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TRENDS IN EUROPEAN CAR DESIGN

U.L. Businaro
Managing Director
FIAT RESEARCH CENTER S.p.A. - Orbassano

G. Bolognesi
Secretary of the Scientific Council
FIAT S.p.A. - Torino

1. FORCES AT WORK IN EUROPE BEFORE 1973

- Since its origin the European automotive industry learnt to live with high gasoline prices due to taxation deemed necessary in order to contain imports in an oil poor continent. The European drivers have a long experience in keeping accounts on liters and kilometers.

- During the sustained growth after the reconstruction (1955-1973), new habits were conquered; the Europeans were discovering the pleasure of ample leisure time, the weekend, the long vacation; the new highways opened access to far places to visit; all of that had a deep influence on car design: more room, more comfort, higher speed and acceleration were needed. But even in those times of fast growth, most of drivers put fuel economy as a condition for their choices.

- With new strata of population reaching the threshold of car ownership, very soon we got to know what it means to drive through narrow streets of our old cities. There is no doubt that the word "congestion" has different meanings in different geographic areas: in Europe it means that it is better to drive a short car.

- Engine displacement. Displacement per class remain within the same range throughout all the years: according to definition (Fig. 1).

- Engine specific power. A larger power is obtained from the same displacement; this fact is due : 1) to higher compression ratios, allowed by anti-knock gasolines, 2) operation of the engine at higher rotations per minute. Racing experience had a role in this changes. Ownership taxes based on displacement and weight containment were also important factors (Fig. 2).

- Engine power. Each class of cars shows an important growth in engine power; this was necessary in order to meet market demand for superior performance after the diffusion of highways and mountain tourism (Fig. 3).

- Passenger interior volume. Growth in affluence gave origin to a search for more comfort = interior volumes were increased in each class (Fig. 4) (See Appendix 2 for definition).

- Curb-weight. In order to keep fuel economy, increase in interior volumes and power were introduced while maintaining curb weight approximately the same. New packaging concepts were introduced (Figs. 5, 6).

- Aerodynamic drag. To allow higher top speeds while keeping consumption down, new aerodynamic shapes were introduced in all segments (Fig. 7).

- <u>Acceleration</u>. Driving in congested cities seems easier if one can accelerate at the traffic lights; safety also seems to increase if one can count on elasticity. Acceleration here is shown as seconds required to run 0,62 miles (1000 mt) from idle. Small cars follow the general trend. Main factor is the ratio between power of the engine and curb-weight (Figs. 8, 9).

- <u>Top speed</u>. As a consequence of improved aerodynamics, higher power and constant weight, top speed increases for all cars. The small cars also reach top speeds that once were prerogative of the large cars. Highway speed is available to all (Fig. 10).

- <u>Fuel Economy</u>. Fuel Economy in each class, measured at different constant speed levels, grows for all cars. Under heavy fiscal pressure on fuel prices, the market would not allow increase in performance with a lower Fuel Economy (Fig. 11).

- <u>Purchasing price</u>. Until 1972 real prices of cars were decreasing due to a strong competitive climate, increase in production volumes and new product and production technologies. The abrupt change for all classes after 1972-1973 is the result of several interrelated causes:

  - increase in international prices of energy and raw materials
  - decrease in steel production volumes
  - increase in Unemployment
  - growing in social tension in the factories — especially in Italy and U.K.
  - growing absenteeism

- increase of rate of inflation
- decrease in market size particularly in some regions, and for some class of cars (lower subsegments of classe A and C, and class B)
- decrease in competitive capability on extra European markets in front of strong Japanese efforts (Fig. 12).

° Penetration of front wheel drive, the hatch back and the diesel engine. Show the response of European manufacturers to the new challenges of traffic congestion, air pollution, and energy dearth = the penetration of front wheel drive, the hatch back body, and the diesel engine. Radial tires, not shown, now cover about 95% of production of most European car-producers (Figs. 13, 14, 15)

° Interior volume x fuel economy. As a conclusion of this fast panorama the last figure shows that one of the most comprehensive indices (interior volume x fuel economy) went up 1,2% per year for classes A and B and 2,1% for class C (Fig. 16).

2. THE EUROPEAN AUTOMOTIVE INDUSTRY AND THE NEW FORCES AT WORK

° It is a well known fact that the auto industry planning requires a time span of at least 15 years. In fact 4 to 5 years are required to design an entirely new model base upon proved technologies, and 10 to 12 years of commercial life are required for an acceptable return on capital. As an example the models that will come on the roads next year will reflect the state of technology and market perception of 1975-76.

