and industry. MICMAC analysis has been also carried out for the classification of barriers based on dependence and driving power.
Results and conclusion: This research shows that all barriers of autonomous car are not required the same amount of attention. There exists a group of barriers that have high driving power and low dependence, requiring maximum attention, and another group that has a high dependence but low driving power. This classification will help decision makers to focus on those variables (barriers) that are most important for the adoptability of the autonomous car.

Keywords: Autonomous Vehicles, Driverless Car, Interpretive Structural Model (ISM), MICMAC analysis

I. Introduction

Volpe (2002) found that driver error is the primary cause of about 90% of reported crashes involving passenger vehicles, trucks, and busses. Distracted driving is emerging as a major cause for concern. Safety research suggests that common errors in driving result from lack of timely driver action or reactions to unpredictable events and incomplete information.

Researchers believe that these driverless cars can reduce the total number of crashes and in turn, can reduce the total money lost on crash related losses. As we know that human driver makes mistakes in the driving environment with its uncertainty attributes in the same manner the uncertainties also work against the machine. In the opinion of Rupp (et al. 2010) contemporary or even advanced machines in the foreseeable future cannot attain anywhere near the level of holistic human cognition.

According to Markoff (2010) the most outstanding example AV is the Google Autonomous Cars which to date have logged thousands of kilometers of autonomous driving in the United States.

To keep themselves on the track or roadway AV's needed to have real time sensing of their surroundings and environment. This is accomplished with the help of computer vision and the techniques like LIDAR and GPS. All the information gathered by the sensor's and processed by the control system to reach the best suited action in shortest time.

Decisions of choosing the best suited path, avoiding collisions and accidents, speed control and lane change over, are done by control systems. Control system process all the

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information gathered by various sensors mounted on AV for real time decisions Markoff (2010). As AV is continuously moving on the specified track, the surrounding and the environment around it is changing, this change is sensed by the sensors' and the map of the AV is for tracking is continuously updated. The autonomous vehicles extend various advantages to the humans such as. Brookhuis, (et al.2009), Stanton and Marsden (1996) put forth that Vehicle to Vehicle (V-to-V) communication is more accurate than a human driver and it decreases mental workload and enhances the psychological well-being of the driver. AV's facilitate preventive maintenance hence condition of the vehicle is maintained which results in reduced maintenance costs. AV facilitates 'just in time' scheduling for pick-up and delivery. The speed can be remotely adjusted to fit demand. Simultaneous monitoring of multiple vehicles is possible .Vehicle downtime is minimized. . Kockelman and Fagnant (2013), Riener and Reder (2014) stated that AV reduces the danger at accident prone areas or spots. Continuous monitoring and lack of human error while driving results in a much safer journey

With the AV people will get extra time for themselves as they are not busy driving. More over problem associated with human driving like heavy drinking, use of drugs, falling asleep, run over red lights can be avoided. Autonomous vehicles can perform in all weather conditions and also during night operations. AV can work fine in environments with high magnetic fields and corrosive atmospheres. These vehicles are very helpful for disabled and physically challenged persons. Lewis.C (2014) put forth the fact that, there is a total cost of $625 billion per year in the US due to motor vehicle-related accident and pointed out that if 90% of accidents are caused by driver error and if this is prevented theoretically the cost of accidents will reduce by 90%. This could save $563 billion (90% of $625 billion) per year.
Identification of barriers in the development and implementation of driverless cars is done in Section 2. Step wise elaborated ISM methodology to find levels of these barriers and ISM based model formation of these barriers follows in Section 3. MICMAC analysis has been presented in Section 4. Section 5 of the paper presents results and discussions. Section 6 Contains the Conclusion.

II. IDENTIFICATION OF BARRIERS IN THE DEVELOPMENT AND IMPLEMENTATION OF DRIVERLESS CARS

The fourteen barriers are identified through literature review, personal narratives and in-depth interviews for the development and implementation of driverless cars. They are:-

Traffic is growing by leaps and bounds and is a major issue which arises in the proper implementation of driverless car. As stated by Mahapatra and Maurya (2013) that in a mixed traffic flow, with no lane discipline the lateral movement of the vehicles are very high due which presents problem for AV's. Phillips and Sagberg (2014) brought the barrier of decision of crossing a unmanned railway crossing is always a critical decision to take for AV's

The price barrier as stated by Kockelman and Fagnant (2013) point outs that the technology needed for an AV includes sensors, communication and guidance technology, and software for each automobile which makes AV very costly. Thus driverless car is currently unaffordable to common people in developed countries and is a dream for others. Pricing of automobiles is a complex issue as it is dependent on fixed cost, economies of scale, technology and other aspects. Competition and consumer demand also play important role in this. Menon (2013) notified that barriers to market penetration include high costs of the technology, which is currently affordable only for a selected group of the society.

