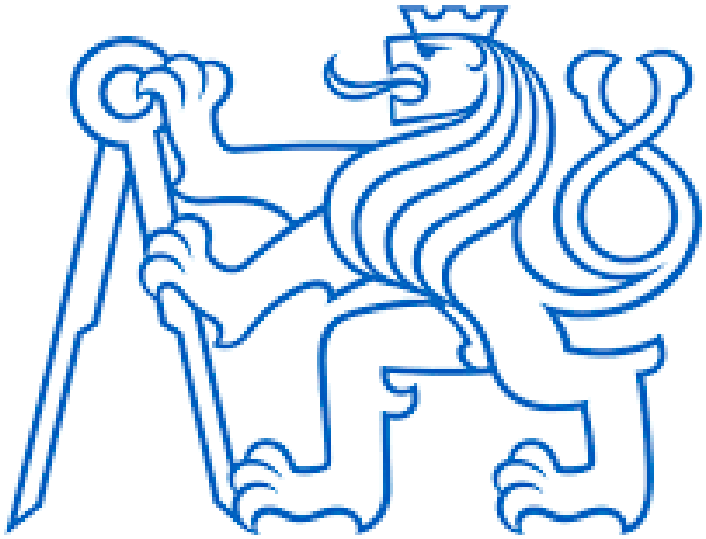
CZECH TECHNICAL UNIVERSITY, PRAGUE

FACULTY OF MECHANICAL ENGINEERING

DEPARTMENT OF PROCESS ENGINEERING



MULTICRITERIA COMPARISON OF AGGREGATE SUCTION COMPONENT

MASTER THESIS

2018 SUJIT PRAKASH PATIL

MASTER'S THESIS ASSIGNMENT

I. Personal and study details

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Faculty / Institute: **Faculty of Mechanical Engineering**

Department / Institute: **Department of Process Engineering**

Study program: **Mechanical Engineering**

Branch of study: **Process Engineering**

II. Master's thesis details

Master's thesis title in English:

Comparison of the aggregate suction components

Master's thesis title in Czech:

Porovnání komponentů systému sání agregátu

Guidelines:

The aim of the thesis are recommendations for components of an aggregate suction system intended for the Indian market. The research part will focus on the Indian automobile market, on the preferences of local customers and on the aggregate suction solutions. Data from the European environment will be provided to the student. In the practical part, data about Indian customer preference will be obtained through the questionnaire. In addition, a multi-criteria comparison of the aggregate suction components from the European and Indian environments will be performed. The output of the work will include the evaluation of the multi-criteria comparison and the evaluation of the results from the questionnaires. The emphasis in the evaluation of the work will be on the practical use of the output of the work.

Bibliography / sources:

Podklady Škoda Auto a.s.
Tripathi V., Rao K. 'Progress Card of the Indian Automobile Industry', 2016, The IUP Journal of Business Strategy, Vol. XIII, No.3
Tiwari R., Phadnis B. 'Commercial Vehicle Industry in India: An Investigation of the Innovation and Business Trends (2000-2015)', 2017, Springer, DOI 10.1007/978-3-319-46392-6_11
Shilpa N., Amulya M. "Corporate Financial Distress: Analysis of Indian Automobile Industry", 2017, Journal of Management, Vol 8, Issue 1, DO:10.18311/sdmimd/2017/15726

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Date of master's thesis assignment: **23.04.2018** Deadline for master's thesis submission: **17.08.2018**

Assignment valid until: _____

Ing. Michal Netušil, Ph.D. Supervisor's signature	prof. Ing. Tomáš Jirout, Ph.D. Head of department's signature	prof. Ing. Michael Valášek, DrSc. Dean's signature

III. Assignment receipt

The student acknowledges that the master's thesis is an individual work. The student must produce his thesis without the assistance of others, with the exception of provided consultations. Within the master's thesis, the author must state the names of consultants and include a list of references.

30/04/2018 — Date of assignment receipt

S.P.Patil — Student's signature

DECLARATION:

I declare that this diploma thesis entitled “Multi criteria comparison of suction aggregate components” is my own work performed under the supervision of Ing. Michal Netušil, Ph.D, with the use of the literature presented at the end of my diploma thesis in the list of references.

In Prague:……. Signature:……

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ANNOTATION SHEET:

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ABSTRACT

This study focuses on the suction system of cars. Introduction is focused on the automotive sector of the Indian market; automobile sector, sales of the passenger car from major manufacturers, their share in the market, production facility of competitors, possibility of growth in the future. The next part focuses on the effects of different environmental conditions on automobiles, problems in suction inlets and design suggestions to suction inlets. It goes further into detail for components of the air inlet system, literature review of pressure drop and climatic conditions of India which could be threat to air suction inlets. In the practical part, suction inlets from each category of cars is compared. Criteria for comparison are decided with the help of a questionnaire. Based on evaluation, higher rated air suction inlets from each category of cars (from Indian manufacturer) are compared with suction aggregates from European environments. In appendix important pictures of different suction aggregates, detail information of suction parts from different manufacturers and research part of design suggestions are mentioned.

KEYWORDS: Air inlet system, Car suction systems, Multi criteria comparison, Indian automobile sector

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List of Abbreviations

ABS	Acrylonitrile Butadiene Styrene
AIS	Air intake system
BUA	Bottom up approach
CAFE	Corporate Average Fuel Economy
CAGR	Compound Annual Growth Rate
CBU	Completely built-up units
CRDi	Common rail direct injection
D	Diesel
DPF	Diesel particulate filter
DPF	Diesel particulate filter
EGR	Exhaust gas recirculation
ERW	Electric resistance welded
EVAP	Evaporative emission control
FPCP	Flexible porous cellular plastic
FY	Fiscal Year
GDP	Gross domestic product
GM	General Motors
GM India	General Motors India
M & M	Mahindra & Mahindra
MUV	Multi Utility Vehicle
OEM	Original Equipment Manufacturer
P	Petrol
PA	Polyamide
PE	Polyethylene
PM	Particulate Matters
PP	Polypropylene
PPM	Parts per million
PUR	Polyurethane
SCR	Selective Catalytic Reduction
SDS	System design specifications
SFT	Short fiber thermoplastics
SOF	Soluble organic fraction –
SUV	Sport Utility Vehicle
USD	United States dollar
VGT	Variable geometry turbocharger
VTVT	Variable timing valve train
VW	Volkswagen

1 Introduction

1.1 Indian economy

Home to a sixth of the world's population, India is set to overtake China and become the most populous country by 2050. Over half of India's current population is under 25 years and more than two-thirds is under 35 years. Given the demographic dividend (that India expects to reap in the coming decades) and the burgeoning working population, the extent of financial inclusion in India will be critical for delivering economic growth to the country. [1]

In 2016, around 11% of household in India has Car [2]. Figure 1 shows the GDP per capita of India. If we see this graph from year 2008 Gross domestic product (GDP) per capita is 1159 USD and in year 2016 it is 1861 USD. In this years this value has been increased and as per prediction it will keep this growth. Till year 2020 this value will be more than 2000 USD.

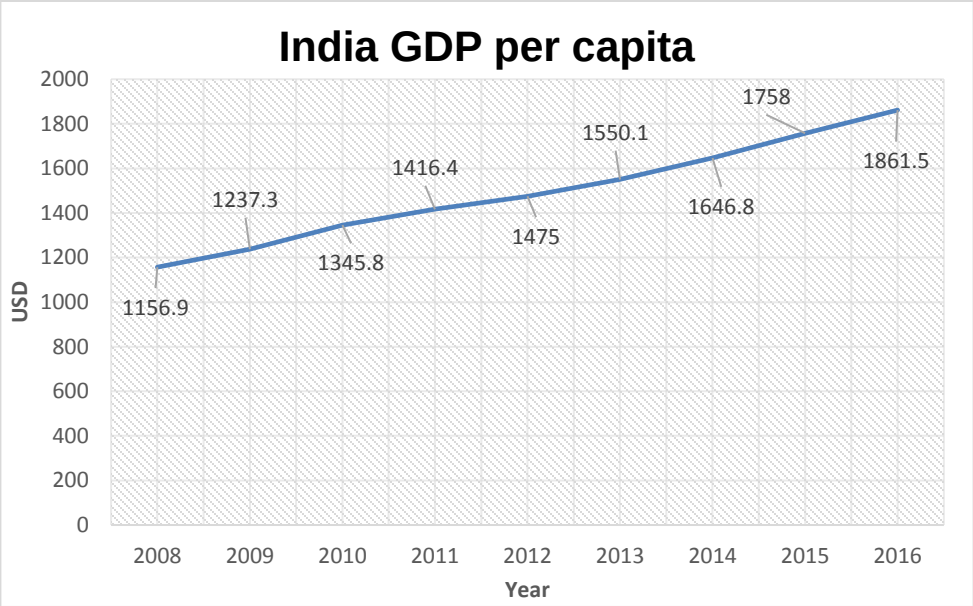


Figure 1. GDP Per capita per year. [3]

Increasing population, less percentage of household has automobiles and increasing GDP Per capita shows that in there are good chances for increase in the percentages of household has automobile. So, automobile company should think about this as a good opportunity in India for coming years. Most important factor is less household percentage has automobiles. 'Poland and Hungary has 63 percent and 52 percent of household with at least one car' [4]. So, we can see there is great opportunity for India if the nation is experiencing growth in GDP per capita.

2017 and 2018 are expected to see over 9,800 km of new high-speed roads and motorways built, that's 22km every day. The road network is expected to double by 2020.

1.2 Indian automobile sector

India was the sixth largest motor vehicle/car manufacturer in the world in 2013. Indian auto manufacturers produced record 20.4 million motor vehicles in 2011-12, refer Table 1. 3.14 million Passenger vehicles rolled out from Indian auto plants in 2011-12. The total turnover of the Indian automotive component industry was estimated at USD 35 billion in 2013-14. Established auto manufacturers and new entrants in the Indian auto market are expanding their production capacities on a large scale. Companies undergoing expansion include Maruti-Suzuki, General Motors (GM), Tata Motors, Volkswagen (VW) Group, Toyota, Honda and Hyundai. New auto makers planning to enter the Indian market include Isuzu, Jeep and possibly Mazda. [5]

In Year 2016 India was 6th largest producers of Automobiles in Passenger car segment. And India's automotive industry is expected to reach 7 million vehicles milestone by 2020, making the country the third-largest auto manufacturer in the world, behind the US and China. [6]

Table 1 show the number of Automobiles produces in India from year 2011-12 to 2016-17. The number is started from 3.146 million in year 2011-12 and gradually increased to 3.791 million till year 2016-17. There was recession period in year 2013-14 but it gained momentum again in next years. The number in production of passenger vehicles are not going down than 3 million units. This recent production trend shows that this graph is adding up more production as years are passing.

Category	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Passenger Vehicles	3.14	3.23	3.08	3.22	3.46	3.79
Commercial Vehicles	0.92	0.83	0.69	0.69	0.78	0.81
Three Wheelers	0.87	0.83	0.83	0.94	0.93	0.78
Two Wheelers	15.42	15.74	16.88	18.48	18.83	19.92
Grand Total	20.38	20.64	21.50	23.35	24.01	25.31

Table 1. Automotive production trends in India (numbers are in million) [13].

As we can see in Table 1, in these six fiscal years the number of production of cars is increasing gradually. After the recession in year 2013-14 the growth rate is even more per more.

Also, according to article in The Economic Times in recent days, the industry forecasts the sales growth of passenger vehicles in Fiscal Year (FY) 2019 at 8-10%. [7]

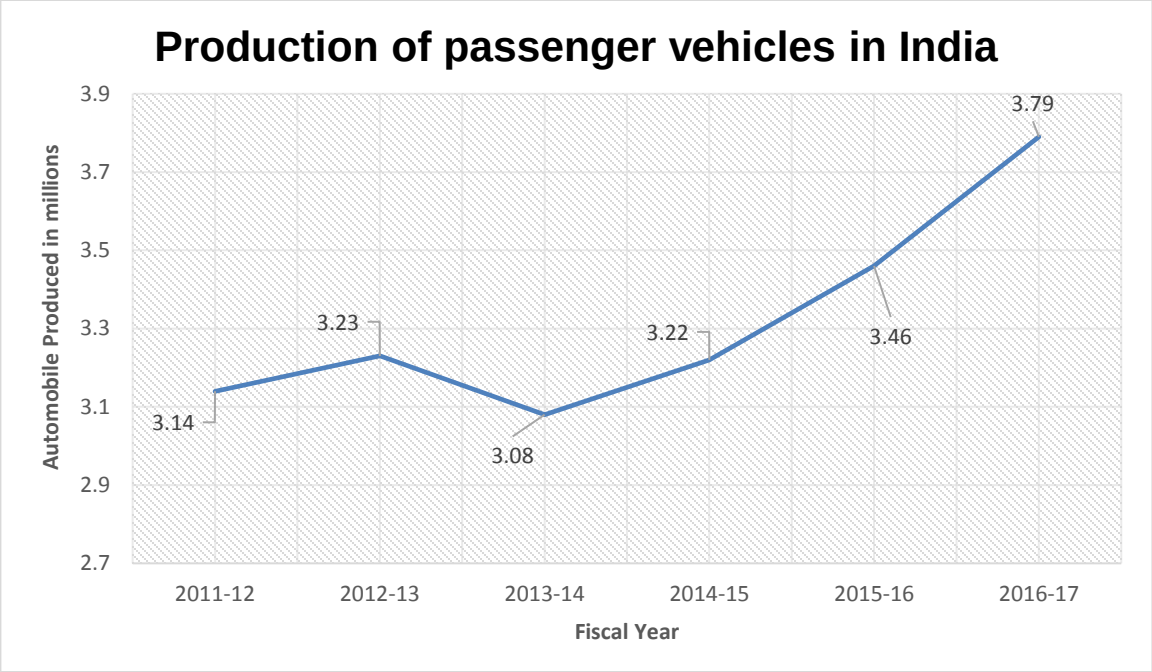


Figure 2. Production growth of automobile in India.

Table 2 shows steady growth of automobile export from Indian market. In FY 2011-12 India exported around half million automobile units. In next year's till now it is increasing rapidly. As we can see in year 2016-17 the automobile units India exported is 758,830. Currently India is mainly exporting automobiles to United States of America, Italy, Germany, Netherlands, Mexico, South Africa, United Kingdoms, Srilanka, Bangladesh, Turkey, Nigeria, United Arab Emirates, Colombia and some other African countries.

Category	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Passenger Vehicles	0.50	0.55	0.59	0.62	0.65	0.75
Commercial Vehicles	0.092	0.080	0.077	0.086	0.103	0.108
Three Wheelers	0.361	0.303	0.353	0.407	0.404	0.271
Two Wheelers	1.97	1.95	2.08	2.45	2.48	2.33
Grand Total	2.93	2.89	3.11	3.57	3.64	3.47

Table 2. Automobile Exports Trends (numbers are in million) [13].

We can observe from Figure 3 that Export is increasing year by year. It was 508,783 in year 2011-12. After year 2015-16 there is rapid increase of growth in the graph, it jumped by 100,000 units. And there is no decline in case of export.

India's automobile exports have grown consistently, with United Kingdom being India's largest export market followed by Italy, Germany, the Netherlands and South Africa. India's strong engineering base and expertise in the manufacturing of low-cost, fuel-efficient cars has resulted in the expansion of manufacturing facilities of several automobile companies like Hyundai

Motors, Nissan, Toyota, VW and Suzuki. In 2008, Hyundai Motors alone exported 240,000 cars made in India. Nissan Motors plans to export 250,000 vehicles manufactured in its India plant by 2011. Similarly, GM announced its plans to export about 50,000 cars manufactured in India by 2011. In September 2009, Ford Motors announced its plans to setup a plant in India with an annual capacity of 250,000 cars. The cars are manufactured both for the Indian market and for export. [8]

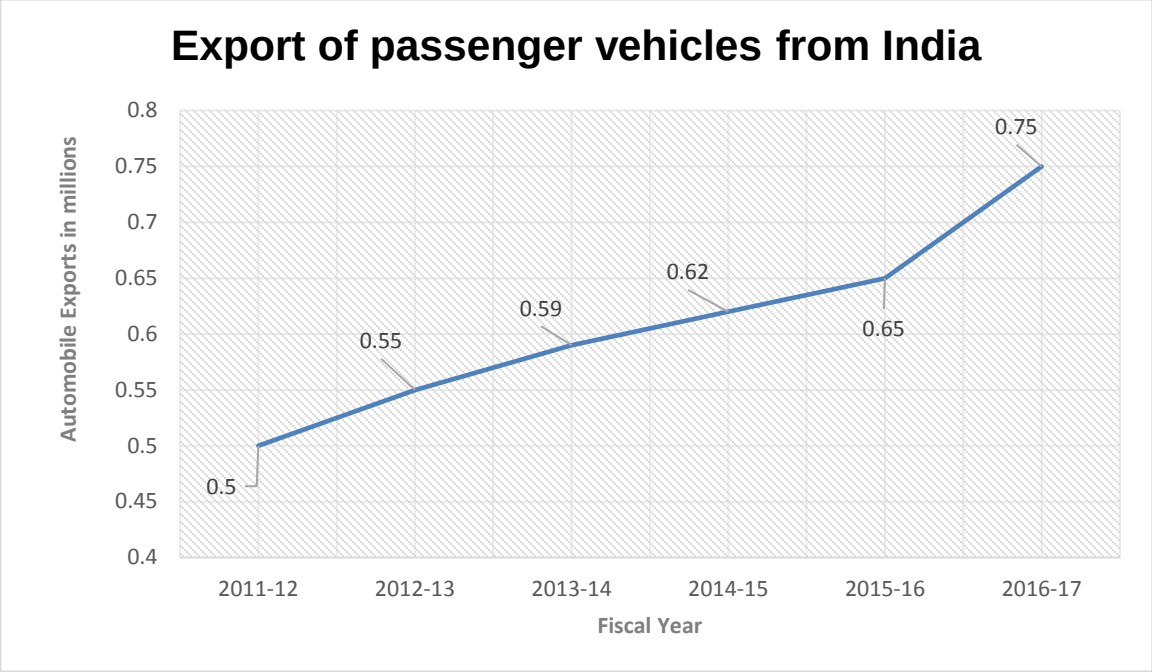


Figure 3. Export of passenger vehicles trend.