° It may be useful to try to list which new forces seem in action that may change the consumers' orientations and needs:

- price of gasoline in real terms
- income and income distribution
- traffic conditions in cities and legislation
- diffusion of two cars families
- access to car ownership by low income families
- change in family and life styles: school leaving age, marriage age, number of children
- pricing of old style cars on the used market
- working hours & leisure
- legislation for safety
- legislation for better environment
- legislation on fuel economy
- legislation on speed limits

and to complicate further the problem, technological responses to these challenges will probably constitute an additional change-inducing factor.

The complexity and the inherent huge risks of automotive planning has induced many governments to reduce the uncertainties at the price of reducing liberty of choices even before complete knowledge is available. To compensate for the effort imposed on this vital industry, government intervention is often accompanied by public funding of research and development, or, in some cases, of restructuring and reorganizations of automotive companies that do not seem in condition to survive the next epochal change.

The following table illustrates some aspects of the variety of government policies for some countries.

2.1 Recent successful models: the new baseline

° Interior volume x miles per gallon is a well known comprehensive index of design efficiency [1].

An alternative index can be proposed in order to facilitate evaluation of gasoline and diesel cars, replacing the capacity measure with the weight of fuel. A handy index could be to consumption of fuel per interior volume:

$$\frac{\text{Pounds of Fuel}}{\text{Cubic Feet of Int. Vol.}}$$

for a given combined cycle (°).

If we then estimate the energy spent (on a given combined cycle) by a vehicle (of a given weight and drag area), we can write down this simple equation:

(°) Definition of a selected "European combined cycle" is given in Appendix 1. Interior volume definition used is commented in Appendix 2.

$$\frac{\text{Pound of Fuel}}{\text{Cubic Feet (Int.Vol.)}} = \frac{\text{Pound of Fuel}}{\text{HP hour}} \times \frac{\text{HP hours}}{\text{Cubic Feet (Int.Vol.)}}$$

for a given combined cycle (°).
That is "consumption per cubic FT" (on cycle) is equal to "vehicle specific consumption" times "energy spent per cubic foot of interior volume" (on cycle).

- The two new indices convoy messages directed to two kinds of creative people whose cooperation is vital for better design of cars. The first index is useful to evaluate the effort of mechanical engineers and engine designers. It is expressed with a unit of measurement familiar to them and they know how to reconcile this figure with their owns. The second is useful to evaluate the job of the structural engineers, aerodynamicists and stylist. It expresses the ability to package a required volume into a streamlined shape and to employ light and strong (and hopefully convenient) materials.
  The two new indices are in fact parameters of efficiency, and reasonable targets can be established for each. We have gathered information on these parameters for some recent successful European cars.

2.2 Lb. of fuel per cubic foot of Int. Volume (on 100 kms of European cycle) (62,3 miles)

- In order to visualise potential benefits form the above concept some data on recent successful European cars

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(°) Estimation of energy spent by a vehicle on the European driving cylce in contained in Appendix 3.

will be presented for each index. The most comprehensive index is consumption per cubic foot of internal volume.

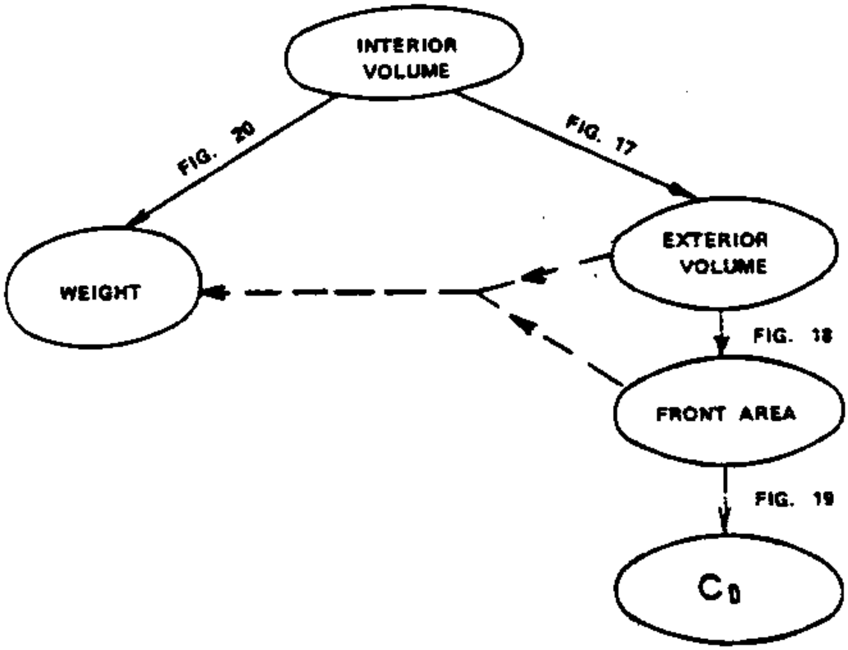
For each class of car data for average, best gasoline car and best diesel car (if available) are given. Only the best recent cars have been selected. In this and following tables "Average" mean "average of the best".