An AV's is made of many software and hardware components and which are interlinked with each other. Maarten (2013) brought forward the e need of a safety certification system for the customers. For many different technical systems procedures and standards exist, but for automated transport systems such standards did not yet exist. The rules and regulations for the licensing of autonomous vehicle vary with place to place. Without a consistent licensing framework and standardized set of safety for acceptance, autonomous vehicle manufacturers may be faced with regulatory uncertainty and unnecessary overlap, among other issues Kockelman and Fagnant (2013).

The contemporary driving is controlled by a regulatory system. AV's would also require a well framed regulatory system for them. A new regulatory system is to be designed. Autonomous vehicle can become a disaster at any time, if it is into wrong hand; there would be need of check posts and traffic tool booth where AV can be diagnosed from any software malfunctioning and any other problem.

Calo (2011) as different countries of the world have different laws over the legality of these autonomous vehicles. Fixing the liability in case of an accidental damage or failure of any system/part is the major barrier for AV's. Further more in the unforeseen event of a crash the challenge of fixing the liability of either manufacturer or the consumer is a barrier. This in turn affects the insurance companies and policies also.

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During the possibility of a crash, the computer will have to make decisions regarding which lane to shift to or to stop and other many complex decisions. These decisions are yet not possible to take for the AV's system and they are also not able to distinguish between a pedestrian and a cop on roadside giving some signal. Autonomous vehicle also cannot predict or anticipate the movement of other independently driving vehicles or a reckless driver driving in the streets.

There are many security concerns related to autonomous vehicle. Av's bring many security threats along with them. There may be attacks from computer hackers or terrorist's organizations. AV manufactures have to ensure proper working under the multi –agent system. Hostile nations may target autonomous vehicle and intelligent transportation systems with a motive driven either by finance, politics or violence, causing collisions and traffic disruptions. To prevent these Communication systems of AV's needed to be robust and fail safely in case of corruption or cyber-attack.

AV made by Google, relies over four major technological components i) LIDAR (Light Detection and Ranging) ii) A set of on board cameras iii) GPS (global positioning system) iv) Stored maps in the vehicles on board computer for its operation. Like all other electronic components they are vulnerable for malfunctioning and in that case the functioning of the AV will be in doubt.

Road design is another barrier which needs to be clearly examined. Every country have there, own road design depending upon the geographical diversity. Each country will have different population density, different environmental condition and different culture and hence will have different road design. With such a vast diversity in road design this is becoming a major barrier for the developer to develop a world-wide autonomous car.

Maintenance of AV is one of the various important aspects which need to be clearly examined. The availability of various parts at all the location has to be ensured by the manufacturers. If the problem which occurs is related to software, a technical expert has to be present to get the problem corrected. Also the availability of high priced sensors availability is a major concern for the manufacturers and the buyer's also. Thrun (2010) in their study stated that, Google verified that during test ride of its AV, a safety driver and software expert was present in the car always to take over the controls in case there was a problem in the software or any other technical problems

It has been observed peoples trust in AV's is missing. The idea that a machine could kill a human being, however rare the chance of that has to be, is found to be a major deterrent in the mind of the human being. Human Rights Watch (2012). Lee and Moray (1994) identified that the common consumer and researchers together fear that an overdependence on automation might possibly lead to a degradation of skill for the user of the automated vehicle

The climatic conditions changes as the geographical situation changes around the world. Furthermore with the change in climatic conditions the AV has to perform in adverse conditions like snow, fog, dust, rainfall, etc. As AV's performance fully depends on sensitive and high quality sensors it is not possible for AV to quickly adapt to these conditions. In case of bad weather conditions like dust storm or heavy rainfall the poor quality image will be detected by the camera and LIDAR sensing capability will be hindered too. Because of poor image quality and difficulty in LIDAR performance level the AV ability to avoid collision and steer on the right track is highly questionable.

Parasuraman (2000) stated that slowly and slowly ,when automation will gain confidence of drivers , operators will start relying more and more on the technology and will result in less utilization of human skills which will ultimately lead to total loss skill which will further increases the dependence on automation. Lee and Moray (1994) and Wilde (1998) stated that another possible situation is of risk homeostasis exist in which drivers could begin to accept more risk as they perceive the automation to be more capable then the humans and because of this more distraction while driving will be seen.