Nissan India has attained a milestone of exporting a total of 700,000 'Made in India' cars to 106 countries around the world within seven years of its operation in the country. The exports include Nissan and Datsun cars, which were manufactured at Renault-Nissan Automotive India Ltd plant in Chennai. India is not only a key hub for completely built-up units (CBU) but also for parts supply. Nissan India exports over 2,500 types of manufactured parts to 25 of Nissan and Renault plants in 18 countries, ranking in the top four in volume of parts shipped within Nissan global operations. [14]

General Motors India (GM India) planned to export over 70,000 vehicles in FY 2016-17 to various markets including Central and South America. GM India has so far exported 70,072 units of Chevrolet Beat and it became the sixth most exported passenger vehicle out of India during 2015-16 fiscal. [15]

In recent years, India has emerged as a leading center for the manufacture of small cars. Hyundai, the biggest exporter from the country, now ships more than 250,000 cars annually from India. Nissan will also export small cars from its new Indian assembly line. Tata Motors exports its

passenger vehicles to Asian and African markets. Mahindra & Mahindra (M & M) is preparing to introduce its pickup trucks and small SUV models in the US market.

Indian auto component industry has seen major growth with the arrival of world vehicle manufacturers from Japan, Korea, the US and Europe. Today, India is emerging as one of the key auto components center in Asia and is expected to play a significant role in the global automotive supply chain soon. India has also emerged as an outsourcing hub for auto parts for international companies such as Ford, GM India, Daimler Chrysler, Fiat, VW and Toyota. [8]

2016 [# units]	Company	Rank	Company	2017 [# units]	Change [%]
162221	Hyundai	1	Hyundai	167120	3
123850	Maruti Suzuki	2	Ford	158469	43
111612	Nissan	3	Maruti Suzuki	122039	-1
110840	Ford	4	Nissan	109459	-2
75989	VW	5	VW	86852	14.30
37082	GM India	6	GM India	70969	91
14786	Toyota Kirloskar	7	Toyota Kirloskar	12748	-14
7090	M & M	8	Renault	10641	7290
5737	Honda Cars	9	M & M	10173	43
4332	Tata Motors	10	Honda Cars	5824	2

Table 3. Top 10 automotive exporter from India [16].

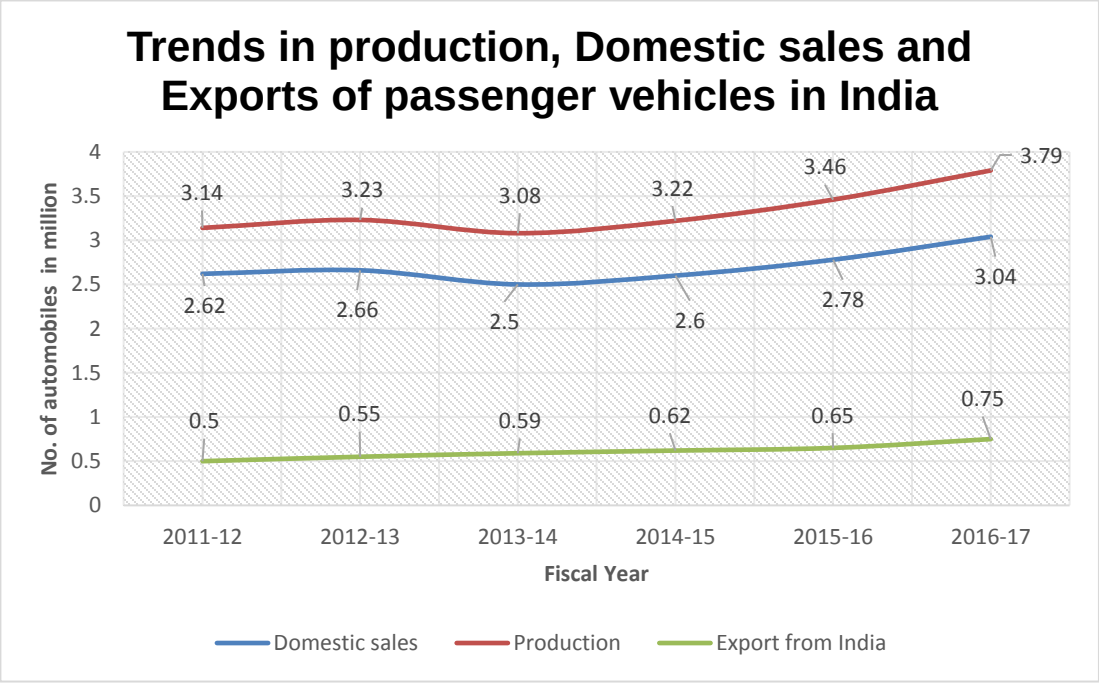


Figure 4. Trends in production, domestic sales and exports of passenger vehicles in India.

In 2017 India became the world's largest producer of Two-wheeler vehicles in the world in competition with China. As per data from 2015-16, 80% Indian market is occupied by Two-wheeler segment and the number of sales in this segment was more than 18 million units. Hero Motocorp, Honda, TVS Motors, Bajaj auto are the main players in two-wheeler segment.

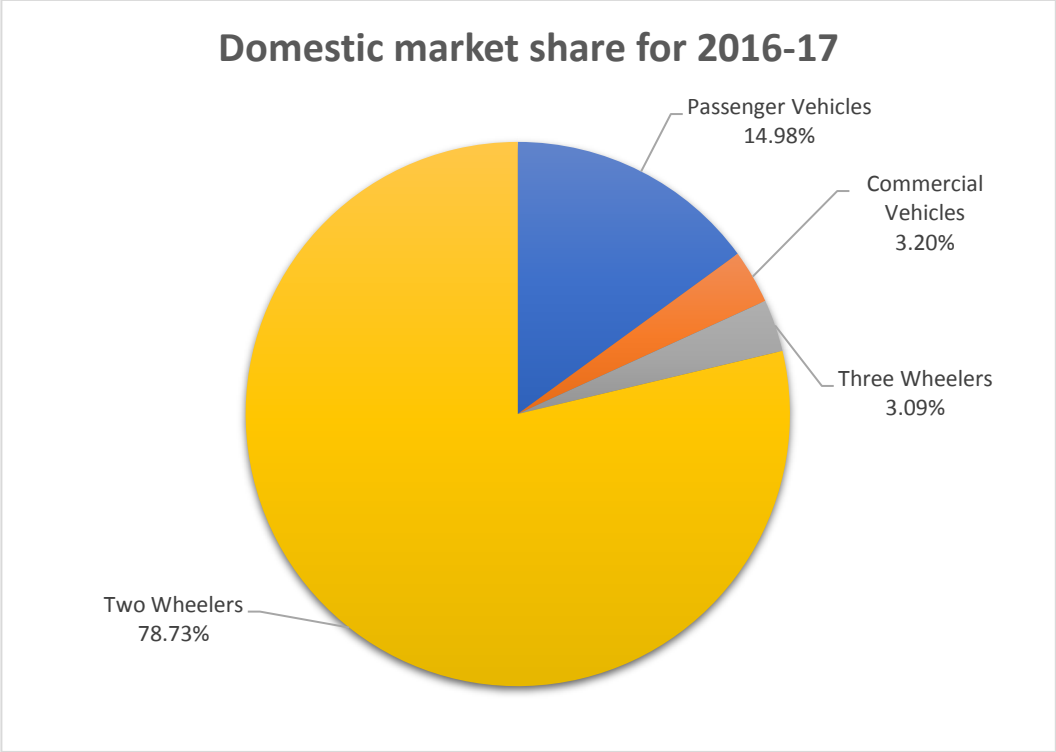


Figure 5. Share of vehicle type in Indian market.

After it Passenger Vehicles are followed with 15% share. Maruti Suzuki is the main player in this category from past decade. And they still occupy approx. half of the passenger vehicle market (refer Table 6). Other companies such as Hyundai, M & M, Tata Motors, Honda, Toyota, VW group, etc. are occupying rest of the Market. Together they produced more than 3.7 million cars in year 2016-17.

Three Vehicles and Commercial Vehicles contribute 3% each in the Automobile market. In three-wheeler segment Piaggio, Bajaj auto, M & M, TVS motors contributes mostly. And Three-wheeler segment is also doing well in exporting. Underdeveloped countries and developing countries demands three-wheelers nowadays. In Commercial Vehicles Tata

Motors, Mahindra, Ashok Leyland, Eicher, Force motors this are main companies.

1.3 Passenger car category

In Passenger Car category there is further category

1. Sedan - A sedan is a passenger car in a three-box configuration and principal volumes articulated in separate compartments for engine, passenger and cargo. The passenger compartment features two rows of seats and adequate passenger space in the rear compartment for adult passengers. The cargo compartment is typically in the rear, with the exception of some rear-engine models. Some examples of sedan in Indian market are Maruti Suzuki Dzire (which is 2nd best seller car in year 2017), Maruti Suzuki Ciaz, Hyundai Verna, and Honda City.
2. Hatchback - The distinguishing feature of a hatchback is a hatch-type rear door that opens upwards and is hinged at roof level. Most hatchbacks use a two-box design body style, where the cargo area and passenger areas are a single volume. The rear seats can often be folded down to increase the available cargo area. Some examples of hatchback in Indian market are Tata Nano, Maruti Suzuki Alto, Hyundai Grand i10, Maruti Suzuki Swift. In year 2017, 7 out of 10 best sellers were from Hatchback category.
3. SUVs – SUV stands for sport utility vehicle that is used to denote any vehicle that looks like a station wagon. It means that is has a mini truck kind of platform. They are known for performing some off road duties. These vehicles are apt for driving rough textured roads. The mid-size and full size SUVs have generally three rows of seats and the cargo area is placed behind the last row of seats. Few vehicles from this segment are Mahindra Scorpio, Toyota Fortuner, Maruti Grand Vitara (7th best seller car in year 2017), Ford Endeavour, Hyundai Creta (9th best seller car in year 2017) and Honda CRV.
4. MUV – MUV stands for multi utility vehicle. It is used for various purposes and the cars of this segment are known for their duty-ness, durability, stability, looks, reliability, etc. It is a type of vehicle designed like a shape of van. Multi Utility Vehicle or cars have bigger chassis dimensions, more seating capacity and most of the models are designed with folded rear seats, and the area that is left can be used for some extra luggage space. A multi utility car can accommodate many passengers and also carry more luggages at a time. Some examples are Toyota Innova, Mahindra Xylo, Tata Sumo and Mahindra Bolero (crossed sale of 1 million in Indian market and helped establish Mahindra's image as a maker of rugged vehicles).

Sedan and Hatchback are the most contributing body type in Passenger vehicles. Together they contribute more than half market of Passenger Vehicles Segments. Major Player likes Maruti Suzuki, Hyundai, Tata motors, and Honda has more variety in Sedan and Hatchback Category. According to Maruti Suzuki's official website, in year 2016-17 they sold 1,444,541 vehicles. Out of them 1,095,891 belongs to Sedan and Hatchback category while rest of them were Utility vehicles. Highest 10 selling cars of 2017 in India includes mostly Hatchback and sedan, list has only 2 SUVs.

One out of every four vehicles sold in India is a SUV. It crossed 25% market share in March 2017. Also, automotive experts claims to rise in sales to nearly 30%. [11] This could be good news for company who wants to launch SUV in Indian market.

Year	SUVs sales	SUVs % of Passenger Vehicles
2016-17	761,997	25.01
2015-16	586,664	21.02
2014-15	553,699	21.28
2013-14	525,942	21.00
2012-13	553,660	20.60
2011-12	367,012	14.01
2010-11	315,123	12.59

Table 4. Percentage of SUVs in passenger vehicles category. [12]

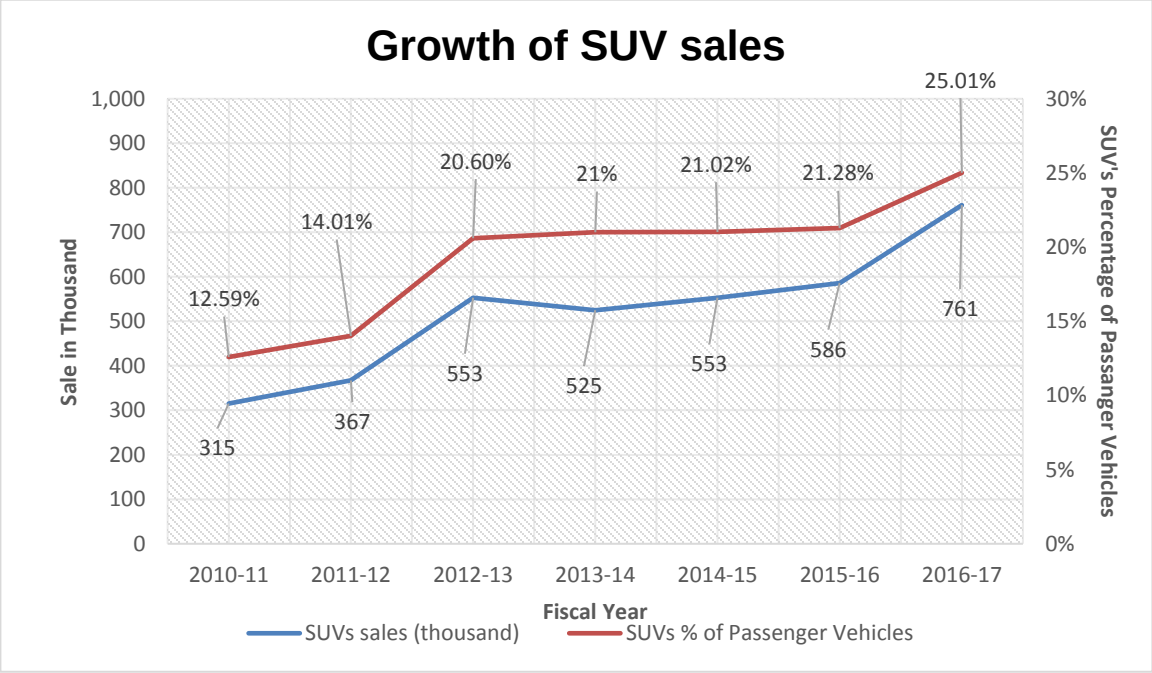


Figure 6. SUV sales and their percentage in passenger vehicles.

So, we can observe Table 4 from that sale of SUVs is increasing from year 2010-11 to till date.

Here are some of SUVs sold in November 2017 (Top six).

Rank	SUV name	No. of sales
1	Maruti Suzuki Vitara Brezza	14458
2	Hyundai Creta	8258
3	Ford Ecosport	5474
4	Mahindra Bolero	4911
5	Tata Nexon	4163
6	Mahindra Scorpio	3660

Table 5. Top 6 SUV sale in November 2017.

Skoda India launches Kodiaq in Indian market in September 2017. They sold 84 units in this month and it already crossed 1000 units till now and already meet the sale expectation of 1000 units within year. Recently it achieved 223 units in February 2018.

1.4 Major automakers and their sales

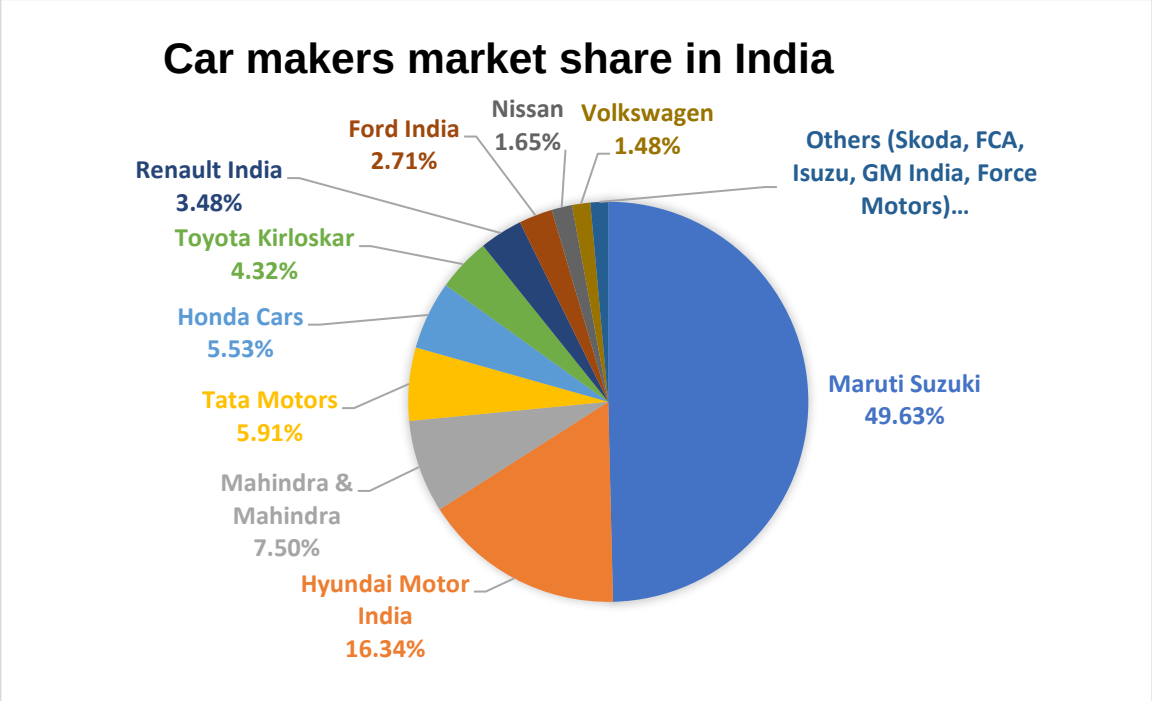


Figure 7. Car makers market share in India. [9]

Car sales in India (domestic sales) has crossed 3 million sales milestones for the first time in a single calendar year in 2017 as the car makers in India sold a total of 3,229,109 units in the Indian domestic market reporting a growth of 8.85% over sales in 2016. Strong demand of SUVs attracted the most growth in the passenger vehicle segment.