	INTERIOR VOLUME FT^3 a	F.E. (MPG) (European Comb. Cycle) b	INTERIOR VOLUME x F.E. c = a X b	FUEL CONSUMPT. on European Comb. Cycle (lb.) d	FUEL ÷ INT. VOL. lb. / FT^3 e = d / a
CLASS A Average	42.4	30.35	1287	12.67	0.30
Best Gasol.	44.5	31.8	1415	12.10	0.27
Diesel	–	–	–	–	–
CLASS B Average	46.4	28.9	1341	13.5	0.29
Best Gasol.	48.4	28.9	1399	13.2	0.27
Diesel	48.4	35.0	1694	12.4	0.26
CLASS C Average	48.8	22.8	1113	17.8	0.36
Best Gasol.	48.4	23.8	1152	16.1	0.33
Diesel	48.0	27.0	1296	16.1	0.33

2.3 Energy spent per cub. FT of Interior Volume (on European cycle)

	INTERIOR VOLUME	CURB WEIGHT	FRONT AREA	C_D	$A_F \times C_D$ (Sq Ft)	ENERGY SPENT ON CYCLE (HP hrs)			ENERGY PER INT. VOLUME
						Prop. to Weight	Prop. to Air Drag	Total	HP hrs / CU.FT
	FT^3	(lbs.)	(Sq Ft)						
	a	b	c	d	e = c X d	$f = 29.10^{-3} \times b$	$g = 1.02 \times e$	h = f + g	i = h/a
CLASS A									
Average	42.38	1589	18.15	0.46	8.35	5.75	8.38	14.12	0.33
Best Gasol.	44.5	1576	18.3	0.43	7.86	5.8	8.0	13.8	0.31
Diesel	–	–	–	–	–	–	–	–	–
CLASS B									
Average	46.4	1874	19.7	0.42	8.29	6.7	8.4	15.1	0.33
Best Gasol.	46.4	1720	19.7	0.42	8.29	6.2	8.4	14.6	0.30
Diesel	46.4	1908	19.7	0.42	8.29	6.5	8.4	14.9	0.31
CLASS C									
Average	48.8	2658	20.8	0.46	9.41	8.9	9.6	18.5	0.38
Best Gasol.	48.0	2237	19.7	0.46	9.04	7.7	9.2	16.9	0.35
Diesel	48.0	2567	19.7	0.46	9.04	8.6	9.2	17.8	0.37

- For this index it is possible to construct torgets based upon the best experience and/or future technologies. One way of determining objectives based upon best current technology is to study current models and try to extract from them the best. The charts in the next page are the result of such an attempt. They show the relationships between relevant parameters for each type of body (Nothback, fast and hatckback).



Dotted lines in Figs. 19 and 20 suggest objectives for the future generation cars.

New targets (for gasoline cars) midway between current best and future technology could be as follow:

	INT. VOL. FT^3	CURB WEIGHT (lb.)	TEST WEIGHT (lb.)	EXT. VOL. FT^3	FRONT AREA FT^2	C_d	$A_f \times C_d$ FT^2	ENERGY SPENT ON CYCLE: Wt. Cost	ENERGY SPENT ON CYCLE: A.D. Drag	ENERGY SPENT ON CYCLE: Total	ENERGY / INT. VOL. HP hr / FT^3
CLASS A TARGET HB	42	1200	1640	220	16.5	0.37	6.10	4.78	6.22	11.	0.26
CLASS B TARGET HB	46	1500	1940	250	17.2	0.36	6.20	5.62	6.32	12	0.26
CLASS C TARGET NB	48	2000	2440	315	18.4	0.35	6.40	7.1	6.52	13.6	0.28

2.4 Pounds of fuel per horsepower required by the vehicle on European cycle

° Data for this parameter found in best recent cars are presented in the following chart:

	FUEL ECONOMY MPG (Composite European Cycle) a	lb. OF FUEL (On European Cycle) $b = \frac{62 \text{ miles}}{a} \times \rho$	HP hr Spent on European Cycle c	LBS OF FUEL / HP hr b / c	ACCELERAT. SECONDS FOR 1000 mt (0.62 miles)
CLASS A					
Average	30.35	12.67	14.1	0.90	40
Best Gasoline	31.0	12.4	14.4	0.86	40
Diesel	–	–	–	–	–
CLASS B					
Average	21.9	13.48	15.1	0.89	37.5
Best Gasoline	28.9	13.2	14.6	0.83	38
Diesel	35	12.4	14.9	0.83	38
CLASS C					
Average	22.8	17.8	18.5	0.96	39
Best Gasoline	23.8	16.1	18.3	0.88	34
Diesel	27.0	18.1	20.3	0.89	44

This index is a measurement of a very complex reality where the main ingredients seem:

1) Efficiency of engine itself (compression ratio, mean piston speed, valve size and timing, fuel introduction, air/fuel ratio, timing of ignition, timing of injection, geometry of combustion chamber, heat dispersion, turbocharging materials of cranckase and cylinders-head, electronic controls);

2) Properties of fuel (calorific power, knock resistance, compatibility with pollution control devices);

3) Pollution control devices;

4) Ratios between piston speed and wheel speed at frequently utilised operating points in cycle;

5) Transmission efficiency, lubricants.

° An objective often found on published statements of many European manufacturers is that electronic control on ignition and injection, new chambers, and turbocharging, can improve the efficiency of gasoline engine by 15%, leaving acceleration & elasticity unimpaired. On the other hand envisaged pollution legislation will reduce efficiency by 10%.
A 5% gain on current gasoline engine efficiency can be expected. The direct injection diesel could show improvements of 15% if noise can be reduced.
Better matching, on the other hand, can introduce important trade-offs beetwen acceleration and fuel economy.
Infact reduction of piston speed (by adopting larger dispacements for the same power) and the correct proportioning of power itself, can improve the pound per horse power used in the cycle by higher percentages, with some reduction of performance that can be acceptable by a not negligeable segment of the market.
To conclude this naturally inconclusive section, the target of lbs/HP-hr could be set at 0.75.
If the two elemetary target are correct, and <u>if</u> the market will accept new shapes, new packagings, new

materials and horsepower lower accelerations, total fuel consumption per cu.ft. of interior volume could be set for popular cars of class A & B as follows:

0,19	=	0,255	x	0,75
Pounds/cu.ft.		HP hr/cu.ft		Pounds/HP hr

or, in MPG (on the European cycle)

	CUB. FT		POUNDS OF FUEL / INT.VOL.		POUNDS OF FUEL ON EUROP. COMB.CYCLE		MPG
CLASS A	42	x	0,19	=	8,03	=	47,5
CLASS B	48	x	0,19	=	9,18	=	41,6

which corresponds to about a 50% increase in mileage relative to the best European gasoline cars, or a 20% improvement on best diesel cars on the roads now.

2.5 Technology promises and european industry commitments

° Discussion on the possibility of setting common fuel consumtpion targets for all European Economic Community countries were initiated in December 1977 at EEC Headquartes in Bruxelles (Special Group for Rational Use of Energy). European manufacturers as a group prefer to participate in voluntary schemes for reducing fuel consumption.

Officially proposed targets are: 10% reduction relative to cars marketed in mid year 1978. Given the time scale, and the size of investiment required for introducing new engines and new technology only few models will be entirely new. Considering that at least two thirds of the car sold in 1985 will belong to the curren generation, the target implies that the new generation vehicles will be torgueted to very ambitious consumption reduction.

So that part of the gains foreseen for 1990, will have to be found in the cars seven years fraom now.

° In U.K., were national average consumption is around 24 mp (US)g: the target for 1985 is 26,4 mpg (4% less than US government standard for the same year).

In Italy and France starting points are much higher (31 mpg), due mostly to a higher proportion of class A and B cars, but the targets are equally expressed as a 10% improvement on 1978.

In Germany the governement shows a different attitude: a generous government supported program to generate different models of integrated research vehicles has been started in early 1978.

An objective of 30% reduction in consumption on current average cars has been set for three classes of cars under the "three E's" slogan (Energy, Environment, Economy) (33,6 mpg for cars under 2200 lbs of curb-weight, 24,8 for cars more than 2200 and less than 3300 lbs and 21 mpg for car over 3300 lbs). This is a height urgency plan: testing of prototype should be finished by fall of 1982. Judging by intermediate reports already published German researchers and engineers are working on these programs with a far longer perspective than the announcement of objectives let believe.

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