In many countries one of the barriers in the implementation of driverless car is emissions and getting clearance certificate from environmental department because of high standards. If autonomous vehicles do increase road capacity, this could lead to more vehicles on our roads, thereby increasing emissions. All the identified barriers for the development of driverless cars are listed in table 1.

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Table 1 Identified Barriers of the Driverless Car

SN.	Barriers to the driverless cars	Description of barriers	Authors
1	Overall traffic increment	With increase in traffic car design will become more complex.	9 , 26 , 7
2	Cost of driverless car	Cost of driverless car is very high and in not affordable in developing countries.	6 , 8 , 27 , 28 29 , 11
3	Autonomous vehicle licensing problem	The process of licensing will be a tough process and because of various parameters like age etc.	12 , 6 , 30
4	Regulatory issue	With increase in no. of cars, the regulation will become tougher.	31
5	Responsibility(Liability)	Who will be the responsible for accidents according to law.	13 , 32 , 33 , 12 , 6
6	Decision making of car	There are various barriers in the decision making under critical circumstances.	12
7	Cyber security	Security is always a concern because of hacking and tracking.	6 , 34
8	Technological barrier due to incomplete R & D work.	Various technological barriers which are yet to be removed.	35 ,36 ,37 ,38 , 12
9	Road design	Present road design in various countries is a major concern.	6
10	Maintenance (After Sales Services)	Maintenance will always require a skilled worker and will require very good after sales services.	14
11	Consumer acceptance and trust	How consumer will interpret safety, privacy and security.	32 , 16 , 18
12	Geographical Barriers	Geographical conditions are different in different part of world.	38 , 39
13	Loss of skill and employment of drivers	More driverless cars will lead to Loss of skill and employment of drivers.	40 ,41 , 16 , 18 , 42 , 7
14	Environmental issues (pollution)	More will be the cars, more emission will be there.	43 , 12 , 44

III. Interpretive Structural Modelling Methodology

Interpretive structural modelling (ISM) is a methodology proposed by J. Warfield in 1973 which deals with complex problems in a structured way. ISM combines words, graphics and discrete mathematics to develop a multilevel model which clearly maps the relationships between the various elements related to the model. The multilevel model shows the various sublevel and the elements along with their interrelationship with each other at each level. The ISM provides a better understanding of the complex issue and help in reaching a solution of the complex problem. The initial phase of the ISM methodology depends on the response given by the experts. The experts knowledge and their know how about the various element involved in the model decides the type of relationship elements may have.

The various steps involved in ISM development are (Kumar et al. 2011):-

- Identification and listing of all the various issues and barriers concerning the system under consideration is done. In this research all the barriers in the development and implementation of driverless cars have been identified.
- Relationship among all the variables identified in 1st step is determined thus finalizing the pairs to be taken in consideration.
- Pair wise relationship is indicated with structural self-interaction matrix for the complex system.
- From structural self interaction matrix (SSIM) a reachability matrix is developed to check for transitivity among the variables. The con-textual relationship transitivity is checked on the principle that if variable M is related to variable N and variable N is related to variable L, then variable M and L are necessarily related to each other.
- Different levels are obtained by partitioning of reachability matrix obtained in earlier

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- Removal of transitive links and drawing of the direct graph is done, based on the relationships of the reachability matrix.
- Variable nodes are replaced by statements to convert the diagram in to ISM.
- The ISM model developed in the previous step is modified if required after checking the conceptual inconsistency.

The various authors used this ISM techniques in different areas.-

Jia.P (et al, article in press) analyzed and identified dominant sustainable supply chain management (SSCM) practices in the mining and mineral industries with the help of ISM. Mathiyazhagan.k (et al, 2013) analyzed the barriers for the implementation of Green supply chain management (GSCM) concept by dividing the divided the research study in to two phases i) identification of barriers and ii) qualitative analysis. Twenty six barriers were identified in the Indian auto industries. Problem in maintaining the environmental awareness of suppliers is found as the key barrier for the implementation of GSCM. Tamrakar and sudhindra (2014) tried to create a hierarchical framework of barriers to Green Supply Chain Management in the Indian Construction Industry. Using Delphi technique thirteen barriers were finalised. Finally the awareness, training and development and Government support is identified as the key factor for successfully implementing GSCM in the organizations. Jayant and Azhar (2014) identified twenty barriers out of which nineteen barriers are identified as linkage barriers , one barrier as driver barriers . No barrier was found as dependence and autonomous barriers. Ansari M.F (et al. 2013) identified thirteen barriers for implementing solar power installations from experts and literature. They also suggested the ways to remove one top and six bottom level barriers identified in the study.