Rank	Company	# Sales	Share [%]
1	Maruti Suzuki	1,602,522	49.63
2	Hyundai India	527,320	16.34
3	M & M	242,365	7.5
4	TATA Motors	191,107	5.91
5	Honda cars	178,755	5.53
6	Toyota	139,566	4.32
7	Renault	112,492	3.48
8	Ford India	87,587	2.71
9	Nissan	53,390	1.65
10	VW	47,796	1.48
	Total	31,82,900	98.56

Table 6. Number of top 10 company sales in year 2017.

India's largest automaker Maruti Suzuki continues to dominate in India with a massive market share of 49.6 percent in the Indian passenger vehicle space. Maruti Suzuki India sold a total of over 1.60 million vehicles in India. In the year 2017-18, the company is growing at almost 15 percent with exports almost like that in FY 2016-17. India's second largest automaker is Korea's Hyundai Motor India that crossed half million sales marks for the second time in a row. The company reported a total sale of over 527,000 units and its plants in Chennai are working at full capacity to meet the growing domestic and export demands. Indian automobile giants Mahindra and Tata Motors stand at third and fourth place respectively. This year Tata motor manufactures Tata Hexa, Tata Tigor and Tata Nexon, it means they are focusing on Sedan, hatchback and SUV, in all format of Passenger vehicles. Interestingly Renault started their production in India from year 2011 and they captured around 3.5% of Indian market in year 2016. [9]

Skoda Auto India planned a 30% growth for the year 2017. The automaker sold 17,438 vehicles in the previous year and Skoda Rapid contributes the most. Also, they claimed that new Octavia and Kodiaq also contributing significantly to the brand's growth in 2017. [10]

In Figure 8 we can see map of India with major company's automotive Plant. Most of the plants are located Near to Indian capital (Near to Delhi), in West region (Maharashtra, Gujarat state) and in southern part of India (Karnataka and Tamilnadu State). Following are the information about major Passenger Vehicle plants.

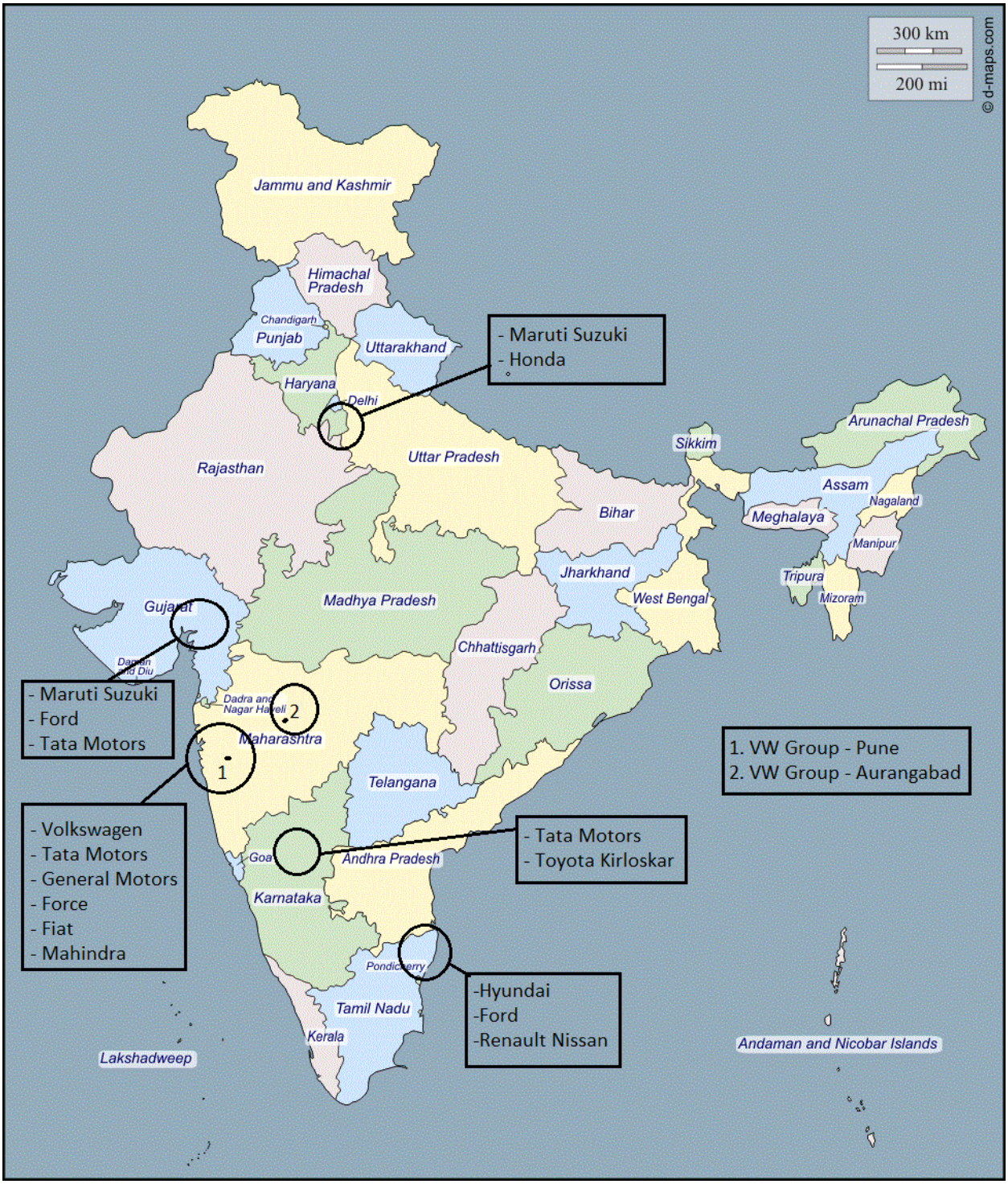


Figure 8. India map with major automotive companies and their location.

1. Hyundai Motor India Limited – The Company has 2 manufacturing plants near to Chennai (In tamilnadu State) with annual capacity of 700,000 cars.

2. Tata Motors – Tata motors has 6 manufacturing plants in India. Company is producing Passenger Vehicle and Commercial vehicle as well. They have plant in Jamshedpur, Pantnagar, Lucknow, Sanand, Dharwad, and Pune. Plant capacity is around 790,000 cars.
3. M & M – Mahindra group is also in Passenger Vehicle and Commercial vehicle segment. Company has many plants for both segments. For Passenger Vehicle company has manufacturing plant in Pune, Mumbai, Nashik, and Kanchipuram. Installed annual capacity is 620,000 cars.
4. Renault Nissan Automotive India PVT LTD – Renault Nissan alliance sharing common production line. It is situated near to Chennai. Plant has annual capacity of 480,000 cars. But both companies share half capacity.
5. Ford India – Company has two manufacturing plants. First plant is in Chennai with 200,000 cars annual capacity and second is in Gujarat which has capacity of 240,000 cars, makes total of 440,000 cars annual production capacity.
6. VW India Group – The group has 2 plants, both are in Maharashtra state. First plant is in Pune which has annual capacity of 200,000 cars and second plant is in Aurangabad which has annual capacity of 89,000 cars.
7. Toyota Kirloskar Group – Toyota Motor Corporation entered India in 1997 in a joint venture with the Kirloskar Group. Company has 2 manufacturing plants, both are in Karnataka State with annual capacity of 310,000.
8. Honda Cars India Ltd – Honda has two manufacturing plants in India. Both plants have annual capacity of 120,000 cars each. Company has plant in Noida and in Rajasthan.
9. General Motors India – Company has production annual capacity of 240,000 cars. Plant is in Pune, Maharashtra state.
10. Force Motors – Company has annual capacity of 75,000 cars.
11. Fiat India Automobiles – Fiat has manufacturing plant in Pune with annual capacity of 200,000 cars.

Recent Sales in Indian Market

In Fiscal Year 2016-17, around 3.79 million passenger cars were produced. In this year Maruti Suzuki occupied approximately half of Indian market with 49.63% and followed by Hyundai with 16.35%. Top 10 sales of car in year 2017 lead by Maruti Suzuki's Alto with 257,732 units. In top 10 sales, 7 cars belong to Maruti Suzuki group while rest of them are Hyundai's. Also 7 out of 10 cars are in Hatchback segment, 2 of them in SUV and only one in Sedan Category. In table 6, we can see top 10 cars by sales in year 2017. Some cars are available in both variant i.e. Petrol (P) and Diesel (D). Also in Hyundai's cars, they are available with 'Common rail direct injection' (CRDi) engine, Kappa engine, Variable timing valve train (VTVT) and Variable geometry turbocharger (VGT). Segments are shown as follows- Hatchback (H), Sedan (S) and SUV. Price is shown for city Mumbai and also tax is included.

Rank	Manufacturer	Model	# sales	Segment	Specification (L - KW)	Price [€] (Basic Models)
1	Maruti Suzuki	Alto	257,732	H	0.8/35 - P	4053
2	Maruti Suzuki	Dzire	225,043	S	1.2 - 61 – P 1.3 - 55 – D	8105
3	Maruti Suzuki	Baleno	177,209	H	1.2 - 62 – P 1.3 - 55 – D	8092
4	Maruti Suzuki	Swift	167,371	H	1.2 - 61 – P 1.3 - 55 – D	7500
5	Maruti Suzuki	Wagon R	166,814	H	1 - 50 – P	6362
6	Hyundai	Grand i10	154,787	H	1.2 - 55 CRDi 1.2 - 61 Kappa	6905
7	Maruti Suzuki	Vitara Brezza	140,945	SUV	1.3 - 66 – D	11550
8	Hyundai	Elite i20	134,103	H	1.4 - 66 CRDi 1.2 - 61 Kappa	7877
9	Hyundai	Creta	105,484	SUV	1.6 - 94 CRDi VGT 1.4 - 66 CRDi 1.6 – 90 Dual VTVT	13810
10	Maruti Suzuki	Celerio	100,860	H	1.0 - 50 – P	6476

Table 7. Highest selling cars of India in 2017 [24].

1. Alto – This car is very popular in Indian Market. This is entry level car in automobile market in hatchback category. This car was launched in year 2000 in Indian market. In 2017, it was on top by number of sales with 257,732 units. In February 2018 this car achieved sale of 3.5 million units of sale which makes it highest selling of car around the globe.

Figure 9. Maruti Suzuki Alto.

2. Dzire – The only sedan in top 10 sales in year 2017. Maruti Suzuki's Dzire available in two variant Petrol and Diesel. This car is available in Indian market since year 2008. After this, company also launched its second and third generation in year 2012 and 2017. This car already crossed 1 million sales marks in year 2015.

Figure 10. Maruti Suzuki Dzire.

3. Baleno – This is Maruti Suzuki's premium hatchback car. Baleno launched in the Indian car market in October 2015 and ever since has been highly popular and one of the bestselling car models from Maruti Suzuki India.

Figure 11. Maruti Suzuki Baleno.

4. Swift – This car was introduced in Indian market in year 2005. Roughly sale of this car from launch is 2 million in India. This is one of the best model in Hatchback category in India. This undisputed segment leader clocked 167,371 units in 2017 averaging around 13,948 units every month.

Figure 12. Maruti Suzuki Swift.

5. The Wagon R has been the workhorse for the Indian market fulfilling the basic needs of what a 'car' is supposed to be. Comfortably selling almost 14,000 vehicles throughout the year, the Wagon R was a choice of 166,814 buyers. The reliable, efficient and low maintenance Wagon R also crossed two-million unit sales mark in September 2017.

Figure 13. Maruti Suzuki WagonR.

Figure 14. Hyundai Grand i10.

Figure 15. Maruti Suzuki Vitara Brezza.

Figure 16. Hyundai Elite i20.

Figure 17. Hyundai Creta.

Figure 18. Maruti Suzuki Celerio.

Carmaker	Model	Remark
Jeep	Renegade	SUV
Maruti Suzuki	Vitara	SUV
Volvo	XC40	SUV
Hyundai	Ioniq	Sedan (Electric)
Tata	Q501	SUV
Hyundai	Kona	SUV (Electric)
Nissan	Leaf	Hatchback (Electric)

Table 8. Upcoming car models in Indian market for year 2018. [31]

#	Car Name	Seg	sale	#	Car Name	Seg	sale
1	Maruti Suzuki Dzire	S	22,540*	14	Ford Ecosport	SUV	6,833
2	Maruti Suzuki Alto	H	19,134	15	Maruti Suzuki Omni	Van	6,155
3	Maruti Suzuki Baleno	H	17,770	16	Hyundai Eon	H	6,111
4	Maruti Suzuki Swift	H	14,445	17	Maruti Eeco	Van	6,095
5	Maruti Suzuki Wagon R	H	14,182	18	Renault KWID	H	5,590
6	Hyundai Grand i10	H	12,109	19	Maruti Suzuki Ignis	H	5,472
7	Maruti SVitara Brezza	SUV	11,785	20	Mahindra Scorpio	SUV	5,230
8	Hyundai Elite i20	H	9,650	21	Maruti Suzuki Ciaz	S	5,062
9	Hyundai Creta	SUV	9,284	22	Tata Nexon	SUV	4,917
10	Tata Tiago	H	8,287	23	Maruti Suzuki Ertiga	SUV	4,696
11	Mahindra Bolero	SUV	8,206	24	Hyundai Verna	S	4,601
12	Maruti Celerio	H	7,641	25	Honda WR-V	SUV	4,273
13	Toyota Innova	SUV	7,028	* - Other websites claimed sale of 18053 [26].			

Table 9. Sales of top 25 cars in India (January 2018) [25].

2 Research

2.1 Parts of air inlet system

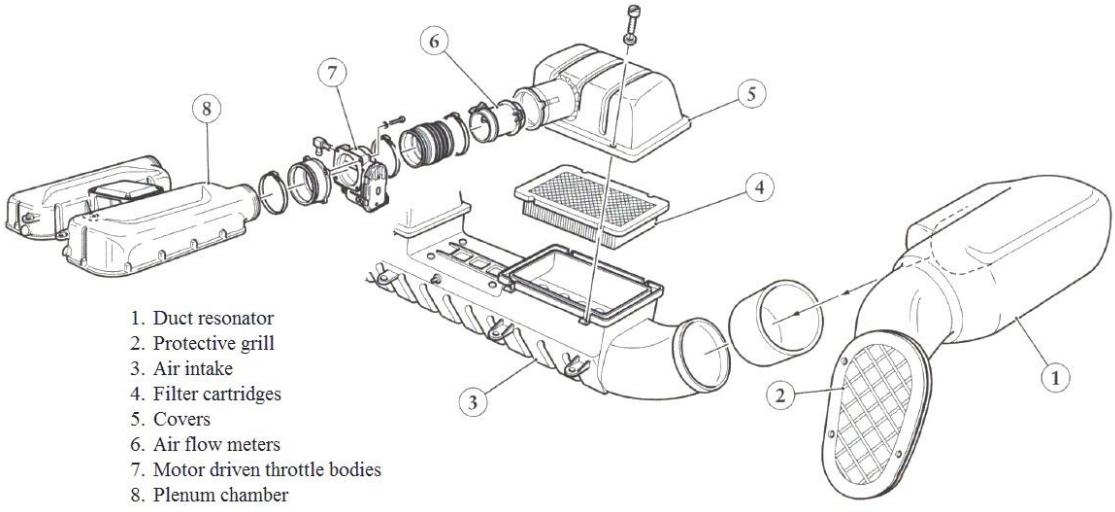


Figure 19. Air intake schematic diagram. [36]

A system in automobile which takes air from surrounding and delivers it to the engine after filtering is known as Air intake system. The air intake system is critical to the function of the engine, collecting air and send it to cylinders. The best air intake system grants for clean and continuous flow of air to the engine, so that achieving more power and better mileage of car. Today's automotive air intake systems are developed to deliver maximum filtration efficiency, maximum holding duct holding capacity and maximum service interval range based on engine performance and reliability requirements. Lot of parts are involved in this intake system, such as duct resonator, filters, air intake or air flow channel, air flow meter or mass air flow sensor, water drainer etc.

Air inlet system were conventionally made from metals, such as cast iron and aluminum but this trend has been changing with the change in the market dynamics. Government stringent regulations are putting pressure on the automakers to either curb the overall vehicle weight or downsize the engines to increase fuel efficiency or reduce emissions. Short fiber thermoplastics (SFT) based composites are most widely preferred in the global automotive air inlet system market as it offers many benefits over competing materials, such as low part cycle time, ability to manufacture complex products, recyclability, good surface finish, excellent strength to weight ratio, lightweight, and excellent temperature resistance.

If we talk about why more research and time is needed for air inlet system of car. Then is it noticed that Asia-Pacific is expected to remain the largest air inlet market during the forecast period. The region is also expected to experience the fastest growth in the same period. Increasing automobile production mainly in China and India is likely to drive the demand for air inlet system

in the region. Europe is expected to remain the second largest automotive air inlet market over the next five years but the region is expected to experience a moderate growth due to low growth in the light vehicle production. [18]

In Figure 19 we can see all the parts of air inlet system and also it shows position of all parts one after another. Now let's see the function of each part of air inlet system.

Resonator - The air first enters in a resonator chamber which has been carefully designed to tune the induction noise. Due to various reasons throughout intake system cause noises which is known as Intake noise. A resonator is mostly used to suppress this intake noise. This chamber shape is vary for different cars, it depends upon space availability, noise requirements, air handling capacity, etc.

Dull and less than 600 Hz low range noise generated from this intake system is called intake noise. The main reasons for this noise are known as the pressure pulsation of air flow in the intake system and the resonance inside intake valve. Intake noise types consist of intake air discharge sound, surface radiation sound, pipe radiation sound. The proportion of this intake noise is around 30% of total automobile noise. [37]

The operational principles of intake and exhaust silencers can be divided into two types: dissipative and reactive types. The dissipative silencers contain absorptive materials that physically absorb acoustic energy from the gas flow. The reactive silencers operate on the principle that when the sound in a pipe or duct encounters a discontinuity in the cross-section, some of the acoustic energy is reflected back towards the sound source thereby creating destructive interface [43].

A typical Helmholtz resonator is used in cars. It is a container of air with an open hole or neck. The volume of air in and near the open hole vibrates because of the springiness of the air inside. The air jet in the intake duct forces the lump of air a little way down the neck, thereby compressing the air inside. This allows for some mass of air to drive out of the hole to some extent. This rarefies the air inside the body, which then sucks the lump of air back in.