3.1 Data gathering and formation of structural self-interaction matrix (SSIM)

As mentioned earlier in section 3 the nature of the contextual relationships among the barriers was identified in the development and implementation of driverless cars.

Following four symbols have been used for developing SSIM to denote the direction of relationship between two barriers m and n:

V: Barrier m will help achieves barrier n;
A: Barrier n will help achieve barrier m;
X: Barrier m and n will help achieve each other;
O: Barriers m and n are unrelated.

SSIM has been developed on the basis of contextual relation- ships (Table 2). Barrier 1 leads to barrier 4 so symbol 'V' has been given in the cell (1,4); barrier 4 leads to barrier 5 so symbol 'A' has been given in the cell (5,4); barrier 6 and 6 lead to each other so symbol 'X' has been given in the cell (6,6); barrier 1 and 6 do not lead to each other so symbol 'O' has been given in the cell (1,6) and so on.

Table 2: Structural Self-Interaction Matrix

Barriers to driverless cars	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1.Overall traffic increment	X	O	O	V	V	O	V	A	A	V	A	A	V	V
2. Cost of driverless car		X	A	A	O	O	O	A	O	A	O	O	O	O
3.Automated vehicle licensing problem			X	X	A	O	O	A	O	A	A	O	V	V
4. Regulatory issue				X	A	A	V	A	A	O	V	A	O	O
5. Responsibility (liability)					X	O	A	A	O	O	V	O	O	O
6. Decision making of car						X	O	A	A	O	V	O	O	O
7. Cyber security							X	A	O	O	V	O	O	O
8. Technological barrier due to incomplete R&D work.								X	O	V	V	V	V	V
9. Road design									X	V	O	A	O	O
10. Maintenance(after sales services)										X	V	A	O	O
11 Consumer acceptance and trust											X	O	A	A
12. Geographical barriers												X	O	O
13. Loss of skill and employment of drivers													X	O
14. Environmental issues(pollution)														X

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3.2 Reachability Matrix

Initial reachability matrix obtained is converted in to SSIM. SSIM is purely a binary matrix as only '1' and '0' are placed in the matrix substituting the symbols (A, V, X, 0). Following rules are followed for substituting the symbols.

1 In SSIM if value of cell (m,n) is V then value of cell(m,n) is '1' and cell(n,m) value will be '0' for initial reachability matrix. In this case in SSIM the cell (1,4) value is V ,so in the initial reachability matrix , cell (1,4) is given value '1' and cell (4,1) is given value '0'.

2 In SSIM if value of cell (m,n) is A then value of cell(m,n) is '0' and cell(n,m) value will be '1' for reachability matrix. In this case in SSIM the cell (2,4) value is A ,so in initial reachability matrix , cell (2,4) is given value '0' and cell (4,1) is given value '1'.

3 In SSIM if value of the cell (m,n) is X , then value of cell(m,n) and cell(n,m) will be '1' for initial reachability matrix. In this case in SSIM the cell (3,4) value is X ,so in initial reachability matrix , both cell (3,4) and cell (4,3) are given value '1'.

4 In SSIM if value of the cell (m,n) is O , then value of cell(m,n) and cell(n,m) will be '0' for initial reachability matrix. In this case in SSIM the cell (5, 9) value is 0, so in initial reachability matrix , both cell (5,9) and cell (9,5) are given value '0'.

For the development and implementation of driverless cars an initial reachability matrix has been developed as shown in (Table 3). As mentioned earlier, transitivity is added to initial reachability matrix and final reachability matrix is obtained. Then the driving power and dependence power of each barrier is obtained.

Table 3 Initial reachability matrix for barriers for driverless cars

BARRIERS TO DRIVERLESS CARS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1.OVERALL TRAFFIC INCREMENT	1	0	0	1	1	0	1	0	0	1	0	0	1	1
2. COST OF DRIVERLESS CAR	0	1	0	0	0	0	0	0	0	0	0	0	0	0
3.AUTOMATED VEHICLE LICENSING PROBLEM	0	1	1	1	0	0	0	0	0	0	0	0	1	1
4. REGULATORY ISSUE	0	1	1	1	0	0	1	0	0	0	1	0	0	0
5. RESPONSIBILITY (LIABILITY)	0	0	1	1	1	0	0	0	0	0	1	0	0	0
6. DECISION MAKING OF CAR	0	0	0	1	1	1	0	0	0	0	1	0	0	0
7. CYBER SECURITY	0	0	0	0	1	0	1	0	0	0	1	0	0	0
8. TECHNOLOGICAL BARRIER DUE TO INCOMPLETE R & D WORK.	1	1	1	1	1	1	1	1	0	1	1	1	1	1
9. ROAD DESIGN	1	0	0	1	0	1	0	0	1	1	0	0	0	0
10. MAINTENANCE(AFTER SALES SERVICES)	0	0	1	0	0	0	0	0	0	1	1	0	0	0
11 CONSUMER ACCEPTANCE AND TRUST	1	0	1	0	0	0	0	0	0	0	1	0	0	0
12. GEOGRAPHICAL BARRIERS	1	0	0	1	0	0	0	0	1	1	0	1	0	0
13. LOSS OF SKILL AND EMPLOYMENT OF DRIVERS	0	0	0	0	0	0	0	0	0	0	1	0	1	0
14. ENVIRONMENTAL ISSUES(POLLUTION)	0	0	0	0	0	0	0	0	0	0	1	0	0	1

3.3 Level's partitioning

The level's partitioning is done to get the importance level of each barrier .From the final reachability matrix; the reachability and antecedent set Warfield. J (1974) for each barrier have been obtained. The reachability set of a barrier is the set of barriers influenced by it and the barrier itself, whereas the antecedent set of a barrier is the set of barriers which may influence it and the barrier itself. Reachability set, antecedent set and intersection sets for all the barriers have been found. In the ISM hierarchy level 1(top level) hierarchy is given to those barriers which have the same reachability sets and intersection sets. (Table 5) Level 1 is then not considered for the next iteration for finding further levels. Table 6 shows the second iteration for partitioning the levels of barriers in the development and implementation of driverless cars. The iterations are repeated till levels of all the barriers are found. Summarizations of all the levels are given in table 7. Over all 10 levels are identified in this study. At the top level Cost of driverless car has been identified barrier and 'Technological barrier due to incomplete R & D work.' has been identified as most important bottom level barriers. Fig 2 shows the ISM model for barriers of driverless cars.

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3.3 ISM based model formation for barriers in the development and implementation of driverless cars.

From the final reachability matrix (Table 4), the structural model is generated by vertices and edges Jharkharia and Shankar (2005). Out of the fourteen barriers identified, 'Technological barrier due to incomplete R & D work' is lying at the bottom level of model and 'Cost of driverless car' is lying at the top level of model. Rest twelve Automated vehicle licensing problem , Responsibility (Liability), Loss of skill and employment of drivers, Cyber security, Maintenance (After Sales Services), Overall traffic increment, Regulatory issue, Consumer acceptance and trust, Environmental issues (pollution), Decision making of car, Road design, Geographical Barriers are lying in between top and bottom levels. Furthermore MICMAC analysis has been carried out for classifying these 14 barriers and digraph is made. After removing the transitivity's as described in the ISM methodology, ISM model has been made as shown in Fig. 1.