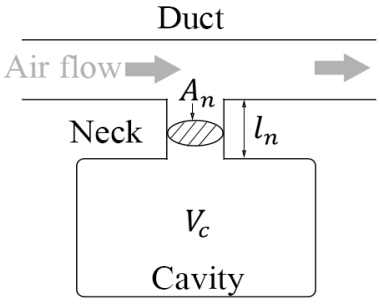


Figure 20. Structural diagram of Helmholtz resonator. [37]

One has to find out the particular frequency creating that noise and calculate corresponding volume of the required resonator.

$$V_c = 2983.12 \cdot \left(\frac{A_n}{L_n} \cdot f^2\right) \quad (1)$$

Where, V_c = Volume in m^3.
f = Frequency, Hz.
A_n = Surface area, m^2.
L_n = Length of neck, m.

Ideally the resonator should be of spherical shape. But based on vehicle packaging constraints, another shape can also be used avoiding sharp edges. Inner surface of resonator should be smooth. The joint between intake duct and resonator must be perfectly sealed and isolation is recommended. A small hole should be provided at the bottom of the resonator for drainage of condensate. [38]

Duct integrated resonator – Due to its existing shape of neck and cavity, it was hard to mount the Helmholtz resonator in addition to an already designed engine room. The duct integrated resonator is designed to minimize this space requirement. The biggest feature of the duct integrated resonator is that it shares one side of the duct and resonator to reduce the space required in the engine room. In addition, the resonator's neck is made to have a cylinder type hole that is shared by the duct and resonator. It is confirmed that the hole at duct can play the role of the neck for Helmholtz resonator, it can be efficient space design method for limited engine room space. [37]

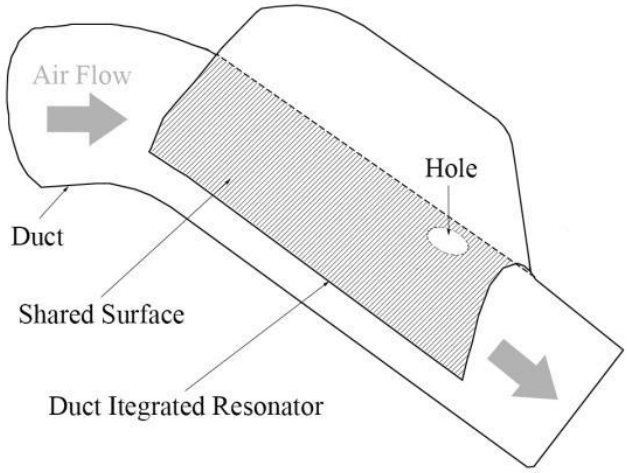


Figure 21. Simple diagram of duct integrated resonator. [37]

Mousetrap – To avoid the rats entering inside the air intake system, the mousetrap with the wire mesh is sometimes used at inlet of dirty side hose or it can be done on the inlet of system as a protective grill refer Figure 19. [38]

Inlet duct – Generally air inlet system is starts with inlet duct. This is one opening behind the front grill of car. The exact position of this inlet duct can be varied, sometimes it is at the bottom part of grill or in upper part of grill depending upon the surrounding or condition of area where car is running. This opening as we can see in picture lets air to flow inside the air inlet system. Design of this duct can be varied depending upon the engine size and air requirement to engine. Sometimes this duct can be eliminate if air inlet system is in space of engine.

Figure 22. Inlet duct.

Air inlet/outlet hose – Generally air inlet system has two types of hoses which are dirty side hose and clean side hose. Dirty side hose takes atmospheric air to the air filter and clean side filter takes the filtered air from filter to the intake manifold or compressed inlet. In cases where lengthy hoses are required on clean side, air intake metal pipes are used for certain length to reduce the high costs of hoses and to get vacuum collapse resistance. In such cases, based on the length of pipe, sufficient mounting bracket should be provided. Electric resistance welded (ERW) tubes are generally recommended for pipes.

The diameter of dirty hose is decided based on the inlet diameter of the filter. Open cross section area of the dirty side must be equal to the open cross section area of the filter. For clean hose, filter outlet diameter and manifold/compressor diameter are considered. Thickness of the hose should be decided based on internal diameter and inlet depression levels. Typical materials used for the hoses are Polypropylene/Santo-prene/NBR PVC (for 110° C), HDPE (for 60-70° C), EPDM (for 120°C), Vamac (for 150°C), Silicon rubber (for 200°C), CPE (140°C), Nylon (150°C).

The outlet hose are generally located after air filter unit and turbocharger. After filtering, air goes to turbocharger (in case of turbocharged engine). During turbocharging, air is pressurized. So handling such an outlet air one need special material hose to withstand such a high pressure and temperature. So material of outlet hose can be varied as compared to inlet hose.

Figure 23. Example of hose.

Pre-filter – This filter is placed before the main filter. The purpose of this filter is to remove majority of heavy dust particles from colliding with main filter element. There prefilters work on the principle of cyclonic effect. The swirl is generated in the housing, which causes air to flow cyclonically inside the housing. During the process, majority of the dust particles are segregated at bottom of housing due to gravity effect. To remove the dust collected in the housing due to pre cleaning effect, there is a small dust ejector valve installed at the bottom of the housing. This valve ejects the inside dust out when sufficiently high amount of dust gets collected in the housing.
Polyester material is suggested for pre-filter, sometimes spongy material can be used as well. As it is easy to clean so that it can reuse for couple of times before replace it.

Figure 24. Air pre-filter of car

Air Filter – Air filter is a heart of the air inlet system. It is one of the most important part for functioning of whole air system. This air cleaning assembly from air inlet system can be divided as following parts.

1. Filter box – This box is generally holding the filters in right position. It can be known as Filter housing as well. This box contains upper and bottom part which has space of air inlet and outlet as well.

Figure 25. Air cleaning assembly.

2. Filter element – This filter element is fits inside the filter box, main function of this element to trap dust particles and should have minimum pressure drop. In next part of this article has other information related to air filter.
3. Snorkel - This part is also works as water drainer in system. Sometimes water can get inside of air inlet system which is not good for functioning. So this water drainer removes water time to time, also it confirms that water should not enter from its other end.
4. Connecting materials – Like every system need some materials for assembling as a single part. It can conclude nut, bolts, clamps, some special joints for ensuring there should no gap as a unit. If there is any gap in unit then it can lead to huge pressure drop.

So let's discuss more about air filters in next part.

Basic function of filter in cars are

- To arrest maximum proportion of dust from entering the engine. (Filtering efficiency should be more than 99 %.)
- To allow minimum restriction to the intake air flow to the engine.
- To have large dust holding capacity to increase the element cleaning interval.
- Dampen the intake noise by designing the filter to act as a reflection sound absorber.

The filter size should be selected such that the rated size is the same or larger than the rated airflow. The calculation for size should take into consideration airflow requirement, pulsation factors and volumetric efficiency. In case of turbocharged engines, boost pressure ratio has to be considered to find out air requirement. Greater the restrictions in airflow, greater the power loss.

Till some years back, wet air filters were in use commonly. Major disadvantages with them type was higher flow restriction and non-user-friendly service procedures. Then emerged the paper or dry type of air filter. The paper is typically cellulose with a resin binder. Contaminant collection

is by direct interception and impaction. Particles in the air stream that are too large to pass through pores in the filter medium get trapped on the surface of the filter medium. These filters are called Surfacing loading filters. The element is usually stacked or cylindrical in shape. In most of the cases, the paper is pleated to present a large surface area to the air. The maintenance of this type of filter is simple. After every specified period of vehicle running, the element is taken out and cleaned with compressed air blown in opposite direction. After certain cleaning frequencies, the element is replaced with a new one.

Figure 26. Air filter of automobiles.

When dust loading occurs, the filter quickly goes into cake filtration mode. The formation of dust cake enhances the efficiency of the filter. However it also increases the air flow resistance and hence pressure drop. Increase in depression is a major disadvantage in this filter. Figure 27 shows airflow vs pressure drop characteristics of a typical dry type air filter in fresh condition. As flow increases, pressure drop across filter also increases. Figure 28 shows increase in pressure drop with accumulation of dust inside the filter. [38]

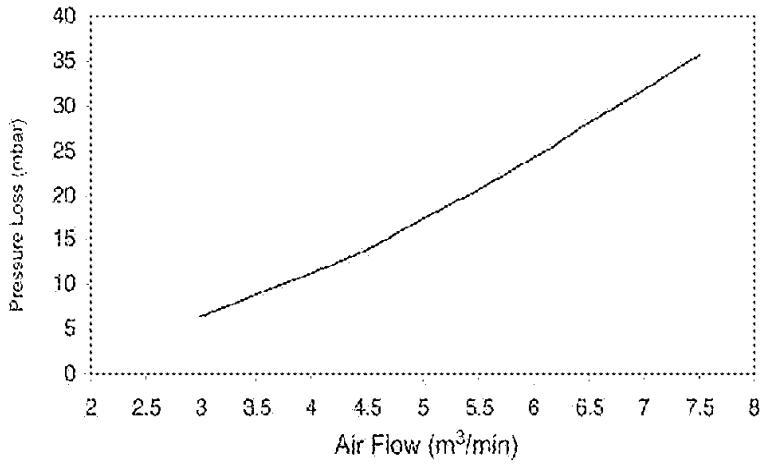


Figure 27. Pressure drop vs airflow for a new dry filter.

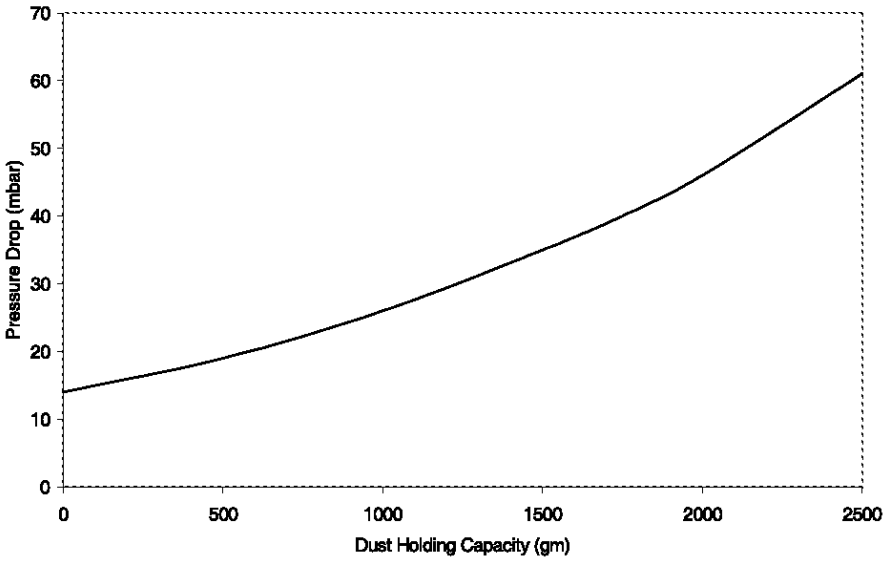


Figure 28. Dust holding characteristic of a typical dry air filter.

Recently, developments are going on to find out suitability of reticulated Polyurethane foam as automotive air filtration medium popularly known as Flexible Porous Cellular Plastic (FPCP). It consists of a 3D structure of dodecahedrons, which are completely interconnected, which form an incredible 210 square meter of internal surface area in every cubic foot. FPCP also has almost 97% void volume, which means it has an enormous dust holding capacity compared to paper elements. This material does not lint or fray, resist tearing, is chemically inert and can be elongated up to 400%. FPCP is available in pores/inch PPI 4 (very course) to PPI 110 (very fine) and is available in thicknesses of 5 to 500 mm. To effectively remove small particles, foam filters are usually operated at high flow velocity. At high flow velocity, particle may bounce from the fiber after impaction. Therefore foam medium is often treated with oil to reduce particle bounce. It acts as a depth-loading medium for filtering (PM) from gases and liquids. Major advantages with foam media are much lower inlet air restriction, high dust holding capacity, equally good filtration efficiencies, filtration of particle of even 1 micron diameter and longer life. FPCP media has been predominant medium of air filtration for racing cars in the year 2004, Ford introduced an FPCP based air filter for the PZEV Ford Focus passenger car. [38]

HFM Sensor - For clean and efficient fuel combustion, the injected fuel mass must be perfectly matched to the air supply in the engine cylinder. A mass air flow sensor is used to find out the mass of air entering a fuel-injected internal combustion engine. In other words, this sensor measures actual intake air mass into engine very accurately during specific instant acceleration and deceleration, and determines engine loads and detects intake air pulsation and air flows. From mass flow sensor, then, does it goes to the throttle body. The hot wire uses a series of wires strung in the air stream. The electrical resistance of the wire increases as the wire's temperature increases, which limits electrical current flowing through the circuit. When air flows past the

wire, it cools, decreasing its resistance, which in turn allows more current to flow through the circuit. However, as more current flows, the wire's temperature increases until the resistance reaches equilibrium again.

Figure 29. HFM Sensor.

After looking functions of this system it seems what is current design challenges in this field and how could face it. So major progress in engine air filtration in recent years has been made by introducing inline; flow-through fluted and pleated filters, and nanofiber filter media. The fluted and pleated in-line, reduced-volume filters provide high filtration performance while occupying less space. In these designs, almost the entire volume of the filter housing accommodates the filter media. The engine air filter market is driven by the performance requirements for engine air induction systems such as; low flow restriction, high dust-holding capacity long life or service-free designs, high gravimetric and fractional efficiency, small, compact components, integrated air intake & silencing system, permanent air intake systems with zero evaporative emissions, exclusive designs, volumetrically efficient filters to fit into available space. 30% of contaminants penetrating the air induction system and entering the engine passes out the exhaust. Engine operation, lifetime, engine emissions, and fuel consumption depend on the air induction system design and its performance. Excessive pressure across a dirty air filter" can cause a 1–15% increase in fuel consumption. [32]

Now we can look what is requirements of ideal air inlet system and what are conditions for better durability which can found in literature.

Requirement of Air Inlet systems

1. Air intake bottom shall be above ground level by 400 mm minimum. The entry at the dirty side hose should be as high as possible.
2. The engine's air intake also needs to be designed in such a way that it doesn't clog up with snow.

3. Installation shall be such that there is no water ingress or water trace in the air intake system. Even though, water wading test (BIS 11839) is done at 150 mm (for passenger vehicle) of water level, it is suggested to test also at 300 or 350 mm of water level considering flooding of Indian roads during rainy season.
4. It should meet required inlet air filtration with minimum noise and minimum restriction to flow.
5. The resonator shall not contribute to any increase in the pressure drop and should help to reduce the vehicle interior noise.
6. Initial pressure drop and dust holding capacity shall meet the vehicle project target.
7. Vehicle interior noise level shall conform to Indian Automotive Industry Standard on interior noise AIS-020-D3 / SAEJ1477 / ISO 5128 and shall be less than 90 dB (A) at stationary high idle.
8. Air cleaner housing shall be generally of sheet metal or reinforced polypropylene.
9. The dust ejector valve of the air cleaner, if present, shall face vertically downward or at 45 degrees for easy removal of dust.
10. Length of clean side hose shall be as small as possible and with minimum change of directions. And all system joints shall be leak proof.

For durability

1. The life of air cleaner element shall be at least 40000 km.
2. Air filter element shall withstand oil fumes and compressed air pressure of 6 bar maximum during cleaning.
3. Air cleaner element shall not collapse at vacuum of 400 mbar.
4. Hoses and hose clamps shall withstand minimum life of 30000 km or 5 years whichever is earlier.
5. Dirty side hose shall be designed such that it shall not collapse under vacuum of 100 mbar.
6. Clean side hose shall be designed such that it shall not collapse under vacuum of 150 mbar.
7. If the hoses collapse even up to 10% of its diameter, internal coil springs shall be provided or the hose should be stiffened.
8. All the parts shall withstand temperature up to 100° C.

2.2 Problems in suction inlets

Engine air cleaners are designed to effectively remove airborne contaminants in order to protect the engine throughout its service life. The engine requires that the ingested air meets a minimum level of cleanliness to reduce the engine wear, improve the engine efficiency and protect the electronic sensors. The function and design of intake air filters must address the following.

- Engine durability
- Filtration
- Flow management
- Water/snow ingestion management
- Pressure loss
- Overall noise, vibration, and temperature standards
- Competitive pricing requirements
- Service requirements
- Packaging
- Styling/appearance
- Emissions

Problems for suction mainly divided in three parts

1. Dust – it can further divided as Biological dust and Inorganic dust. Filtering both of types of dust is important in suction system. The effects of dust are discussed in next discussion.
2. Water – this can be divided as Droplets and Wading. It can block suction system or create some problem to engine if its gets in suction air. Some places in India experiences heavy rain every year also some city has bad management of water drainage. So in this places it is big problem while driving the car.
3. Snow – the problem created by snow is somewhat similar to the water. Some systems or parts are deteriorate because of heavy snow. Sometimes it can block the intake system and also it can increase pressure drop in the system.

Because of recent global warming, vehicles are required even better fuel economy. Aerodynamic performance which has a strong effect on fuel economy should be balanced with exterior design and packaging. In the torrid zones, larger front grille openings are preferable to cool the engine. Furthermore, since these days the regions where the flooding occur increase due to unusual weather, vehicles are required to run through flooded roads at some certain condition. The front grille opening has trade-off relationship among such aerodynamics performance, heat resistance and water resistance. Hence, it is required to predict the front grille design effect on these performances at the early development stage. [20] Countries in Sub-continent of India faces Monsoon season which is rainy season. And flood during this time is not rare. So, this problem is typical for India.