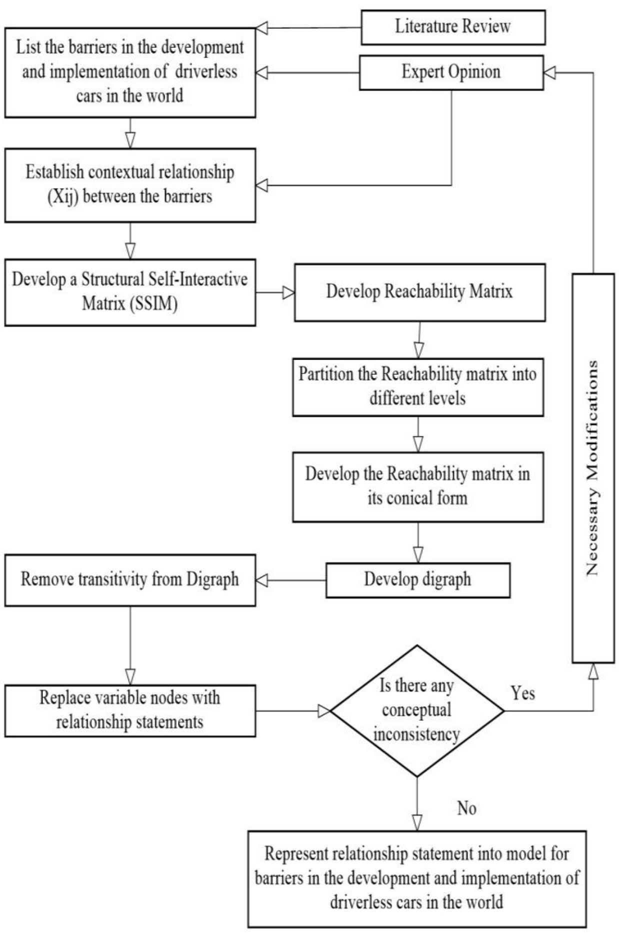

Figure 1. Flow diagram for ISM construction

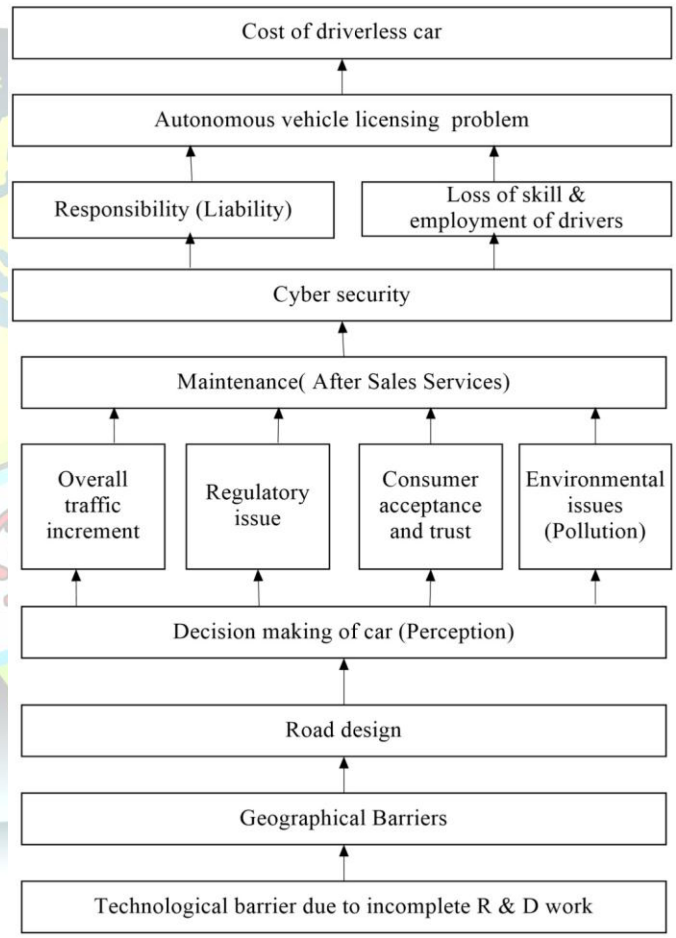

Figure 2: ISM based model for barriers of driverless cars

Table 4: Final reachability matrix for barriers for driverless cars

Barriers to driverless cars	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Dp
1.Overall traffic increment	1	0	1	1	1	0	1	0	0	1	0	0	1	1	**8**
2. Cost of driverless car	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**

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3.AUTOMATED VEHICLE LICENSING PROBLEM	0	1	1	1	0	0	0	0	0	0	1	0	1	1	**6**
4. REGULATORY ISSUE	1*	1	1	1	1*	0	1	0	0	0	1	0	0	0	**7**
5. RESPONSIBILITY (LIABILITY)	0	1*	1	1	1	0	0	0	0	0	1	0	1*	1*	**7**
6. DECISION MAKING OF CAR	1*	1*	1*	1	1	1	1*	0	0	0	1	0	0	0	**8**
7. CYBER SECURITY	0	1*	1*	0	1	0	1	0	0	0	1	0	1*	1*	**7**
8. TECHNOLOGICAL BARRIER DUE TO INCOMPLETE R & D WORK.	1	1	1	1	1	1	1	1	0	1	1	1	1	1	**13**
9. ROAD DESIGN	1	0	0	1	1*	1	1*	0	1	1	0	0	1*	1*	**9**
10. MAINTENANCE(AFTER SALES SERVICES)	0	0	1	1*	1*	0	0	0	0	1	1	0	1*	1*	**7**
11 CONSUMER ACCEPTANCE AND TRUST	1	0	1	1*	1*	0	0	0	0	0	1	0	0	0	**5**
12. GEOGRAPHICAL BARRIERS	1	1*	1*	1	1*	1*	1*	0	1	1	1*	1	1*	0	**12**
13. LOSS OF SKILL AND EMPLOYMENT OF DRIVERS	0	0	1*	1*	1*	0	0	0	0	0	1	0	1	0	**5**
14. ENVIRONMENTAL ISSUES(POLLUTION)	1*	0	0	1*	1*	0	0	0	0	0	1	0	0	1	**5**
DEPENDENCY	**8**	**8**	**11**	**12**	**12**	**4**	**7**	**1**	**2**	**5**	**11**	**2**	**9**	**8**	**100**