The service life of the internal combustion engines depends on many factors. The main wear factor is the atmospheric dust that reaches inside the engine cylinders and it is carried on by the oil from lubrication system that drives it further to the kinematic couplings of the engine. Vehicles' air filters are usually made of cellulose paper or felt. These are placed in prismatic or cylindrical enclosures, depending on the available space and are specifically designed for the maintenance activities Air filters have relatively low initial efficiency. As they are used, air filters are impregnated with a layer of fine dust and their filtering efficiency is increasing. On the long term, the effect of the filtering process is the accumulation of solid particles inside the air filter and the increase of restriction on the intake air flow of the engine. The evolution of the dependence between the mass of dust collected by the air filter and the resistances generated by the air filter depend on many constructive and functional parameters and environmental factors also. [21] One of the most overlooked and least serviced components in vehicle is the engine air filter. One of the possible reasons for this is the increased service life of air filters as they are replaced at every 40,000-50,000kms. [32] Because of tropical climate, we can see more dust and dirt particles in normal air. Also in recent years some cities from India are in the list of highly polluted cities. So, filtering the air is also one of the biggest challenge one can face.

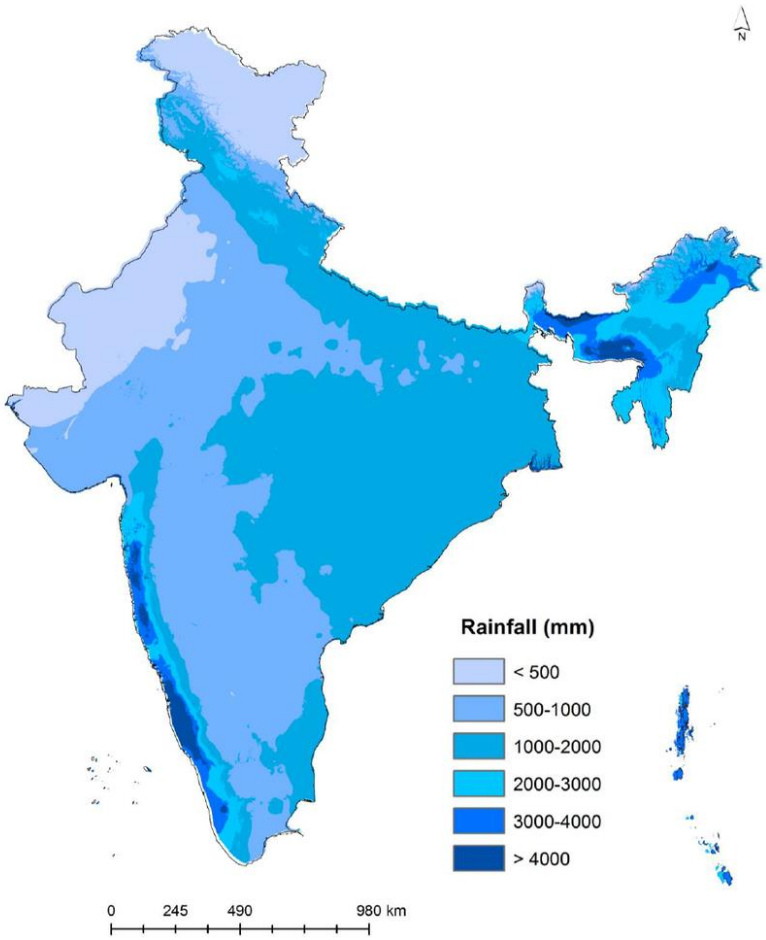


Figure 30. India map with rainfall indication.

In engine intake air filtration, the airborne dust particles of 5 µm to 10 µm diameter are known to cause major engine wear. The automotive engine intake air filters are therefore designed to filter out mostly these particles. In Figure 31 it is noticeable that in India pollution is higher than specified by World Health Organization, it is showing pollution level for PM 2.5 in mm/m^3. But this level of pollution can be applicable to higher diameter of PM i.e. for 5 µm to 10 µm diameter. This pollution level is even worse in north side of India near to India's capital New Delhi, where population density is also higher in neighboring states.

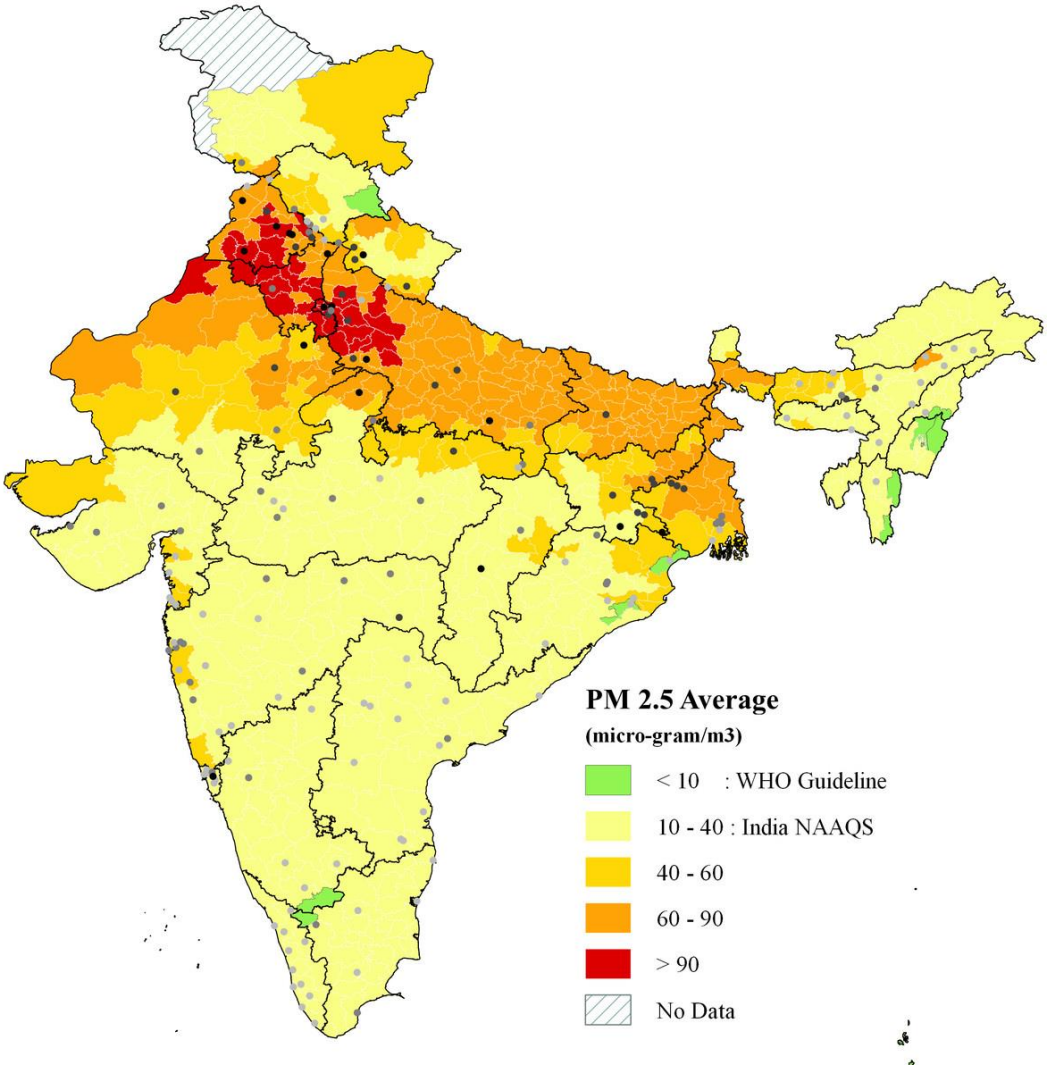


Figure 31. PM level in India. [34]

Further, besides higher filtration efficiency, longer service life and lower pressure drop are also desired for such filters. Of the many filter media available in the market, the cellulosic filter media is mostly used especially in Asian countries due to its low cost, high performance, and good packaging benefits. The particle capture by cellulosic filter media is primarily determined by fiber diameter, packing density, and face velocity. With ever-increasing trend of engine

downsizing, the space available for installation of the filter media is reducing, as a result, the face velocity is increasing. With the increase of face velocity for a constant fiber diameter and a constant particle diameter, the stokes number dependent filtration efficiency is known to increase due to dominance of inertial impaction mechanism. However, an increase in face velocity causes an increase of energy associated with the particle depending on its mass-inertia relation that could cause particle to bounce back and re-entrain into the air stream to escape through the media. This is also happening in case of dust loaded filter media. The non-uniform flow field within the automotive filter system and the associated dust deposition might increase the local velocities within the pore space of the filter media that in turn results in particle penetration through the filter media at higher velocities. This leads to an elevated risk to the engine components, associated with exposure to dust particles.

Also, a few studies indicated that the non-uniform flow distribution across the automotive filter housing and the reduced installation space under the engine bay might cause a remarkable increase of media face velocities that in turn resulted in particle penetration to increase across the filter media. [22]

The primary task of the air filter element is to clean the air taken in of dust and biological material. Decisive factors for the lifetime of filter elements include, on the one hand, the filter media used and, on the other, the available installation space. The more volume there is available, the greater the filter area that can be accommodated. The introduction of new safety- and function-relevant components in the engine compartment has lead however to intense competition for the available installation space. [23]

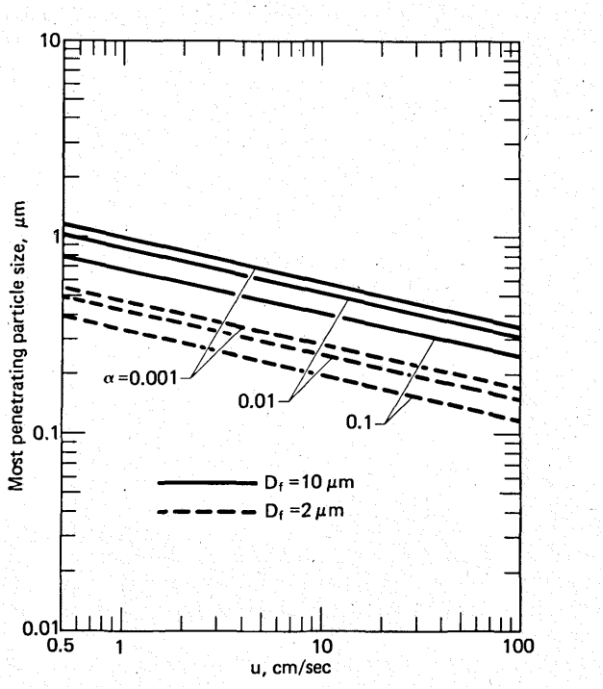


Figure 32. Theoretical penetration of fiber material with varying velocity. [35]

Where, α = fiber volume fraction of filter

D_f = fiber diameter

The study conducted on Fiat multi jet engine showed that engine adaptability under varying loads were better no filter conditions compared to when new filter was installed. It was also found that increased air filter clogging correspondingly increased the air flow resistance and in turn decreased the flexibility to varying loads and fuel economy of the engine, and best to replace the filter frequently according to manufacturer's recommendations. [32]

The filter has three basic components first dirty side case housing, clean side cover housing and filter. These housing and filter restricts the air flow which increase the pressure drop. If there is a large pressure drop downstream of the air cleaner then the supply of air to the engine is insufficient which will cause incomplete combustion leading to pass unburnt particles from the exhaust causing to air pollution.

Efficiency of engine is also depends on temperature of air inlet to suction system. Usually there is turbocharger after the filtration of air. We know that after compression of air, temperature is also increased. So the question is how this temperature of air affects efficiency of combustion. Higher temperature means less density of air in another words we can say that less oxygen in same amount of volume as compared to low temperature air. So availability of lesser oxygen molecules tends to lowers the combustion efficiency of engine. This problem arise usually in hot region. Because, already the incoming air to suction system has high temperature and after turbocharging it might get higher. It can be seen in some experiment that increase in air suction temperature also increases exhaust emission and the exhaust temperature. Also it causes a decrease in volumetric efficiency. For solving this problem generally automakers prefer to keep front grill fully opened. Purpose of this grill is air coming from this grill cools the under hood area of car, which is good thing for maintaining air temperature from suction system. But open grill creates problems of dust, wading and water droplets from rain. In cold region some part of grill is closed. Because outside air can freeze air under hood or it can help to block the suction system with very low temperature. So blocking this outside air partially helps to run the system. In the cold regions an anti-snow system can be applied. The system brings hot air from an area behind the aggregate to the bottom part of the filter box. This prevents snow plugging by melting the snow.

There are chances of pre-ignition and knocking, if temperature of the inlet air is higher than normal. As the temperature of the air will be higher, the temperature of air-fuel charge will also be higher (petrol engine) which means there are chances of ignition of air-fuel mixture even before the piston reaches its precise point during normal combustion.

Figure 33. Maruti Suzuki Dzire (Front grill open).

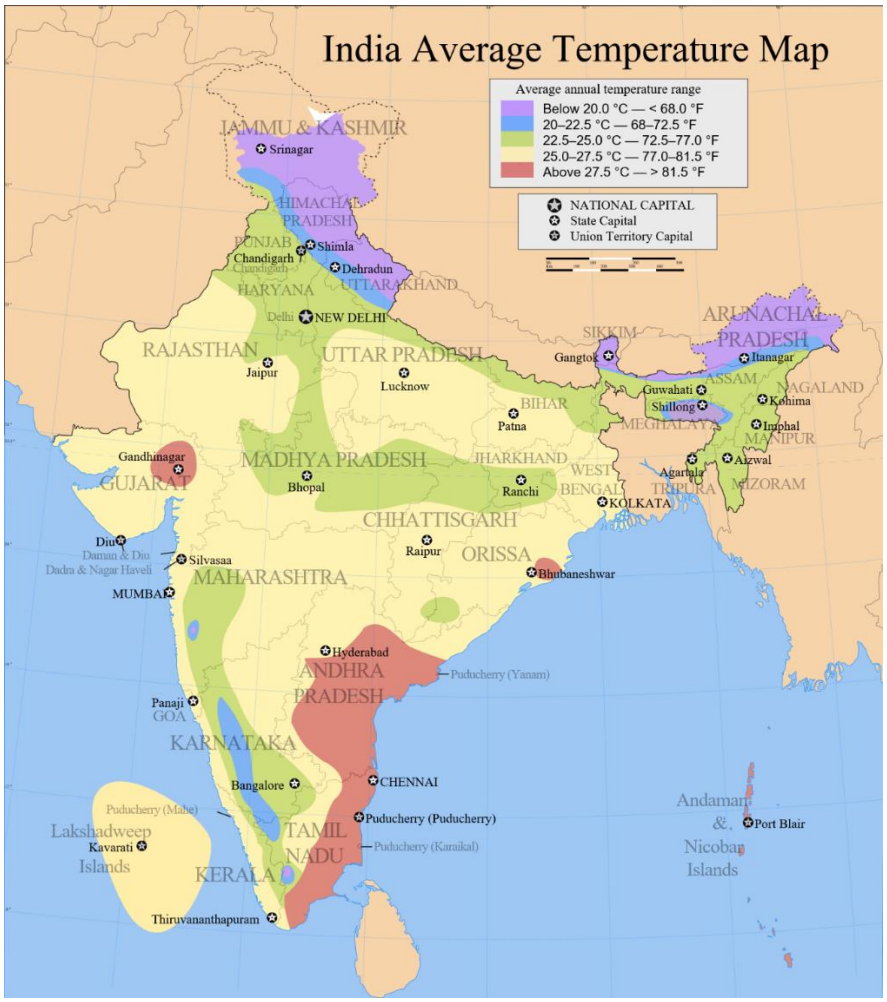


Figure 34. India average temperature map.

3 Practical part

3.1 Background

Practical Part is focused on comparing the Air inlet system available in Indian market. This comparison is done after studying components of this system. The comparison is done based on the 2 base criteria. They were some other factors under consideration. Based on survey i.e. questionnaire, it were chosen this criteria. Also there was problem with some factors like Material. In material category same component can have different material from OEM, and it is hard to decide which material composition is best or worst for the application.

This comparison is done for three automotive segments; they are Hatchback, Sedan and SUV. When we look in recent top sale of cars in January 2018 then it can see that customer in Indian market prefer these category cars. Sale of small cars shows that **Price** is very important for this market. And then **Aesthetics** we can say from the questionnaire 7 out of 10. If we look in the questionnaire carefully people wants better looks in their future car, also when to compare the car with other brand's car people prefer looks of car on first space. Other most noticeable thing in questionnaire is Mileage of car. Mileage of car is one of the important factor while choosing car. So design of air inlet system is one of the important parameter, as we have seen in research that **Good Design** of air inlet system push car to perform better in terms of reduced pressure drop, more revolutions per minute and better combustion. Since small cars are famous in this market choosing 1L-1.2L engine was relevant in Hatchback category. Bestseller like Maruti Suzuki's Dzire in sedan category and Vitara Brezza in SUV category from same manufacturer will be compared in the practical part. While considering other car for comparison it is important to have nearly the same engine size. Hyundai has second largest share in the Indian car market so it make sense to compare its air inlet system. Also engine of nearly same size is available. Companies like Mahindra and Tata has major contribution in research and development from past few decades in domestic market so it makes sense to add this companies for comparison.

For comparison part 1-10 rating system is used. 1 is worst and 10 is highest. While comparing it is very important to have car specification with similar size. One cannot compare if for example engine size is too different. In Hatchback we choose smaller engine of 1 to 1.2L. There were some car available with smaller engine like Tata nano (624cc), Maruti Suzuki's Alto 800 but engine of 1-1.2L is more common in Indian market, most of the top selling in January 2018 has engine of around 1.2L. In sedan category engine of 1.2L is the most typical in India. Some companies create same engine for both hatchback and sedan category, front body of the car is also same only difference of two box or three box type i.e. hatchback or sedan. But luxurious sedan can have bigger engine. In other case, sale of SUV is booming as we noticed in earlier chapter. SUV range is wide in Indian market. Top 2 bestseller of SUV in January 2018 has engine of 1.25L and 1.4L, they are Maruti Suzuki's Vitara Brezza and Hyundai's Creta. In same category Tata launched Nexon which has engine of 1.5L. All three SUV's are new in Indian market so

choosing them for comparison is not bad decision here. Engine specification from all this category are specified in next chapter.

So far we have discussed how some criteria like Price, Aesthetics, Designs, etc are important for customer point of view. Based on this observation we are choosing Price and Design parameter criteria for Multi criteria comparison. So it will be 2 criteria comparison for 3 car segments. And this comparison require some kind of numbering or let's say ranking system. This ranking system is given from 1 to 10 scale where is 1 is worst and 10 is best and based on this system for each parameters in criteria we will evaluate whole system. After this particular evaluation of parameters we can summation of it for each car in each criteria. And based on this summation we can conclude which is best car for each criteria. But this is about criteria comparison, how we can get overall result i.e. which is best car in each category?