Table 5. First iteration for partitioning of levels of barriers of driverless cars

BARRIERS S.NO.	REACHABILITY SET	ANTECEDENT SET	INTERSECTION	LEVEL
1.	1 ,3,4,5,7,10,13,14	1,4,6,8,9,11,12,14	1,4,14	
2.	2	2,3,4,5,6,7,8,12	2	1ST
3.	2,3,4,11,13,14	1,3,4,5,6,7,8,10,11,12,13	3,4,11,13,14	
4.	1,2,3,4,5,7,11	1,3,4,5,6,8,9,10,11,12,13,14	4,5,11,13	
5.	2,3,4,5,11,13,14	1,4,5,6,7,8,9,10,11,12,13,14	4,5,11,13	
6.	1,2,3,4,5,6,7,11	6,8,9,12	6	
7.	2,3,5,7,11,13,14	1,4,6,7,8,9,12	7	
8.	1,2,3,4,5,6,7,8,10,11,12,13,14	8	8	
9.	1,4,5,6,7,9,10,13,14	5,9	5,9	
10	3,4,5,10,11,13,14	1,8,9,10,12	10	
11.	1,3,4,5,11	3,4,5,6,7,8,10,11,12,13,14	3,4,5,11	
12.	1,2,3,4,5,6,7,9,10,11,12,13	8,12	12	
13.	3,4,5,11,13	1,3,5,7,8,9,10,11,12,13	3,5,13	
14.	1,4,5,11,14	1,3,5,7,8,9,10,14	1,5,14	

Table 6. Second iteration for partitioning of levels of barriers of driverless cars

BARRIERS S.NO.	REACHABILITY SET	ANTECEDENT SET	INTERSECTION	LEVEL
1.	1 ,3,4,5,7,10,13,14	1,4,6,8,9,11,12,14	1,4,14	
2.				1ST
3.	3,4,11,13,14	1,3,4,5,6,7,8,10,11,12,13	3,4,11,13,14	2ND
4.	1,,3,4,5,7,11	1,3,4,5,6,8,9,10,11,12,13,14	4,5,11,13	
5.	3,4,5,11,13,14	1,4,5,6,7,8,9,10,11,12,13,14	4,5,11,13	
6.	1,3,4,5,6,7,11	6,8,9,12	6	
7.	3,5,7,11,13,14	1,4,6,7,8,9,12	7	

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8.	1,3,4,5,6,7,8,10,11,12,13,14	8	8	
9.	1,4,5,6,7,9,10,13,14	5,9	5,9	
10	3,4,5,10,11,13,14	1,8,9,10,12	10	
11.	1,3,4,5,11	3,4,5,6,7,8,10,11,12,13,14	3,4,5,11	
12.	1,3,4,5,6,7,9,10,11,12,13	8,12	12	
13.	3,4,5,11,13	1,3,5,7,8,9,10,11,12,13	3,5,13	
14.	1,4,5,11,14	1,3,5,7,8,9,10,14	1,5,14	

Table 7 summarized levels of iterations

S.No.	Level No.	Barriers in the development and implementation of driverless cars in the world
1.	1ST	• Cost of driverless car
2.	2ND	• Automated vehicle licensing problem
3.	3RD	• Responsibility (Liability) • Loss of skill and employment of drivers
4.	4TH	• Cyber security
5.	5TH	• Maintenance(After Sales Services)
6.	6TH	• Overall traffic increment • Regulatory issue • Consumer acceptance and trust • Environmental issues(pollution)
7.	7TH	• Decision making of car
8.	8TH	• Road design
9.	9TH	• Geographical Barriers
10	10TH	• Technological barrier due to incomplete R & D work.

IV. Barrier classifications: MICMAC analysis

Cross-impact matrix multiplication applied to classification is abbreviated as MICMAC Sohani and Sohani (2012). MICMAC analysis is done to find the drive and dependence power of the barriers under consideration.
Further more on the basis of drive power and dependence power all 14 barriers are classified in to four categories i.e. autonomous barriers, linkage barriers, dependent and independent barriers Luthra (et al 2011), Attri (et al 2013).

The variable having the strong driving power associated with it is termed as key variable. The key variables will be placed in III or IV quadrant of fig 3. Higher dependence values barriers will require more number of barriers to be removed first, before it can be eliminated where as a large number of barriers cam be eliminated when barrier with high driving value is removed. Fig. 3 shows the graph between dependence power and driving power for the barriers in the development and implementation of driverless cars.
Applying MICMAC analysis, all 14 barriers have been classified into four categories as shown in table 8.

Table 8 Categorization of barriers

S.No.	Barrier category	Drive power	Dependence power	Identified barriers	Total	Quadrant
1	Autonomous barriers	Weak	Weak	• Maintenance(after sales services)	01	I
2	Linkage barriers	Strong	Strong	• Overall traffic increment	01	III

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3	DEPENDENT BARRIERS	WEAK	STRONG	• COST OF DRIVERLESS CAR • AUTOMATED VEHICLE LICENSING PROBLEM • REGULATORY ISSUE • RESPONSIBILITY (LIABILITY) • CONSUMER ACCEPTANCE AND TRUST • LOSS OF SKILL AND EMPLOYMENT OF DRIVERS • ENVIRONMENTAL ISSUES(POLLUTION)	07	II
4	INDEPENDENT BARRIERS	STRONG	WEAK	• ROAD DESIGN • CYBER SECURITY • TECHNOLOGICAL BARRIER DUE TO INCOMPLETE R & D WORK • ROAD DESIGN • GEOGRAPHICAL BARRIERS	05	IV

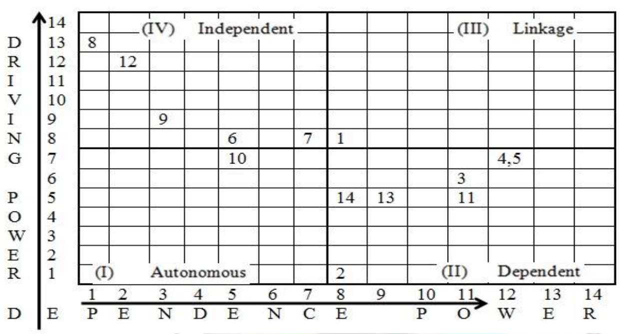

Figure 3 Graph between dependence power and driving power for the barriers of driverless cars

IV. RESULT AND DISCUSSION

The key findings of the present research are as follows:-

- Positioned at the bottom of ISM, 'Technological barrier due to incomplete R & D work', is the key barrier. As it has highest driving power and drives other factors also, it should be removed first.
- The factor 'Cost of driverless car' occupies the highest hierarchical level and 'autonomous vehicle licencing problem' is placed below it in the hierarchy. These factors represent the desired objective of removing barriers in the development and implementation of driverless cars. For obtaining these objectives the bottom level variables should be improved continuously.
- The factors 'Maintenance (After Sales Services)','Overall traffic increment', 'Regulatory issue', 'Consumer acceptance and trust', 'Environmental issues(pollution)', occupy a middle-level position in the ISM hierarchy indicating that these variables have high driving power and strong dependence power. These variables offer a most complex set of relationships and require special attention. Furthermore as these variables are not interdependent, improvement in any of these variables will not necessarily bring improvement to other variables of this level.

AV through its sensors gathers all the available information about the driving environment and provides information to assist the driver in optimal vehicle operation. The main objective is to provide assistance in the basic functions of driving like steer control, braking and stopping of the vehicle. Automotive manufacturers all over the world are investing significant resources in active safety systems for collision avoidance, accident avoidance, mitigation, and driver monitoring/support.

VI. CONCLUSIONS

In this study fourteen barriers for the development and implementation of driverless car have been identified and interpretive structural modelling (ISM) methodology has been used for finding contextual relationships among them. The technological barrier due to missing research is coming at the bottom of the structural model and cost of driverless car is coming at top of the structural model. Decision making, road design and geographical barrier which are coming at the bottom level of ISM model are also driver barriers or independent barriers. It indicates that they are most powerful barriers and removal of these barriers will remove maximum number of other barriers.

Based on experts' opinions a hypothetical model is developed for the identification of barriers in the

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development and implementation of driverless cars. Model validation can be done by real world conditions and furthermore the relationship between the variables as given by ISM model can also be checked for practicality.

On the basis of outcome of validation it may be found that more new barriers can be considered for analysis and due to inclusion of new barriers existing relationship between the variables may change. The relationship between the fourteen variables is clearly depicted by ISM model but the quantification of the relationship between the variables cannot be done by this method.

In this paper only fourteen barriers are identified but researcher can include more number of barriers. In that case, mathematical calculations may become difficult and tedious. Related software may be used to deal with large number of barriers. Further Interactive management (IM) and structural equation modelling (SEM) may be used to test the validity of the suggested model.

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