So answer is we have two basic criteria here one is price and second design of air inlet system. While selecting best car from each category we can give some certain weightage to each criteria. Based on questionnaire Indian customer seems to choose economical car over luxurious one. And as we seen good design for them is second main important parameter. Thanks to this we can assign 60% weightage to final summation of Price and 40% of weightage to final summation of Design criteria. Multiply Price summation and design summation with weightage. Then add this two results. In this way we can final winner from each category of car. This is for Indian market comparison. But how that is going to help us to compare this with European environment? So final winner from each category is going to next comparison with one size air inlet system from Skoda Auto. This further comparison between Indian and European environment will give us some conclusion.

Till far we discussed about customer point of view. But this comparison can have more views, which are Economical point of view and Engineering point of view. What it means exactly, it means the weightage we are using for customer point of view can be changed for economical and engineering point of view. The economical department might give more weightage to Price criteria while it will be vice versa in case of engineering department. And then final results can change accordingly to type of view. Because this calculation is done in Microsoft excel. All we have to do is just put the formula in cell and then we can check difference in final results by changing weightage.

Now let's have a quick look at questionnaire which we referred for deciding weightage.

This survey was filled by 31 people. Unfortunately we don't have much information from female candidates, only 1 female candidate was able to understand all this criteria. Out of 31 people 20 people are employees, 4 owns business and 7 of them are students. Most of them are living in city part of India. Main aim of this survey is to know about customer preferences from Indian market, so people who participated in survey were Indians. These preferences extends to know particularly about some parameters like economy point of view, design point of view, etc. We

design this survey with 12 questions, most of the questions have multiple choice answers so people can fill it easily and faster.

	Questions	Answers	
		Yes	No
1	Are you Skoda owner?	1	30
2	Do you have any experience with Skoda car?	12	19
3	Why you need car?		
	a. Business Purpose (Daily running in city – Company employees, Business owner)	4	
	b. Business Purpose (Such as Tour business – daily longer distance)	2	
	c. Family car (such as shopping, family trip)	25	
4	Which car type you are looking for you?		
	a. Hatchback	7	
	B. Sedan	13	
	C. SUV	11	
5	What things you are looking in your future cars – specify all the points by priority for example better looks, more mileage, more space	Most people says Better Mileage, better Looks, good space	
6	What things you don't mind in car (from 1-5 scale) – 1 – I don't care 5 – That's most important		

		1	**2**	**3**	**4**	**5**	**Total**
a.	Aesthetics	1	0	6	9	15	31
b.	Noise of Engine	2	2	8	10	9	31
c.	Acceleration Performance	1	0	6	11	13	31
d.	Vibrations	2	2	9	7	11	31
e.	Mileage of car	1	0	7	8	15	31
f.	More safety with high initial cost	1	2	8	7	13	31
g.	Electronic gadget	2	1	10	11	7	31

7	Which type of fuel engine are you looking for?	
a.	Petrol only	2
b.	Petrol / CNG	18

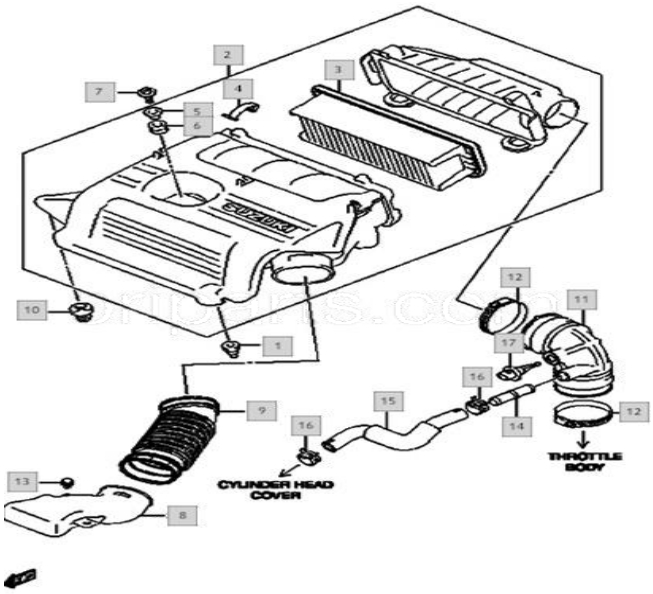
c.	Diesel	10
d.	With LPG kit	1
8	Which factor do you think Skoda is missing in their car? What is your opinion?	Mostly people says Looks
9	What is your opinion about Skoda servicing? Currently Skoda offers 4 years/100000 kms warranty.	a. Very good b. One special comment - Performance is only good under the servicing period only
10	What are the aspects when you compare car of same category with another brand car? For example looks, mileage.	Looks, Mileage, Space, Initial Cost (Important aspects)
11	What you prefer before purchasing car?	
	a. High Initial cost and Low maintenance cost	17
	b. Low initial cost and Moderate Maintenance cost	14
12	How often you see advertisements of Skoda Cars?	
	a. Never	3
	b. Sometimes	22
	c. Often	6

After looking this survey we can conclude some things.

1. Mostly people are looking for family car.
2. They wants Sedan and SUV mostly as a future car. (but from actual sale in January 2018 we can say while buying they prefer Hatchback)
3. Aesthetics and Mileage of car are most important for customer.
4. Because most of the participant are from city part as mentioned, they are more convenient with Petrol/CNG and Diesel cars. (CNG is mostly available in city part of India)
5. Again looks and mileage are important aspects while comparing with other brand car.
6. Some improvement is needed in marketing strategy. Companies boost their sale, such as Hyundai and Maruti Suzuki by advertising and marketing strategy.

3.2 Figures of Air inlet system for comparison

We already seen in the last part that logic behind choosing cars for comparison. From each segment of cars we have 3 cars each. We got the drawings of inlet system of this cars from one source. For comparison it's really good to have drawing details in front of you. In front of following of pictures specifications of engine, category of cars, type of air inlet systems, and performance of engine are specified. Based on this pictures and part information we can compare the system with one another.



Specification

Category - Hatchback
Fuel type – Petrol
Engine size – 1L (998cc)
Engine power – 68 HP 51KW
Mileage – 20.5km/l
Motorfest inlet system.

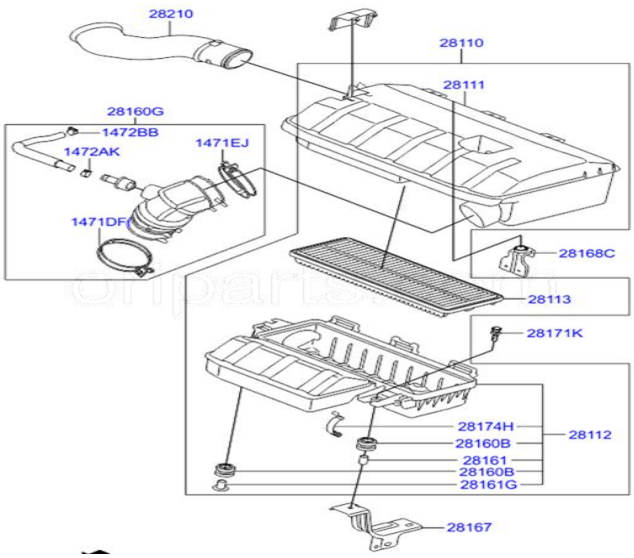
Figure 35. Maruti Suzuki WagonR

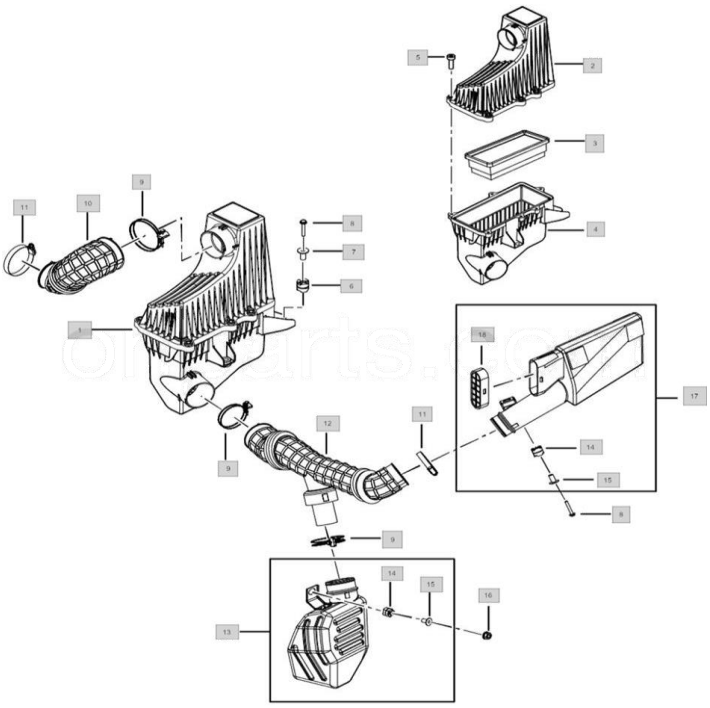
.

Specification

Category - Hatchback
Fuel type – Petrol
Engine size – 1L (1000cc)
Engine power – 69 HP 51KW
Mileage – 20.3km/l
Motorfest inlet system.

Figure 36. Hyundai EON.





Specification

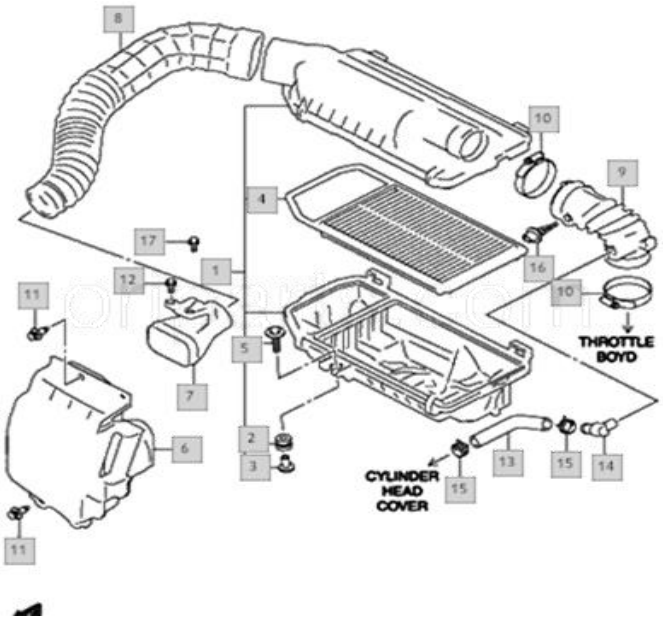
Category - Hatchback
Fuel type – Petrol
Engine size – 1.2L (1198cc)
Engine power – 82 HP 61KW
Mileage – 16-18km/l
Next to engine

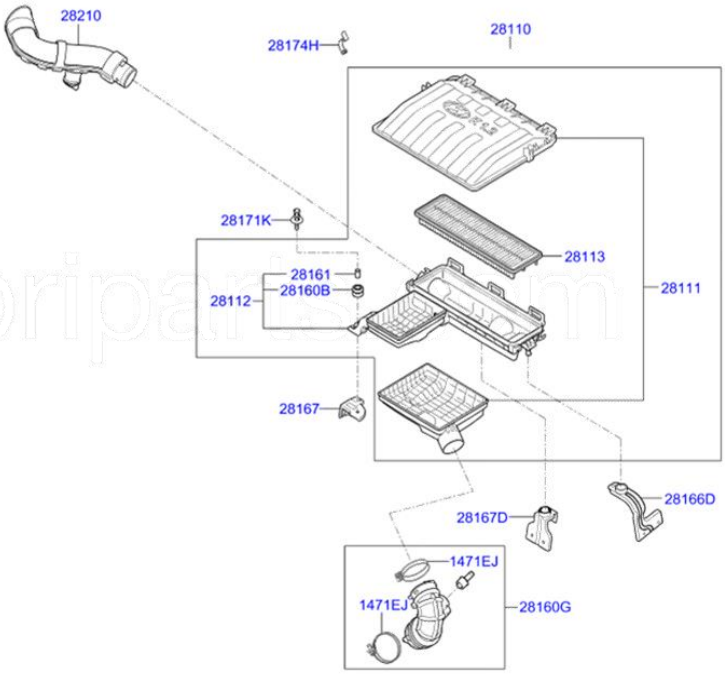
Figure 37. Mahindra KVU 100.

Specification

Category - Sedan
Fuel type – Petrol
Engine size – 1.2L (1197cc)
Engine power – 82 HP 61KW
Mileage – 22km/l
Motorfest inlet system

Figure 38. Sedan – Maruti Suzuki Dzire (1.2L).

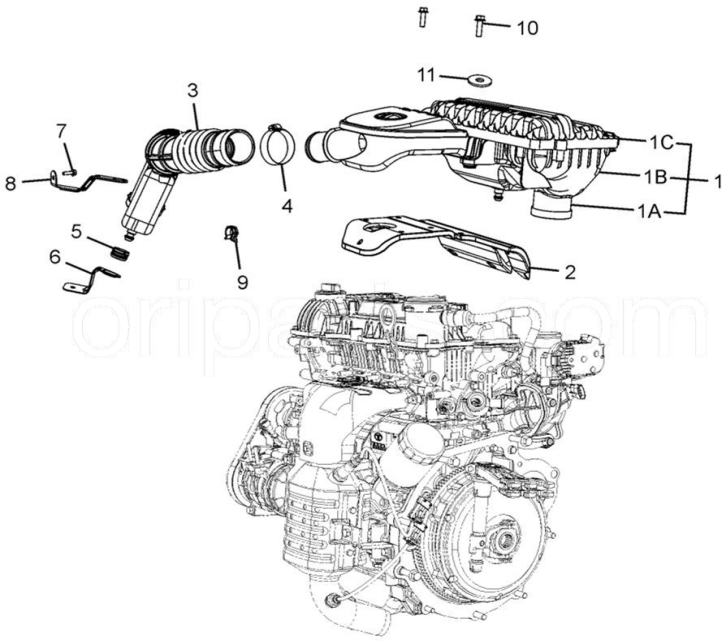




Specification

Category - Sedan
Fuel type – Petrol
Engine size – 1.2L (1197cc)
Engine power – 82 HP 61KW
Mileage – 17-19km/l
Motorfest inlet system

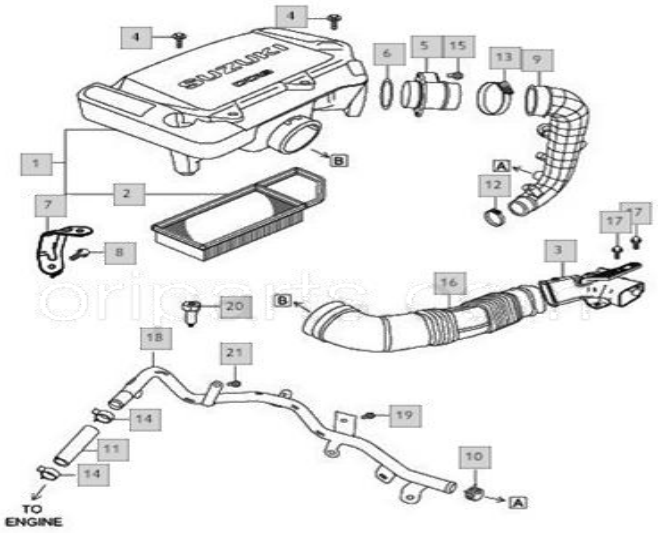
Figure 39. Hyundai Xcent.



Specification

Category - Sedan
Fuel type – Petrol
Engine size – 1.2L (1199cc)
Engine power – 85 HP 63KW
Mileage – 20.3km/l
Motorfest inlet system

Figure 40. Tata Tigor.



Specification

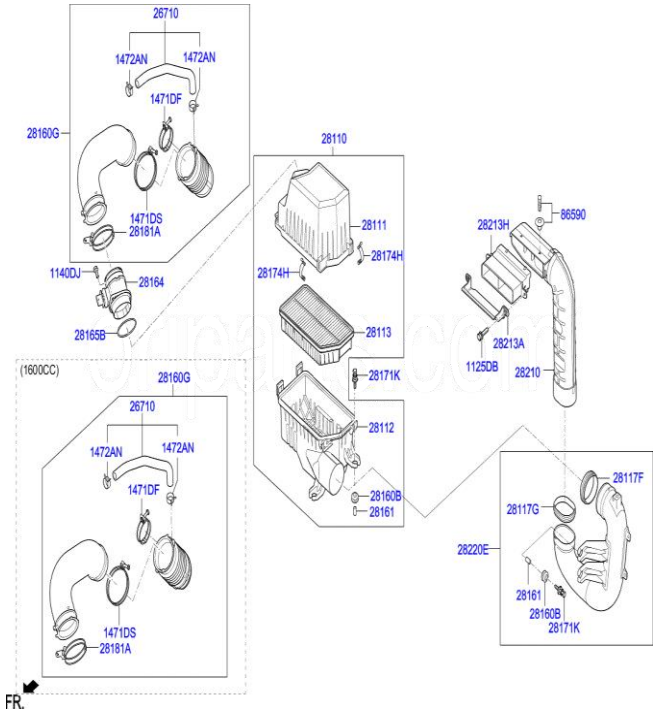
Category - SUV
Fuel type – Diesel
Engine size – 1.25L (1248cc) turbocharged
Engine power – 85 HP 63KW
Mileage – 24.3km/l
Motorfest inlet system

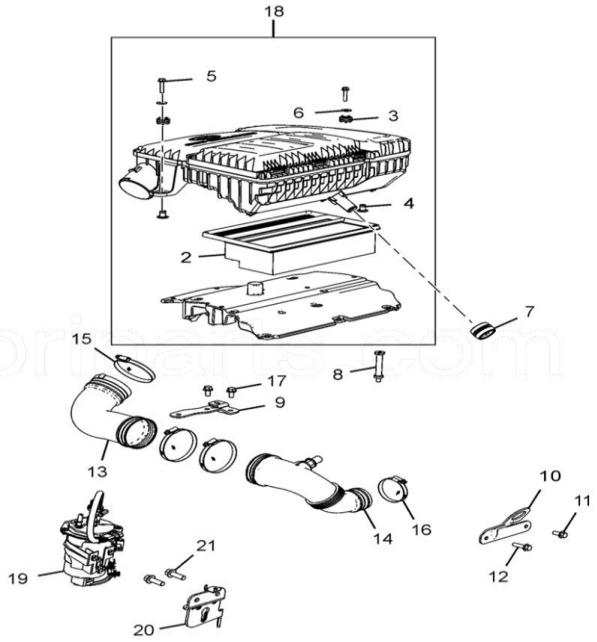
Figure 41. Maruti Suzuki Vitara Brezza.

Specification

Category - SUV
Fuel type – Diesel
Engine size – 1.4L (1396cc)
Engine power – 90 HP 67KW
Mileage – 21.3km/l
Next to engine

Figure 42. SUV – Hyundai Creta (1.4L).





Specification

Category - SUV
Fuel type – Diesel
Engine size – 1.5L (1497cc) turbochrged
Engine power – 108 HP 81KW
Mileage – 21.5km/l
Motorfest inlet system

Figure 43. SUV – Tata Nexon (1.5L).

3.3 Multi criteria comparison for Indian Market

Price – From figures in last chapter we can see all the components used for air inlet system. Different manufacturer has different design for air inlet. Sometimes is used less components or sometimes high no. of components depending on engine size and overall cost of car. So in this criteria we are trying to make table with list of components for each category car and write their prices in each column. We got prices in Indian Rupees but for our purpose we are going to convert it to Euro (1 Euro = 79.59 Indian Rupees). Then we are going to sum it in the last. We are going to compare this sum to **Rating of price** and according to it we assign the rating to each car. Table 10 and Table 11 shows the Rating of price.

For this criteria most of the components of air inlet system are covered for comparison. Some prices were not available so there was expert estimation for it. For example, connections materials such as screws, bolts, clamps and joints etc. Its better way to estimate the total weight of this small parts and put price of this metals per kilograms. Price of some parts are not mentioned in some cases because that part is not used in actual air inlet system in that car. Also, in some cases function of one part is not only one, it can serve two or many functions. For example, in Hyundai EON price of inlet duct and inlet pipe is not shown. Because duct resonator plays role as resonator and inlet pipe simultaneously, and it doesn't use duct.

For final rating of price, we selected two ranges for ratings, one is for Hatchback and Sedan category and second is for SUV segment. These two ratings are important here. Because in case of small car category the deviation of final price is somewhat closer, not so big difference in final summation. So, it is hard to compare air inlet system though you have different price but in same

range. For SUV range is different because deviation in price is higher. So range for rating should be higher. Rating is based on 1-10 points. 1 is worst and 10 is best. In this case 10 means it is the cheapest in market. On the other hand, 1 is most expensive.

Prices compared here are from only single source for all the compared cars. And these prices are for direct customer. These are not wholesale prices.

Prices shown in red colours are expert estimations. Because prices of some parts are not available on the same source. The assumption is based on approximate closer price to same part of another car. Cells with prices shown with coloured background are not added in final total for price estimation. They are subpart of assembly.

Range in Euro		Rating
6	12	10
12	25	9
25	37	8
37	50	7
50	65	6
65	80	5
80	100	4
100	120	3
120	145	2
145	above	1

Table 10. Price rating chart for Hatchback and Sedan

Range in Euro		Rating
6	12.5	10
12.5	25	9
25	50	8
50	90	7
90	125	6
125	175	5
175	240	4
240	300	3
300	375	2
375	above	1

Table 11. Price rating chart for SUV category

Design – We already discussed how the design is important in the earlier chapter. In design category we are looking on full air inlet system from engineering point of view. It includes aspects like number of components and connection materials, space utilization, complexity, filter element size and use special parts such as sensors or resonators. And based on this aspects we are again giving ratings from 0-10.

No. of main components plays important role as it decides the size of whole air inlet system. More number can be results in big system. But utilization of space can compensate this factor. Proper use of space looks good when one sees the inlet system of car and advantage to use it for other components such as resonator. It is also important that which type of aggregate suction system the car has. For example, some suction system is mounted on engine which can serve as engine cover as well. But from point of view of vibration, manufacturer has to make some certain vibration test. Also, some suction systems are next to engine (on the wheel casing) which withstands in case of vibrations, but it takes some space and serves only one function unlike system on engine. In some air inlet system no. of connecting materials is big. More connections can tend to more pressure drop or sometimes stress concentration, even risk of failures as well.

Also, it can add more money to overall price. In today's world use of advance technology is important such as HFM sensor to measure air flow, resonators to reduce the noise and snorkel or water drainer to discharge water from air inlet system. From questionnaire it can see that noise is also important for customers, they said that they care about noise of engine and we have seen in research part that the proportion of this intake noise is around 30% of total automobile noise. So, use of resonators becomes one of the factor but which can add some price as well.

As we discussed **No. of components** can decide the size of air inlet system. So in rating table one can see that more no., lower the ratings. For example having lot of components in air inlet of small car can demand more space which can get be trouble from point of view of designer. On this base we decide the rating for no. of components parameter. In next parameter i.e. **No. of connecting materials** it's same like previous parameter. More no. gets lower rating. In next parameter of **Space utilization**, worst utilization gets lower rating. In picture we can see some inlet system has some components but with big size and they are not good for space utilization. Also it is important to which type of air inlet they are using, sitting on engine or next to engine. On this basis we rated here in space utilization parameter. Then it comes to **Complexity rating**. This rating is judged on fact that how simple is design and layout of air inlet system. Complexity brings some other challenges for designers for example if the length of pipe is twisted and it is long then pressure drop can gets high. Then there is parameter of use of **Sensors, resonators and snorkel**. So according to no. of this components in inlet system rating is given. Use of this components getting more important because it's really needed from design point of view for reducing noise, measuring air flow rate (to ensuring proper combustion), use of water drainer to keep air inlet system dry. Filter element size is also mentioned here in this criteria. It has no rating here, it's just for study purpose here. One more thing is we really can't give rating to filter material based on size or material, it can get ranking based on area of filter, material, efficiency but OEMs nowadays usually don't share this information. We could able to get just dimension of filter. Some filter dimensions were unavailable, so it is done by expert's estimations.

Following are the table of rating for design category for all the parameters.

Component range		Rating
0	3	10
3	5	8
5	7	6
8	10	4
10	12	2

Table 12. No. of components.

Component range		Rating
0	5	10
5	10	9
10	15	8
15	20	7
20	25	6
25	30	5
30	35	4
35	40	3
40	45	2

Table 13. No. of connecting materials.

space utilization	Rating
worst	1
bad	3
good	5
better	7
best	9

Table 14. Space utilization rating.

complexity	Rating
simple	9
average	6
complex	3

Table 15. Complexity rating.

condition	Rating
3 components	9
2 components	7
1 component	5
Integrated component	3

Table 16. Sensors, resonators and snorkel rating

1. **Hatchback (Fuel type - Petrol)**
   a. **Price**

No.	Component	Maruti Suzuki Wagon-R - 1L	Hyundai EON – 1 L	M & M KUV 100 – 1.2L
1	Inlet Duct	1.28	-	5.88
2	Inlet Pipe	1.26	-	5.70
3	Duct resonator	-	2.17	14.83
4	Filter assembly	11.87	30.27	13.90
4a	Filter Element	2.14	2.78	4.46
4b	Casing	-	9.80	14.64
5	HFM sensor	3.86	-	-
6	Outlet Pipe	2.63	10.11	4.61
7	Breather	0.33	-	-
8	Connection Materials	1.26	1.26	1.26
	Sum	22.48	43.81	46.17
	Rating	9	7	7

Table 17. Price comparison of hatchback.

b. Design

No.	Parameters	Maruti Suzuki Wagon-R - 1L	Hyundai EON – 1 L	M & M KUV 100 – 1.2L
1	No. of components	4	8	6
2	No. of Connecting materials	8	7	4
3	Space utilization	5	7	3
4	Complexity	6	9	3
5	Size of filter element	230*85*55	305*109*36	230*95*60
6	Sensors, resonators and snorkel	5	3	5
	Sum	28	34	21

Table 18. Design comparison of hatchback.

In price criteria Maruti Suzuki's WagonR is winner. It has smaller engine than other two still if we see sum of price in euro it's a big difference. In Design criteria Hyundai's EON is winner. In final rating Hyundai Eon is ahead in race. Simplicity in design is big advantage for Hyundai.

2. Sedan (Fuel type - Petrol)

a. Price

No.	Component	Maruti Suzuki Dzire – 1.2L	Hyundai Xcent – 1.2L	Tata Tigor – 1.2L
1	Inlet Duct	2.46	10.74	-
2	Inlet Pipe	15.44	-	-
3	Duct resonator	-	-	12.82
4	Filter assembly	9.20	28.66	34.95
4a	Filter Element	3.58	2.14	5.68
4b	Casing	-	9.21	5.01
5	HFM sensor	3.86	-	-
6	Outlet Pipe	1.83	10.88	-
7	Breather	0.38	-	-
8	Connection Materials	1.26	1.26	1.26
9	Foam (resist vibration)	-	-	4.40
10	Shroud	8.52	-	-
	Sum	42.95	51.54	53.42
	Rating	7	6	6

Table 19. Price comparison of sedan.

b. Design

No.	Parameters	Maruti Suzuki Dzire – 1.2L	Hyundai Xcent – 1.2L	Tata Tigor – 1.2L
1	No. of components	4	6	8
2	No. of Connecting materials	7	9	8
3	Space utilization	5	5	9
4	Complexity	9	9	3
5	Size of filter element	280*173*25	214*133*34	250*190*25
6	Sensors, resonators and snorkel	5	5	7
	Sum	30	34	35

Table 20. Design comparison of sedan.

In price criteria we have winner from Maruti Suzuki's Dzire. The margin between Dzire and other cars is roughly 10 Euro. In design criteria Tata Tigor got highest rating. But winning margin is not too high, it's just by 1 point. Use of resonator and snorkel makes gives advantage in design.

3. SUV (Fuel type - Diesel)

a. Price

No.	Component	Maruti Suzuki Vitara Brezza – 1.25L	Hyundai Creta – 1.4L	Tata Nexon – 1.5L
1	Inlet Duct	2.51	-	9.40
2	Inlet Pipe	22.62	9.66	-
3	Duct resonator	-	17.50	8.07
4	Filter assembly	16.57	19.04	37.58
4a	Filter Element	4.02	4.02	5.78
4b	Casing	-	10.39	-
5	HFM sensor	38.69	180.14	72.13
6	Outlet Pipe	21.00	42.13	11.36
7	Breather	4.21	-	-
8	Connection Materials	1.88	0.63	1.88
	Sum	107.48	269.09	146.20
	Rating	6	3	5

Table 21. Price comparison of SUV.

b. Design

No.	Parameters	Maruti Suzuki Vitara Brezza – 1.25L	Hyundai Creta – 1.4L	Tata Nexon – 1.5L
1	No. of components	4	4	6
2	No. of Connecting materials	7	4	7
3	Space utilization	5	5	5
4	Complexity	9	6	3
5	Size of filter element	225*200*33	264.5*142.5*54	250*150*60
6	Sensors, resonators and snorkel	5	7	5
	Sum	30	26	26

Table 22. Design comparison of SUV.

SUV has slightly bigger engine as compared to other two categories and deviation in price is also high if we notice. Maruti Suzuki's Vitara Brezza is clear winner in Price (with big margin) and in Design as well.

Category	Company	Car	Price rating	Design rating	Final rating	Remark
Hatchback	Maruti	WagonR	9	28	16.6	
	Hyundai	EON	7	34	17.8	winner
	Mahindra	KUV 100	7	21	12.6	
Sedan	Maruti	Dzire	7	30	16.2	
	Hyundai	Xcent	6	34	17.2	
	Tata	Tigor	6	35	17.6	winner
SUV	Maruti	Vitara Brezza	6	30	15.6	winner
	Hyundai	Creta	3	26	12.2	
	Tata	Nexon	5	26	13.4	

Table 23. Final rating of air inlet system of Indian cars.

From this table we have winner from each category. As we discussed in background part about weightage of criteria. The same we applied here. So we got final rating as follows,

We will see just one example of Tata Tigor. So it has price rating of 6 and design rating of 35.

$$Final\ rating = (Price\ rating * price\ weightage) + (design\ rating * design\ weightage)$$

$$Final\ rating = (6 * 0.6) + (35 * 0.4) = 17.6$$

In this case we are talking about customer point of view. If we want to know final rating from Designer point of view or economical one, then procedure remains same only difference is we need to change weightage of criteria as mentioned earlier. We can do this Microsoft's excel sheet for saving time. For example economists could say they want to go with 40% design weightage and 60% price weightage then in case final rating could be something different and winner could be someone else. For designer price could be least factor and this result could be different than other case.

3.4 European suction aggregate and comparison

1. Hatchback suction aggregate

Specification
Category - Hatchback
Fuel type – Petrol
Engine size – 1L
Engine power – 55 KW
Mileage – 5.8/4.2/4.8L/100km urban/extra-urban/combined
Motorfest inlet system.

We can see Skoda's air inlet system in Figure 44 left side which is used for small car i.e. Hatchback category. Power created by this engine is 55kw used in cars like Fabia hatchback. If we see this picture this system look simple. The parts are designed in such a way that it can fit in small space. This particular system sits directly on engine. As we discussed in earlier that this design saves space but need some certain test to make sure it can withstand vibrations from engine. Air is sucked through inlet pipe from engine space Resonator is fitted on inlet pipe and as outlet pipe directly goes to engine so it is very short length, space saver as well. Filter box looks big but it covers upper part of engine very well in fact good for space utilization.

Škoda vs. Hyundai Eon

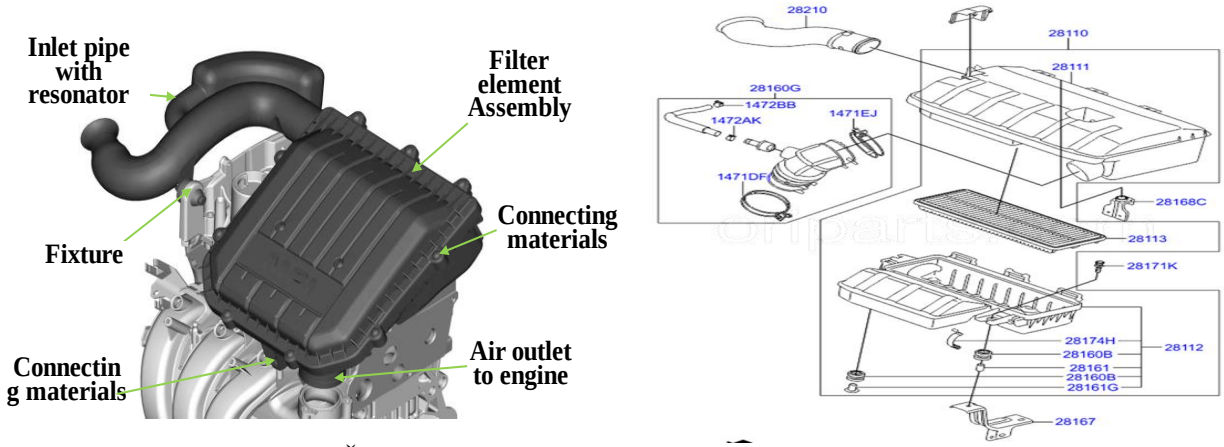


Figure 44. Škoda 1.0L-55KW vs. Hyundai Eon 1.0L-51KW.

As we declared Hyundai Eon's air inlet system as a winner in hatchback category. We can compare it with Škoda's similar air inlet system from same engine size. Firstly both has exact same engine with approximately same power. So while comparing parts from each manufacturer one can begin with inlet pipe. In both system inlet pipe is serves as inlet duct as well. In Škoda system they have resonator on inlet pipe, while in Hyundai inlet pipe is serves as resonator but not effective as a Škoda's one. Filter size of Škoda is 267*154*25 and Hyundai's 356*109*36. Area wise Hyundai's filter is bigger. In case of overall size Hyundai's inlet system looks bigger because of this big filter and big cover they are using on filter box. Both system need connection materials but we can see it is easy to mount and fix Škoda's inlet system. So in the end it seems that Škoda's inlet system is more compact, good space utilization and because use of separate resonator makes it better than Hyundai's Eon.

2. Sedan suction aggregate

Specification
Category – Sedan
Fuel type – Petrol
Engine size – 1L
Engine power – 70 KW
Mileage – 5.2/3.9/4.4L/100km urban/extra-urban/combined
Motorfest inlet system.

Another one air inlet system from Škoda shown in Figure 45. This system is used for sedan category car. Power produced from engine with this system is 70KW. System starts with inlet duct as we can see in picture. Generally this duct is situated behind the grills. It looks like height of duct from ground is approximately same as whole inlet system. This system does not have resonator. Inlet pipe is carrying this air to filter and there is filter box assembly which contains filter element, filter housing and covers. One more thing is added in this case which water drainer. This is one kind of non-return valve, which allows to drain water only on one side, ensuring other particle will not enter from other side. Intention of this water drainer if water get sucked into the passage of system then it can be big problem for sytem. This is also motorfest inlet system which sits on engine so the outlet pipe is directly connected to engine.

Škoda vs. Tata Tigor

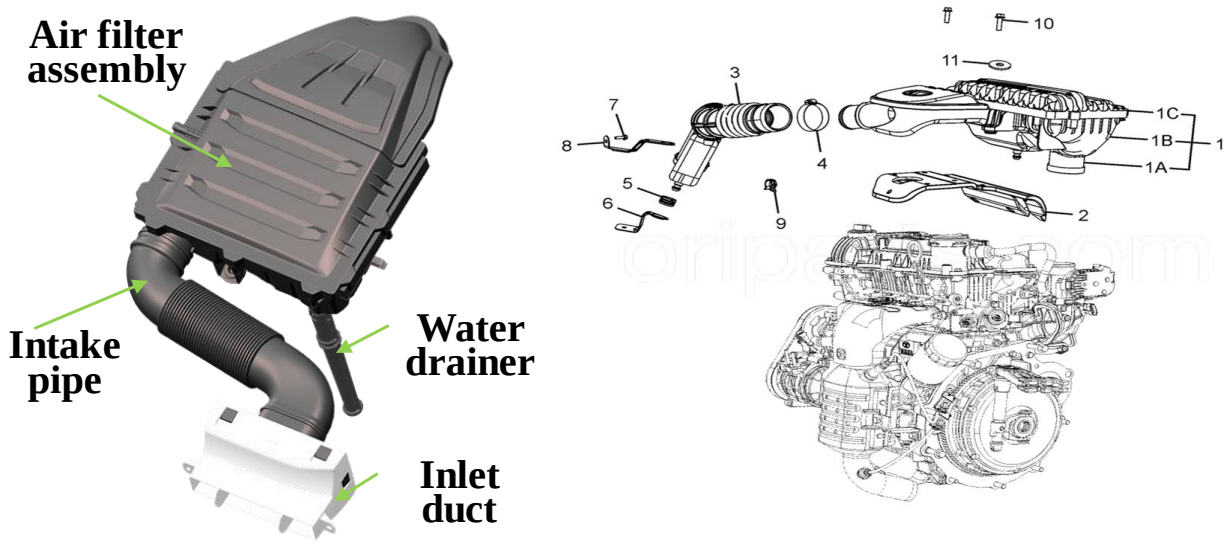


Figure 45. Škoda 1.0L-70KW vs. Tata Tigor 1.2L-63KW.

From sedan category Tata Tigor was above in the list. While comparing this two inlet systems as shown in Figure 45 it can see that both systems are more or less similar in operation except the size. Also there is small deviation in engine specification and power which is not too much. In case of Tigor, it takes air from engine space, it is not connected to grill unlike Škoda. Both system has less length of pipes, in fact no length for outlet of air. Overall simplicity can be seen in Škoda as compared to Tigor's and Tigor's system looks bulky. Both system has water drainer. Tata Tigor has resonator and inlet pipe together. If we compare filtering area based on available data Tigor's filter is bigger than small margin. Because of Tigor's bulky structure, Škoda goes ahead in race of comparison.

3. SUV suction aggregate

Specification
Category – SUV
Fuel type – Diesel
Engine size – 1.4L
Engine power – 77KW
Mileage – 4.2/3.5/3.8L/100km urban/extra-urban/combined
Next to engine space

Figure 46 shows air inlet system from Škoda which is used for low powered SUV. Engine is capable to produce 77KW. This type of system sits next to engine space i.e. on wheel casing, not on engine. This air inlet system is quite bigger than other categories because of quite higher power. It has additional some part such as sensor and has long outlet pipe. This is turbocharged diesel injection so air goes to turbocharger after filtering and then through outlet pipes goes to engine. That's why length of pipe is longer in this case. And we also seen about sensor used in

air inlet system. We can see water drainer is situated below the air filter assembly. And position of inlet duct is just behind to grill of car.

Škoda vs. Maruti Suzuki Vitara Brezza

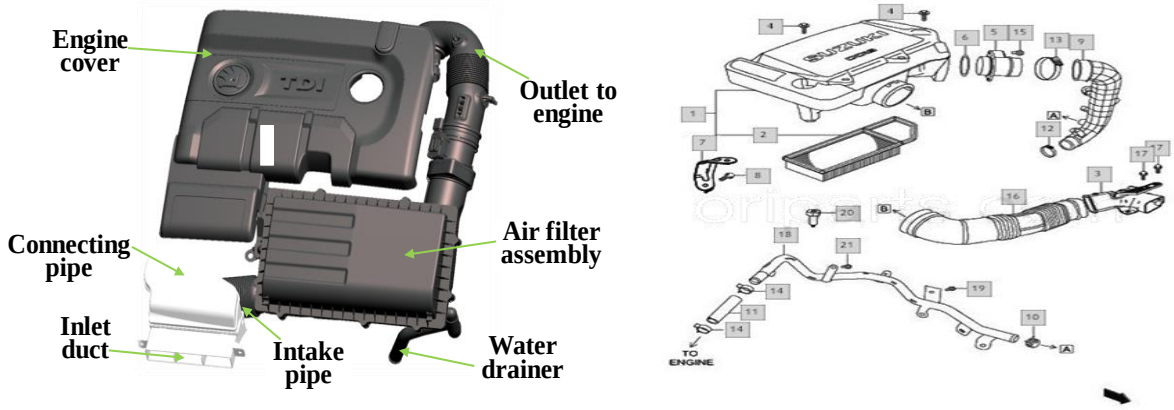


Figure 46. Škoda 1.4L-77KW vs. Maruti Suzuki Vitara Brezza 1.25L-63KW.

In SUV category from Indian environment Maruti Suzuki's Vitara Brezza is winner as we seen in last part. These both engine has slightly different specification, in case of engine size its closer but power produced is different. Type of inlet systems are also different, this Škoda inlet system sits next to the engine space while Vitara Brezza has motorfest system which sits on engine. Both the system are using sensor (not easily can see in picture) for measuring air flow rate. It is advisable to have sensor for big engines. Both systems sucks air from inlet duct which is situated behind the front grill of car. Noticeable thing in Vitara Brezza is length of pipe, it has bigger length of pipe than Škoda's. In case of filter, Škoda has bigger filtering area for one used in Vitara Brezza, one of the reason for it because of bigger engine size of Škoda. Overall Škoda's air inlet system looks good, compact with less connecting material. And Vitara Brezza's lengthy pipe gives disadvantage in competition.

4 Conclusions

This report includes thesis part and appendices. The thesis part is focused on the Indian market for an automotive sector and the practical part of multi criteria comparison. The appendix part is covering Innovative research part and thesis pictures which has design suggestions for air inlet system, Excel sheet which contains photos of the air inlet system from the major manufacturers.

From recent 10 bestsellers in Indian market we can see that 7 out of 10 are from hatchback category. Most of these cars have engine specification around 1-1.4L. This shows preference of small cars in India. From past few years, growing percentage of SUV in Indian market is significant. Launch of new SUV's can be seen in Indian market from different manufacturers. Launching SUV in India could be good option with around 1.5L engine size.

An air inlet system of the car is important. As it has major an impact on engine performance and engine life. Tropical countries like India may face many problems in the air inlet system because problems such as more dust, pollution, water flooding. The air inlet system should withstand all these harsh conditions. While designing, economy factor should be also considered very strictly because of competition between other manufacturers. Two of following instructions can be seen in other literature for the region like India.

1. Air intake bottom shall be above ground level by 400 mm minimum. The entry at the dirty side hose should be as high as possible.
2. Installation shall be such that there is no water ingress or water trace in the air intake system. Even though, water wading test (BIS 11839) is done at 150 mm (for passenger vehicle) of water level, it is suggested to test also at 300 or 350 mm of water level considering flooding of Indian roads during rainy season.
3. Sucking air from engine space is useful in Indian environment.

As we have seen from questionnaire that many people voted for noise is an important factor for them. So, working at this point is useful to win customers. The resonator is one of the important parts of the suction system. Materials such as glass fiber, polymeric fibrous materials, and various types of foams can useful in noise control techniques.

From mileage point of view, active grill shutters can be advantageous, but because of price addition to car it can be suitable with luxurious cars only. Because it can help to reduce fuel consumption by controlling air flow and also reduction in aerodynamic drag. On cheap passenger cars, it is hard to implement it. But in future it can be useful for all cars.

Filtering dust is important for cars, especially diameter of 5 to 10µm as it leads to engine wear. From India's map of pollution we can conclude that it's very problematic there.

One of the focuses of the thesis is a multi-criteria comparison of the suction system between Indian and European environment. From a customer point of view Price, Aesthetics of car, Good

design, Mileage or Performance based on efficiency is really important for them. Comparison between Indian manufacturers based on Price and Design criteria was therefore performed. After evaluating winners from each category of car, a further comparison between Winners from Indian market and European environment is successfully done. Some real pictures of the air inlet system from the major Indian manufacturers are included in the appendix of thesis pictures. Thesis pictures are not only to show an air inlet system, but it's also for showing position of it in a car, front grill openings, height of the air inlet system, etc.

This comparison has many parameters for final results. For example, compactness of system, parts in the system, space utilization, etc. While comparing between Indian manufacturer Price and Design are the main criteria. These criteria are decided by questionnaire results. It is noticeable that Maruti Suzuki is better in all category cars in Price criteria. This was a customer point of view if we put different weightage from the engineering or economical point of view, then we can have different winners from each category. Excel sheet makes this work easy. This excel sheet is attached in the appendices, just changing the weightage in one cell is enough to get other results as discussed. The rest calculation is done by this excel sheets.

While doing internship at Škoda Auto, I have started to learn about Škoda's air inlet system. So, when it comes to the final comparison between Škoda and Indian aggregates, it was not an impossible task for me. Škoda has always advantage of compactness and short length of pipes which is important from price the saving point of view. Also putting directly inlet system on the engine in some cases could be price saver in terms of engine cover. On the other hand, Indian aggregates sometimes looks quite complicated, also using lots of connecting materials, bulkiness, lengthy pipes are one of the reasons which makes them not best in comparison. From a price point of view, these two are different markets so it is not advisable to compare them on base of price. On the base of different sources, it's not allowed to compare them. Also in the SUV category, we can notice that Škoda's air inlet is more compact than Indian one, still engine performance is relatively higher.

Reference

1. Kapoor A., Financial inclusion and the future of the Indian economy, sciencedirect, February 2014, Volume 56, Pages 35-42
2. Pramit,One in three households in India owns a two-wheeler, https://www.livemint.com/Politics/Yd2EAFIupVHDX0EbUdecsO/One-in-three-households-in-India-owns-a-twowheeler.html, December 2012, cited 16.04.2018
3. Trading Economics, India GDP per capita – Forecast, https://tradingeconomics.com/india/gdp-per-capita/forecast, cited 02.04.2018
4. European Automobile Manufacturers Association, November 2017, ACEA Report Vehicles in use Europe 2017, http://www.acea.be/uploads/statistic_documents/ACEA_Report_Vehicles_in_use-Europe_2017.pdf, cited 04.04.2018
5. Shodhganga, June 2015, A study of economic value added based performance measurement of selected automobile companies in india, cited 04.04.2018
6. Dubensky, India to become world's 3rd largest automobile manufacturer by 2020, The economic times, March 2015, cited 04.04.2018
7. Mathur, FY 2018-19 to improve auto sales graph; PVs expect to grow at 8-10%, The Economic Times, January 2018, https://auto.economictimes.indiatimes.com/news/industry/fy-2018-19-to-improve-auto-sales-graph-pvs-expected-to-grow-at-8-10/62462206
8. Gaddam J., Analysis of Growth of Exports and Geographic Concentration of Automobile Industry in India, June 2016, EBSCO, Issue 1 page 60
9. Shah R, Drive Express, Top 10 car manufacturers in India: Know car makers market share in 2017, January 2018, http://www.financialexpress.com/auto/car-news/top-10-car-manufacturers-in-india-know-car-makers-market-share-in-2017/1011187/ , cited 5.3.2018
10. Sameer, Skoda India Posts 30 Per Cent Growth In 2017; Rapid Becomes Bestseller NDTV, January 2018, https://auto.ndtv.com/news/skoda-india-posts-30-per-cent-growth-in-2017-rapid-becomes-bestseller-1795481
11. Pankaj, One out of every four vehicles sold in India is an SUV, The Times of India, April 2017, https://timesofindia.indiatimes.com/auto/miscellaneous/one-of-every-4-vehicles-sold-is-an-suv/articleshow/58137054.cms , cited 5.3.2018
12. Autocar Pro News Desk, Surging SUV sales in India eat into passenger car market, April 2017, http://www.autocarpro.in/analysis-sales/surging-suv-sales-india-eat-passenger-car-market-share-24338, cited 06.04.2018
13. Society of Indian Automobile Manufacturer, Export Trends, http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=15 , cited 24.3.2018

14. Financial Express, Nissan exports 7 lakh 'Made in India' cars to 106 countries within seven years, February 2017, https://www.financialexpress.com/auto/car-news/nissan-exports-7-lakh-made-in-india-cars-to-106-countries-within-seven-years/569931/
15. Financial Express, General Motor India aims to export over 70,000 units this year, October 2016, https://www.financialexpress.com/industry/general-motor-india-aims-to-export-over-70000-units-this-year/407111/
16. The Economic Times, Top 10 PVs exporters from India in FY17: Ford beats Maruti, Renault debuts, April 2017, https://auto.economictimes.indiatimes.com/news/passenger-vehicle/cars/top-10-pv-exporters-from-india-in-fy17-ford-beats-maruti-renault-debuts/58242371
17. INDIA BRAND EQUITY FOUNDATION, March 2017, Iron & Steel Industry in India, https://www.ibef.org/industry/steel.aspx, cited 22.04.2018
18. ReportBuyer, PR Newswire, Global Automotive Air Intake Manifold Market, https://www.prnewswire.com/news-releases/global-automotive-air-intake-manifold-market-by-vehicle-type-by-manifold-type-by-material-type-by-manufacturing-process-by-region-trend-forecast-competitive-analysis-and-growth-opportunity-2017-2022-300492046.html, cited 30.04.2018
19. Ford Sprint shows local innovation, OEM, page 18
20. Kunihiko Y Hiroyuki T, and Atsushi O, Prediction Method for Water Intrusion into the Engine Air Intake Duct while Running on Flooded Road at the Early Stage of Vehicle Development, SAE International, March 2017
21. Marius T and Iordan F, Research on the Air Filters' Maintenance for Diesel Engines, Procedia Technology, October 2015. Page no 970
22. Maddineni A, Das D, Damodaran R, Inhibition of particle bounce and re-entrainment using oil-treated filter media for automotive engine intake air filtration, Powder Technology, September 2017, page no. 369-377
23. Mann+Hummel, Fully synthetic filter materials for engine air filtration, MTZ extra Wiesbaden, https://www.mann-hummel.com/fileadmin/corporate/04_Unternehmen/5_Download%20Center/05_Produktinformationen/1_Luftfilter_und_Ansaugsysteme/Artikel_Filterdesign_EN_V1.pdf.
24. Bilal A. F., Highest selling cars of India in 2017, Carwale, https://www.carwale.com/news/highest-selling-cars-of-india-in-2017/, January 2018.
25. Maxabout team, Top 25 Best-Selling Cars in India | Sales Report (January 2018), Newsabout.com, https://news.maxabout.com/cars/top-25-cars-in-india/, February 2018.
26. Taumar D, Top 10 selling cars in Jan 2018, The Economic Times, https://auto.economictimes.indiatimes.com/news/passenger-vehicle/cars/top-10-selling-cars-in-jan-2018-tata-tiago-outsells-maruti-celerio-hyundai-eon/63078645, February 2018.
27. Nick, Indian plastics industry overview, Bizvibe blog, https://www.bizvibe.com/blog/indian-plastics-industry-overview/, November 2015

28. Jwalit Vyas, Some cheer for underperforming ABS makers, The economic times, https://economictimes.indiatimes.com/markets/stocks/news/some-cheer-for-underperforming-abs-makers/articleshow/58059058.cms, April 2017
29. Dieselnet, India: Diesel Fuel, https://www.dieselnet.com/standards/in/fuel.php
30. Indian Oil, Previous Price of Diesel, https://www.iocl.com/Product_PreviousPrice/DieselPreviousPrice.aspx
31. Car and Bike, Upcoming cars in India, NDTV, https://auto.ndtv.com/upcoming-cars, May 2018
32. Mathews V. J.; Sandhya M.; Balakrishnan K, Effect Of OEM Style And Aftermarket Performance Air Filters On Vehicle Parameters, Procedia Technology, 2016, Page 461-462.
33. Kaur S., Malik R., Design Optimization of Automotive Air Filter Housing for Minimum Pressure Drop, International journal of engineering development and research, 2017, Volume 5, Issue 4, page 1167-1170.
34. Brad Plumer, India's air pollution is so bad it's reducing life expectancy by 3.2 years, Vox, https://www.vox.com/2015/2/24/8094597/india-air-pollution-deaths, February 2015.
35. K. W. Lee, B. Y. H. Liu, On the Minimum Efficiency and the Most Penetrating Particle Size for Fibrous Filters, Journal of the Air Pollution Control Association, March 2012, Page 377-381.
36. Aldous Voice Engineering Limited, https://aldousvoice.com/2013/01/07/ferrari-360-air-intake-system/
37. Ho Seop S., Haeng Muk C., A Study on Duct Integrated Resonator of Automobile Intake System, International Journal of Applied Engineering Research, Volume 12, Number 18 (2017) pp. 7696-7699.
38. Patil A. S., Halbe V. G., Vora K. C., A study approach to automotive air intake system development, SAE Paper No. 2005-26-011.
39. Embitel, Migration to Bharat Stage (BS) VI, Embedded blog, https://www.embitel.com/blog/embedded-blog/what-is-bharat-stage-6-and-bs-vi-norms-in-automotive-electronics
40. Mark J., Morey C., Diesel Passenger Vehicles and the Environment, Union of Concerned Scientists, April 1999, Pages 12-25.
41. Mathur S., Challenges and opportunities for auto industry with BS-VI norms, ET Auto, https://auto.economictimes.indiatimes.com/news/industry/challenges-and-opportunities-for-auto-industry-with-bs-vi-norms/61217044, October 2017.
42. Nik R A A, Nafis S S, Effects of Air Intake Pressure to the Fuel Economy and Exhaust Emissions on a Small SI Engine, Procedia Engineering, 2013, Volume 68, 2013, Pages 278-284

43. Cem M, Haluk E, Aytekin Ö, Design and application of a compact helical air intake system resonator for broadband noise control, Applied Acoustics, February 2018, Volume 131 pages 103-111.
44. S. Mahendran, Ramasamy Devarajan, Design Optimization of Air Intake System (AIS) of 1.6L Engine by Adding Guide Vane, Researchgate, March 2010.
45. Danny's engine portal, The function of the Evaporative Emission Control System (EVAP) is to trap and store evaporative fuel emissions, http://dannysengineportal.com/evaporative-emission-control-system/, April 2018.